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**Advances in accounting for biodiversity and ecosystems: a typology
focusing upon the environmental results imperative**

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Laurent Mermet passed away on June 16, 2019. He contributed to the fundamental deliberations involved with this paper as well as to its drafting.

This paper was first written in French and Robin Humphrey, a professional independent French to English translator produced the English text. Subsequent collaborative revisions have yielded what we believe to be a well-flowing text which is consistent with the original source text. Differences do remain, however. As Gunter Grass wrote: *Translation is that which transforms everything so that nothing changes.*

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Abstract:

Accounting for biodiversity and ecosystems is a new and growing field of research. This is the first time four major areas of leading research in this field have been identified and reviewed simultaneously on the basis of their differences in scope (company, ecosystem or national) and purposes (logics of management accounting or balance sheet). In this paper, the usefulness of pursuing the growth in the developing field of “ecosystem-centric management accounting” is highlighted and makes assessment and monitoring of environmental results possible. In the field of social and environmental accounting, the suggested classification offers one form of response to the main test which arises from discussions over the interlinking of private and collective accounting systems.

Keywords: biodiversity; natural capital; environment; ecological indicators; non-financial reporting

Innovations comptables pour la biodiversité et les écosystèmes : une typologie axée sur l'exigence de résultat environnemental

Résumé :

Les recherches en comptabilité sur le thème de la biodiversité et des écosystèmes constituent un champ nouveau et en plein essor. Pour la première fois, quatre grands domaines d'innovation en la matière sont ici identifiés et discutés conjointement, sur la base de leurs différences de périmètres (entreprise, de l'écosystème ou national) et de finalités (logiques de comptabilités de gestion ou de bilan). L'importance de poursuivre le développement du domaine émergent des « comptabilités de gestion écosystème-centrées », qui rend possible l'évaluation et le suivi des résultats environnementaux, est mise en lumière. La typologie proposée apporte une forme de réponse au défi majeur de l'articulation entre les comptabilités privées et les comptabilités collectives dans le champ des comptabilités sociales et environnementales.

Mots clés : biodiversité ; capital naturel ; environnement ; indicateurs écologiques ; reporting extra-financier

Introduction

Accounting consists of designing and systematically utilizing information systems linked to social accountability practices so as to meet the challenges associated with the collective organization of human activity. Accounting systems evolve in line with these challenges. They are inextricably linked to clear-cut and documented approaches to the world and to accessible reporting methods. They reflect the organisational concerns of those professionals who have designed, enhanced and utilized them at different times and for different purposes (Hudson 2000; Quattrone 2004; Ezzamel 2009; Kuasirikun and Constable 2010; Richard et al. 2018). Humanity today faces a wholly unprecedented challenge: how to deal differently with lifestyles and production so that responsibility for the biosphere, “the life support system” on which we depend (Daily et al, 1996) is assumed in a compelling and sustainable fashion. Even so, efforts over several decades at many levels have been inadequate at taking on what was needed to curtail endless biodiversity and planetary ecosystems destruction (Steffen et al. 2015).

More than 40 years' critical and interpretative accounting research (Naro 2010; Miller and Power 2013) have shown that accounting systems make it possible to establish, initiate and maintain systems of accountability within organizations (Roberts and Scapens 1985; Roberts 1991; Chapman et al. 2009) as well as to structure and to regulate intra- and interorganizational power relations that combine with acknowledgement of responsibilities (Richard 2005; Richard et al. 2018). Moreover, accounting systems grant totemic debate and renewal of conventions on which an organization's, a state's or a human collective's chosen values are based (Amblard 2004; Chiapello 2008). Given such development potential and the performative nature of accounting practice and theories, i.e. their capacity for yielding organizational and institutional effect (Morgan 1988; Carruthers and Espeland 1991; Çalışkan and Callon 2010; Miller and Power 2013), accounting as a branch of knowledge can and must make innovative and germane contributions to the massively varied challenge of protecting the planet's ecosystems and to the organizational changes needed to achieve this. However, the vast majority of accounting systems as they stand render the values of nature invisible along with vital considerations of decision-making and management, both in the private and public sector (TEEB 2010, 2012).

Preservation of biodiversity and ecosystems is indeed a particularly recent challenge in the field of social and environmental accounting research (Thomson 2014a). As Jones (2014a, p.5) reminds us: “*It is fair to say that, with some rare early exceptions (eg Jones 1996, 2003;*

Houdet 2008; Houdet et al. 2009), both practitioners and academic accountants have generally not recognized the importance of biodiversity". In the past decade, the publication of PhD dissertations on the subject (Houdet 2010; Feger 2016; Ionescu 2016), as well as the publication of a collective book entitled *Accounting for Biodiversity* (Jones 2014b) and two special issues of the *Accounting, Auditing and Accountability Journal* (Jones and Solomon 2013; Russell et al. 2017) made it possible to lay the foundations of rich academic debate on biodiversity accounting practices. To be able equally to discuss enquiry into accounting which focuses on various natural entities, and also to support different definitions of "biodiversity" and "ecosystems", we use these two terms here in an equivalent yet broad sense. This in order to describe all types of natural environment and environmental compartments (water, soil, forests, lakes, seas, etc.), animal and plant species as well as issues relating to good ecosystem functioning and services they provide to society (often referred to as "ecosystem services", "natural capital"; see UNEP 2011; or more recently from "nature's contributions to people", Chaplin-Kramer et al. 2019). In the face of increasing deliberation and suggestions concerning domain expansion, it has become necessary to be more familiar with the current state of affairs in order to position investigations in relation to one another and to believe their interlinking is possible to bolster collective accountability regarding the state of ecosystems.

In this paper, we wish therefore to build on our previous work on the development of "ecosystem-centric management accounting" (Feger 2016; Feger and Mermet 2017; Cuckston 2017; Dey and Russell 2014; Feger et al. 2019) by showing how this emerging research stream provides new insight and features for linking country- and company-specific accounting procedures. This drove us to carry out the first exercise to identify, discuss and qualify major areas of accounting for biodiversity research and innovation. We draw on both these ecosystem-centric developments, on existing work and on efforts in the field of national and corporate accounting to address the following questions: where and how can accounting research and development contribute to greater provision for, structuring of and operationalization of public and private acceptance of responsibility for biodiversity and planetary ecosystems? In what way does the development of new "ecosystem-centric management accounting" approaches and experiments complement current biodiversity research and investigation efforts occurring at other levels?

To help steer a path through the plethora of past and current proposals and in order to answer these questions, in Section I we advocate a four-point classification from all angles and of all advances in accounting for biodiversity and ecosystems. In the subsequent four sections,

we will review the quartet of identified areas of innovation to show their diversity and to highlight more effectively their characteristics of origin, nature, scope and purpose, as well as to underline concurrent contentions. We will then demonstrate strong synergies between these four areas of innovation and their respective transformative potential, and that the ability to effectively manage ecosystems for measurable ecological results will depend on how they are interlinked.

If our paper adopts biodiversity conservation as its central inquiry, and as such reviews a substantial part of accounting discourse on this particular topic, its logic stems more broadly from social and environmental accounting literature (Gray 2010; Gray et al. 2014; Russell et al. 2017). Similarly, argument developed around ecosystems may be extrapolated to other topics in environmental accounting and management control, in particular those relating to issues of change of scope and interorganizational management (for example, research on the circular economy) (see Petitjean 2001).

1) A typology for biodiversity and ecosystem accounting

An increasingly diverse and rising number of accounting research proposals today focus primarily on greater consideration of biodiversity and ecosystems in existing accounting systems, and then centre on exploring breakthroughs in accounting that are specifically developed for assessing and managing the challenges of biodiversity conservation. To facilitate matters, we suggest a typology based on exchange between two widely used concepts in accounting practices: the concept of accounting scope and then the distinction made between management and general accounting methods (see Feger 2016, chap. 5 for a first version of this typology).

Firstly, we would like to identify ecosystem accounting developments in three key categories of accounting entity: (1) corporate scope of accounting (and more broadly within formally and legally recognised private organizations); (2) scope of accounting at national or other territorial level reliant upon public government (region, European Union, for example); (3) scope of accounting based on a given ecosystem or ecological issue (for example the preservation of a marshland, a forest or a species habitat) where biodiversity performance is played out - and managed - in exceptionally contrasting operational and decision-making conditions. We group these last two in the same category of scope of accounting for collective biodiversity governance and management, where public and private stakeholder capability is assessed in summary and in relation to organizing the mutual preservation of common environmental goods, i.e. ecosystems.

Secondly, our classification incorporates and transfers to accounting for biodiversity and ecosystems that distinction which is made in French accounting and also made in other traditionally dualist countries (Richard et al. 2018, p.118). This incorporation and replication occurs initially between a) general (or financial) accounting that seeks to produce a standardized and regular overall picture of a situation, i) assets and performance of an organization as a whole, ii) report to its external stakeholders (economic, social, investors, public authorities, etc.) at the end of an audit (Colasse and Lesage 2007, p. 10) and b) in contrast, management (or analytical) accounting — unregulated and ad-hoc — the greatest challenge of which is to help managers within organizations (at project, team or activity sector scale, etc.) formulate and implement strategies for analysis, decision-making, management, planning and operations control, costs, resources, performance and responsibilities relating to results delivery and discrepancies within those results (Horngren and Sundem 1990; Macintosh and Quattrone 2010).

Without delving into the detail of these differences, we will stick with the broad concept of distinguishing between firstly operations and accounting tools, the purpose of which is to establish *ex-post* balance sheets at a given moment in the development of an accounting entity and to report upon its entire influence by calculating aggregate data in line with standardized accounting procedure. We will then continue with accounting activities and tools designed explicitly to support detailed breakdown, actions and strategic management of an entity and the delivery of results within pragmatically defined boundaries.

Our typology (Figure 1) stems from the intersection of these two aspects - corporate accounting perimeters vs. collective accounting perimeters; purpose and logic that fall within management accounting and purpose and logic that fall within general accounting, or more generically what we propose to refer here to as “balance sheet accounting”. This classification recognizes four major areas of biodiversity and ecosystem accounting innovation. With biodiversity accounting innovation, reference is made to a particular type of managerial innovation defined by David (2013, p.92) as “a successful management invention - in the sense of a minimum of acknowledgement and implementation - and which partly changes at least ways of thinking and conducting the broad understanding of organized action”. As such, we identify a highly varied set of accounting method developments, information systems and assessment tools. These have been more or less successful and implemented to varying degrees. They can be based on monetary, biophysical and ecological metrics and are designed to set up coordinated biodiversity activity in different ways and at different levels. As such, we can attribute a less restrictive meaning than that given by Lafontaine (2003) to environmental

accounting innovations, principally because we widen the scope of developments considered beyond only organization-centric accounting systems. The scope of affected stakeholders widens outside that which includes only accounting professionals.

Indeed, each of the four major areas identified covers a vast field of research and practice, which itself has its own chronicle of events and concerns. In that respect, moving from one field to another represents navigation from a specific understanding of accounting and a specific area of research to another. Each time, this means adopting a clear-cut interpretation of what new theory or practice in the field brings to different stakeholders that in turn could effect change which favors ecosystem management. Each domain and the vast array of research and hypotheses which informs a domain is further invigorated by considerable debate.

The first area we have called "government natural capital accounting", is the set of proposals for establishing common protocols for assessment, aggregation, representation and reporting on quality and value of all government sector ecosystems (national, regional, European, indeed global). Essentially, it refers to the world of national accounting and to the many past or current studies which look at broadening scope to include ecosystems and their spatial, biophysical and/or monetary assessment so as to inform state policy (Bérard 2019).

The second area is that of "corporate ecological balance sheet accounting". This category covers all approaches which seek to allow corporate managers to assess and report to society, to the State and to investors on all ecosystem stewardship commitments, operations, efforts and results via simulated and standardized formats, themselves allowing comparison and external appraisal. In this instance, accounting refers essentially to issues of extra-financial reporting (Gray 1994), extended here to biodiversity, and denotes also the transformation of financial accounting and associated norms for natural capital inclusion (Rambaud and Richard 2015; Capitals Coalition 2020).

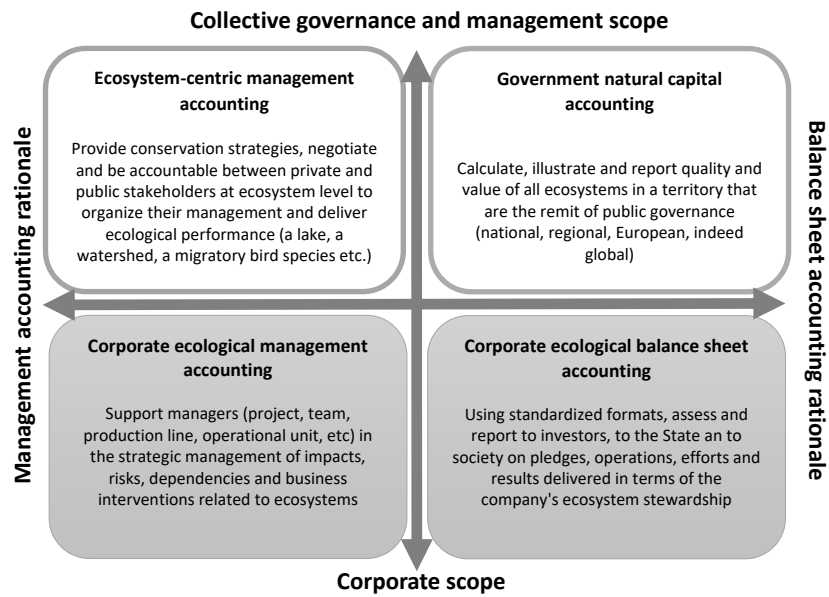
"Corporate ecological management accounting" consolidates all internal accounting innovations designed to support a company's managers (at project, team, business unit, production line or operating site level, etc.) in strategic planning and implementation of biodiversity management. This is intended to improve performance management, impact and risk management and causative management of ecosystem-related operations. In this sense, accounting refers here to the broader domain of Environmental Management Accounting (Jasch 2006; Schaltegger et al. 2011) and more generally to the design of ad-hoc tools for management control and appraisal of corporate environmental conduct (see for example research on eco-control and eco-efficiency: Henri and Journeault 2010; Antheaume 2013), material flow

analysis or lifecycle analysis (Bicalho et al. 2012) that is applied to biodiversity and ecosystems.

Finally, approaches from within the developing field of "ecosystem-centric management accounting" aim to provide negotiation, environmental performance strategic management and accounts exchanges between numerous interdependent organizations at a given ecosystem or environmental entity level (a lake, a wetland, a watershed, a forest, a population of migratory birds, an ecological corridor, etc). As such, the term accounting refers initially to advocacy of theoretical and critical resources in accounting as a discipline which support scientists and conservation practitioners in their design and strategic use of environmental information systems that have been devised to improve ecosystem management (Feger and Mermet 2017; Cuckston 2018; Feger et al. 2019) and in contrast to the development and testing of accounting models especially designed to structure information for the interorganizational management of ecological entities (Feger 2016; Ionescu et al. 2016; Feger and Mermet 2018).

In summary (Figure 1), two accounting for biodiversity and ecosystems domains fall within corporate entity scope, but are differentiated by their character and relative scale. Corporate ecological balance sheet accounting deals with the entity's entire scope for overall illustrative purposes and for reporting in line with protocol (which may still need to be approved) for its external stakeholders. However, corporate ecological management accounting aims to guide internal management upstream of the results cycle. It describes only partial corporate activities. Such rationale is already well-known in socio-environmental corporate accounting and in transferring it to collective biodiversity governance and management scopes, two accounting domains stand out as a consequence of their character and corresponding size. They are i) government natural capital accounting which functions over entire spatial or economic State-level reporting, or a given politico-administrative entity and which yields an aggregated illustration and ii) ecosystem-centric management accounting which maps the relevant management entity specific to each considered ecosystem or ecological issue for which co-operating stakeholders are responsible, and then aligns the wider scope of government accounting which ensues.

Figure 1: Typology of accounting for biodiversity and ecosystems



It is important to note that the first three domains of our typology refer to clearly defined theoretical and practical fields previously addressed in accounting research and many of which have sought over several decades (Richard 2012) to expand the latest environmental stakes - national accounting, corporate accounting. In contrast, the fourth area - ecosystem-centric management accounting, is an area of innovation whose development is particularly recent, even though it covers a real need that cannot be met by other attempts at innovation. In the following four sections, we will sequentially introduce characteristics and studies of these four areas. We will start with the developing field of ecosystem-centric management accounting and will discuss matters of complementarity and relationships with the other three (Text boxes 1, 2 and 3).

2) Ecosystem-centric management accounting: delivering collective ecosystem management strategies

Ecosystem-centric management accounting as a domain characterises the body of work aimed at developing new theoretical and practical accounting approaches for strategic management between stakeholders of a specific ecosystem or ecological issue.

Consequently, the question of actual activity between organizations arises in relation to ecosystem management — efforts to negotiate, organize and implement operations that deliver tangible ecological results for which stakeholders can be held responsible. Stakeholders

would then be accountable to one another. (Dey and Russell 2014; Feger 2016; Ionescu 2016; Feger and Mermet 2017; Cuckston 2017; Feger et al. 2019). Innovation in this field can be summarized by a quotation from the programmatic paper by Feger and Mermet (2017, p. 1524). This offers theoretical foundations for the development of such accounting practice: *“Overall, we think that four main [elements characterize] full-fledged accounting systems for emerging perimeters of collective ecosystem management: (1) the use of evaluative information and calculative practices in a way that establishes or strengthens reciprocal commitments among various organizations concerned by a shared ecological issue; (2) the possibility to effectively enforce these inter-organizational accountabilities through accounts exchange; (3) the periodicity of account exchange practices and their maintenance over time; (4) the gradual routinization and technical equipment of these accountabilities and associated organizational practices.”*

This new field of research touches upon an existing phenomenon in strategic environmental management: with the exception of rare cases, entire ecosystem land control (a privately owned forest for example), obtaining quantitative results about the improvement of a given ecosystem's condition at a specified location does not depend solely upon a single company or organization's responsibilities and interventions. On the contrary, the creation or destruction of ecological value occurs from the back-and-forth of interactions between several organizations with often divergent interests and strategies which impact the ecosystem or which contribute to its management in a unique and often frequently uncoordinated manner (Ostrom 1990; Mermet et al. 2005; Ostrom 2009; Mermet et al. 2013; Mermet et al. 2014). As such, negotiations and combined management between stakeholders have a positive or negative effect on a predetermined ecological entity and require the development of specific accounting utilities that are explicitly adapted to the degree of precision and diverse nature of collective operations challenges that these stakeholders must face — they must confront them in order to deliver tangible results for ecological quality improvement within the entity and to be able to report upon them (Feger and Mermet 2017). However, neither accounting practice within the confines of business entities, nor national environmental public authority accounting practice were meant to fulfil the rigorous task of providing organizational, decision-making and accountability processes for stakeholders interacting at an ecosystem scale.

The development of this field, which is still in its infancy, is at research crossroads in environmental accounting and in the research of conservation science and strategic environmental management (Feger and Mermet 2017; Cuckston 2018; Feger et al. 2019).

Firstly, it answers calls to move socio-environmental accounting research away from the “obsession with corporate accounts” in order to focus on new types of accounting entities and new forms of “accounts” (“*new accounts*”) (Gray et al. 2014, p. 271). As a result, its beginnings are to be found in recent works that investigate by *means* of critical and interpretive accounting approaches: (1) in the first instance, the dynamics of exchange of accounts between different stakeholders about an ecosystem analysed as an accounting entity. Work by Dey and Russel (2014) exemplifies such a case with River Garry salmon populations in Scotland. The authors demonstrate how “the demanding and giving” of biodiversity accounts and “counter-accounts” (sustainable development reports on the effects of the dam operator’s actions; counter-study produced by a citizens’ association; public studies on ecological restoration costs and on the condition of bodies of water etc.) gradually build relations between river stakeholders and transform their collective responsibility for salmon protection; (2) and secondly information systems and nascent calculative practices associated with developing new biodiversity management systems, which themselves are aimed at fostering relations between organizations to deliver environmental performance. The latter includes for instance critical accounting research about certification mechanisms as part of rainforest management (Cuckston 2013; Elad 2014); on the restoration of a peat bog in England (Cuckston 2017); or again on the production of “biodiversity credits” and various environmental offsetting tools (Tregidga 2013; Sullivan and Hannis 2017; Cuckston 2019).

Secondly, the development of ecosystem-centric management accounting is based on researcher and practitioner biodiversity conservation work. For decades, they have been designing, experimenting and using more and more environmental data and assessment tools. Such tools are increasingly efficient from a technical perspective and in relation to data and dedicated accounting systems which support decisions and ecosystem intervention management. Various examples include work on developing red list endangered species monitoring (Young et al. 2014); the development of multi-criteria tools for biophysical assessment and mapping of ecosystem services (Kareiva et al. 2011; Levrel et al. 2017); or more broadly on biophysical or monetary biodiversity indicators (Levrel 2008; Jørgensen et al. 2013). However, the designers and users of such tools often encounter difficulties in establishing strong links between the use of environmental data for decision-making and negotiation of long-term reciprocal stakeholder pledges — this is a condition which is nevertheless necessary for delivering environmental results (Laurans et al. 2013; Ruckelshaus et al. 2015). Moreover, these tools support little from accounting as a discipline and its theoretical and methodological resources. Consequently, despite computational and evaluative

characteristics of a given ecological entity or ecosystem, these conservation information systems ultimately are still broadly speaking "proto-accounting" since they are relatively disconnected from the implementation of "systems of accountability" (Roberts and Scapens 1985) between stakeholders acting on this ecosystem, and from the strategic organization of collective action to deliver ecological achievement (Feger and Mermet 2017, p. 1518).

Furthermore, concurrent opinion held by conservation and accounting researchers alike has resulted in a work agenda that is both theoretical and practical. It seeks not only critically to analyze the dynamics of accounts exchanges within an ecological entity, but also to expose the limits of existing conservation tools and their uses, and actively to design new accounting innovations explicitly dedicated to strategic biodiversity management on an individual ecosystem scale (Feger et al. 2019). To do this, the aim is to combine the skills of conservation researchers who have carried out genuine research in experimenting such ecological data systems in real-world ecosystem management interventions ; and those of accounting researchers who have the systemic know-how and wealth of theory gained from critical and interpretative accounting — thereby enabling consideration of complex links between information systems and accounting; and organization of action and assumption of responsibility (Miller and Power 2013). Such ecosystem-centric management accounting has to be able to support conservation strategies as well as stakeholder groups, de facto ecosystem managers, and discussion about and assessment of ecological results delivered. This needs to happen via exceptionally diverse activity and power relation frameworks which command in-depth analysis in each case. In this respect, for example, work on the development of the ecosystem-centric "Ecological contributions accounts" model aims at monitoring the condition of a particular ecosystem as well as the various pressures deriving from stakeholder operations. Central in this research is discussion and scrutiny of the various steps taken by different stakeholders to reduce impact or to contribute to regeneration. Monitoring also comes in the form of evaluation of collective ecosystem-level environmental performance data and agreement from each stakeholder to offset labor and costs (Feger 2016; Feger and Mermet 2018).

3) Government natural capital accounting: taking the value of ecosystems into account in public policy and decision-making

The logic behind government natural capital accounting innovation is essentially that of national accounting. It involves frequent national entity level (or any other political area), retrospective balance sheet accounting on environmental condition, value and development offering various types of spatial, biophysical or economic summary (Bouni 1996; Edens and Hein 2013). Schröter et al. (2014, p. 540) carefully summarize the purpose of this type of experiment: *“The main aim of ecosystem accounting is to monitor changes in ecosystem conditions and ecosystem services over time from a spatial perspective in a way that is consistent with national accounting”*.

Contrary to the new field of ecosystem-centric management accounting, these developments have their beginnings in the decades-long chronicle of economic, statistical and environmental sciences (Nordhaus and Tobin 1971; Bouni 1996; El Serafy 1997; Richard 2012, p.15-36; Vanoli 2013; Bérard 2019). A documented example we offer in reference to this are the incomplete projects concerning the introduction of natural environments (flora, fauna, soil, wetlands, rivers, etc.) to national accounting which took place in France in the 1970s and 1980s (see research on accounting for natural resources: CICPN-INSEE 1986; Weber 1987; Bouni 1996, p. 290-314). More recently in this area, a vigorous momentum for innovation has been made possible by particular progress in the use of satellite imagery, data processing and inventory and modelling technologies in environmental sciences (Edens and Hein 2013; Weber 2014a; Hein et al. 2015). Since 2010, political resolution has been to incorporate "biodiversity values" into national accounting practice. This is now a declared aim in biodiversity strategy planning at international and European level (EP 2012). Launched in 2012, the EFESE (Évaluation française des écosystèmes et des services écosystémiques - French Environmental Assessment and Environmental Services) is an example of domain-specific action designed to carry out biophysical condition diagnoses of all ecosystems in France and to establish multidimensional assessment of their contribution to public good (Puydarrieux et al. 2016).

Such accounting innovation supports and regulates public and sectoral ecosystems policy. This transcends transformation of collective representation of values referenced by national development goals; it guides public investment in environmental protection (Jackson 2010, p. 144-145). Such accounting innovation explains environmental policy and investment efficiency to a nation's inhabitants. It may even facilitate the implementation and monitoring of international biodiversity commitments. As Bérard (2019, p.83) emphasises, with time this work produces new statistical data and standardization seeks also to “provide material responses to the SDGs [Sustainable Development Goals] set out by the United Nations for 2030” (see in particular Aims 14 and 15 which relate to aquatic and terrestrial life).

Government natural capital accounting, which can be described as "macro-environmental", aims to consolidate, structure and summarize biophysical and economic data about natural resource reserves - or natural capital, to coin the phrase - and to assess their interaction with human activity and macro-ecological systems. The notion of "ecosystem services", which has its roots in both environmental sciences and economics (Gómez-Baggethun et al. 2010), now forms the prevailing conceptual basis for national scale development of these new green accounting principles. Some advocate an explanation of what ecosystem services are via a submission of useful classification systems formed from an accounting perspective or which are compatible with the definitions, classification systems and indicators for national accounting purposes (for example GDP) which already exist (Boyd and Banzhaf 2007; Mäler et al. 2008; TEEB 2010; Banzhaf and Boyd 2012; Edens and Hein 2013).

Additionally, in 2012 the United Nations Statistics Commission adopted the *System of Environmental Economic Accounting "Central Framework"* (SEEA-CF) which aims to widen the scope of the System of National Accounts (SNA) to include the environment — its concept is primarily as a source of *input* (natural resources) and as an *output* sink (emissions, pollution, waste, etc.) — this arose in addition to (UN 2014) a second submitted volume which focuses exclusively on experimental ecosystem accounting. Consequently, the latter acknowledges the specific nature of the challenge as well as the enduring argument between different schools of thought. It encourages research into new theoretical and functional approaches (EC 2013).

In light of this fact, many techniques are currently in development testing throughout the world. Project diversity is demonstrated in: (1) programmes for assessing monetary value ecosystem utility for society and to the economy at a national level (eg costs obviated for water treatment; carbon storage, soil fertilization, etc.) — this stemmed from previous biophysical accounting set-ups. This pioneering work was developed by the *Green Accounting for Indian States Project* (GAISP) which offers a corrected version of Indian State accounting and of the GDP index — it takes into account loss or gain in monetary value associated with environmental degradation or renewal (Gundimeda et al. 2007; Sukhdev and Feger 2012); by the *Wealth Assessment and Ecosystem Valuation of Ecosystem Services* program (WAVES) which began in 2010 at the World Bank (WAVES 2014) and which supports pilot projects in several developing countries; or by the recently published natural capital accounts of The United Kingdom (ONS 2019) and The Netherlands (Horlings et al. 2019). (2) Research from Ecosystem Natural Capital Accounts, or the ENCA-QSP model. This is founded on the inclusion of geo-localized land use databases as well as on environmental data and socio-

economic statistics. The suggestion is to establish a new cumulative biophysical accounting unit (*Ecosystem Capability Unit*) making it possible to assess how well a country's ecosystems may support or renew themselves, given an annual decay ratio subsequent to human activity (Weber 2014a; Weber 2014b). (3) The *Joint Perspective Model* developed by the Australian Government's *Bureau of Meteorology* which offers an innovative multidimensional theoretical approach (economic, human and cultural, living system and physical system) of Earth (BoM 2013). (4) Research similar to the SEEA-EEA framework and which covers the development of accounting systems that are more centered upon animal and plant species (ie type, number, habitats size etc.) (UNEP-WCMC 2016), or on a specific environmental compartment such as rivers (Nel and Driver 2015) or coral reefs (ABoS 2015) in a particular country.

Finally, development may be extended further still beyond the SEEA-EEA framework from this area of accounting methodology to all systematic proposals that researchers, associations or independent think-tanks make and which aim consistently to assess, compare and challenge political leaders on management outcomes in ecosystems where they have political remit. Just one example would be research from *The Global Footprint Network* which assesses the national ecological debt according to the share of the planet's renewable resources that a country consumes each year. The Network alerts citizens, policy makers and international institutions on "budget overspend" (Borucke et al. 2013).

The breadth of present-day research is controversial, but this is par for the course when dealing with government natural capital accounting (Bérard 2019). Such discourse chiefly concerns how accounting concepts are defined and which accounting conventions should apply to biodiversity, natural capital and ecosystem services. They involve the representation of the world they underpin, how to set up biophysical ecosystem accounting and benchmarking (Comte et al. 2020). They also link to front-runner types of ecosystem monetary assessment. Is it in fact a question of measuring present-day economic value or a forecast value for all ecosystem services so as to gain a broad view of capital, as recommended by research adopting a weak sustainability perspective (eg WAVES 2014)? Or is it more a question of evaluating "unpaid ecological costs", ie costs that would have to be borne to avoid or renew that portion of an ecosystem degraded by human activity over a given period, which then leads to calculation of "environmental debt" (Levrel et al. 2012; Edens and Hein 2013; Vanoli 2015) in line with strong sustainability approaches (Dietz and Neumayer 2007)?

Apart from such important discussions about theory and method, one of the main problems remains, however, poor operationalization of national environmental accounting practices. Although to date 24 countries have published national ecosystem accounts with

varying degrees of progress (Hein et al. 2020), the few studies which have sought to assess the effectiveness of this type of accounting reflect poor take-up for decision-making and public policy making. This is linked primarily to technical implementation difficulties and then, to lack of political and institutional support (Recuero Virto et al. 2018). Admittedly, there is a problem associated with complex issues around defining and negotiating quantification norms to be accepted. Then, there are uncertain associated measurement procedures. The same applies to intransigent attitudes to existing accounting norms and those supporters of them - norms which are already part of the framework of National Accounting Systems. A yet more fundamental limitation of government natural capital accounting arises from their precise nature. This cannot be resolved by esoteric debate only: they cannot operationalize and support “the spread of ecosystem management”, which nonetheless has been called for by some of those who are behind its existence (Weber 2014a, p. 18). Given the main job of government natural capital accounting is to enhance genericity and to define and to align categories, their nature removes the profound contextual differences associated with strategic action and collective intervention from which clear ecological results are likely to be produced. What arises from this is firstly a deep gulf between the job of balance sheet production and communication of ecosystem status updates and development data and, secondly the set of management issues and institutional structure and stakeholder commitments that must be addressed in order to effect change and bolster effective ecosystem management (Hein et al. 2015, p. 90), notwithstanding the spatial scale to which they are applied (see for example a recent application of the ENCA-QSP model to the Rhône basin: Argüello-Velazquez 2019). It is in fact incumbent upon ecosystem-centric management accounting to define the missing link between consolidated balance sheet accounting and management operationalization in a less consolidated fashion (Text box 1).

Text box 1: Matters arising from coupling government natural capital accounting and ecosystem-centric management accounting

Government natural capital accounting could pioneer new joint representations of a common viewpoint given ecosystem importance. This could be a basis for a "top-down" assessment of the degree of physical decay and level of attendant maintenance costs. It could thereby enable public bodies to regulate aspirations to respect ecological limits and better manage policies and investments in favor of ecosystem renewal (see in particular strong sustainability research, such as the ENCA-QSP model and approaches to assessing unpaid ecological costs, Weber 2014a;

Vanoli 2015). Seen from this angle, ecosystem-centric management accounting is quite reciprocal: (1) it delegates and tracks accountability linked to conservation or ecological restoration activity associated with operationalization of large numbers of stakeholder groups — these have real power to drive a particular ecosystem (for example assume responsibility for aquatic biodiversity quality of an individual river). Ecosystem-centric management accounting aims to establish new and steady types of collective organization (which for example, involve stakeholder obligation - a company, an environmental association, a fishing association, and a project operator - on which ultimately biodiversity quality of a particular river depends) that is able to deliver ecological results and report on them; (2) that is able to acknowledge (by using standardized “macro-ecological” frameworks of government accounting prototypes), i) collectively produced cumulative values and ii) to command well calculated results *in situ*, true costs and efforts also that have been brokered and committed to jointly by stakeholders. In so doing, they can help "bottom-up" enhanced denotation of unit size definition. This is advantageous in government accounting in environmental, biophysical and cost monitoring terms.

4) Corporate ecological management accounting: improving corporate performance within ecosystems

Let us now leave the field of accounting which focuses on collective entities and turn attention to corporate entities. In corporate ecological management accounting, we assemble all developments in accounting practice which aim to help managers who are in charge of specific corporate activity. Such managers may also be responsible for projects which are meant to develop and implement strategies for improving biodiversity and ecosystems impact and performance management of such endeavours. The drive to combine the domain's corporate development across different business sectors, known as *The Natural Capital Protocol*, illustrates the challenges of stated aims: “*It is aimed primarily at managers from sustainability, environment, health and safety, and operations functions to help them to generate natural capital information that can be integrated into existing business processes, such as risk assessments, procurement, operational delivery plans, financial planning, or board papers. It is important to note that information generated is not an end in itself and should be clearly connected to a business decision*” (NCC 2016, p. 6).

The aim with such accounting innovations may well be to (1) support efforts to reduce ecosystem impact caused by production and service activity (habitat biodiversity destruction,

water pollution, etc.); (2) give greater consideration to risks posed to long-term activity sustainability and corporate economic performance that is linked to ecosystem destruction or mismanagement (reputational risk, reduction of ecosystem services such as pollination or water quality and availability, access to renewable natural resources such as wood, etc.); (3) adapt corporate strategies and business models accordingly, while managing economic cost implications; (4) or assess investment opportunities in ecosystem management or regeneration activity (see for example Schaltegger and Beständig 2012).

Developments which try to respond to these challenges include some pioneering domain authors who recommend tracing and quantifying methods for physical aspects of ecosystem use across production chains and for integrating associated corporate cost accounting and income analysis (Houdet et al. 2009; Houdet 2010; Houdet 2012; Houdet and Germaneau 2014; Eftec 2015). In keeping with this research, other authors also suggest development of existing analytical accounting models, not only to reveal corporate costs linked to ecosystem destruction, upon which corporate production operation is contingent, but also in order to define and monitor costs linked to potential corporate involvement in environmental restoration operations. The aim here is to sustain quality above scientifically defined ecosystem conservation thresholds with regard to strong sustainability (Lamberton 2000; Altukhova 2013; Ionescu 2016).

Other research has similar aims yet does not recommend integrating corporate analytical accounting. For example, there are proposals for life-cycle analysis methods to be extended to biodiversity and ecosystem services (Zhang et al. 2010a; Zhang et al. 2010b) as well as tools for assessing corporate and product biodiversity footprints, each of which is based on different scientific referencing system choices of pressures assessment (for example the “*mean species abundance*” unit in the case of *Global Biodiversity Score* tool, see CDC 2019; or the five biodiversity degradation drivers identified by the *Millennium Ecosystem Assessment* and the *Product Biodiversity Footprint*, see Asselin et al. 2019). Full-cost accounting techniques for biodiversity measurement of hidden societal costs have also been identified and linked to ecosystem deterioration caused by commercial production operations (TEEB 2012; Davies 2014; Kering 2015; Chaplin- Kramer and Green, 2016). On a broader level, it is possible to link this research domain to the development of new qualitative tools or ad-hoc quantitative evaluation of i) decision-making assistance and ii) risk analysis and iii) opportunities linked to aspects of corporate ecosystem interrelation. The bulk of these methods try to enhance conventional data accounting systems and their use in planning and strategic management of corporate operations vis-à-vis each business sector and its specific interdependencies on

ecosystems (water sector; agriculture; cosmetics, etc.) (For comparative reviews of these different tools, see: Hanson et al. 2011; Havas et al. 2014; Waage and Kester 2015; Addison et al. 2018; Lammerant et al. 2018; Ionescu et al. 2019).

This field of research and innovation is also beset by much controversy. Critical literature in socio-environmental accounting notes above all the importance of interrogating metrics, modes of environmental and human-nature relations representation that are conveyed by these new accounting models. It also points to examination of management philosophy models and the underlying worldviews on which they are based (Birkin 1996; Milne 1996). In relation to the performative nature of these developments and in the same way as for nation-level green accounting, several decades of research into environmental accounting endeavours reiterate how difficult it is to ensure that innovation in this area is successfully adopted by corporations and then systematically applied by teams involved in post-pilot experiment (Bebbington and Gray 2001; Larrinaga-Gonzalez and Bebbington 2001; Herbohn 2005). This becomes all the more true if such development reveals significant costs and underlying inconsistencies between the pursuit of economic goals and the aim of improving ecosystem performance. In turn, limitations of “business case” type approaches and the importance of developing complementary mandatory regulation are expressed (Brown and Fraser 2006).

Finally, notwithstanding debate in this development field, a fundamental question remains besides — biodiversity management and how a corporation is almost always reliant upon other players in the field (Feger 2016; Ionescu 2016). How is it possible therefore to make sure that the pledges, organizational changes or production methods that a corporation develops for greater biodiversity accounting really do deliver quantifiable results to an ecosystem with which it and other stakeholders interact? This challenge again articulates the importance and complementary nature of ecosystem-centric management accounting (Text box 2).

Text box 2: Matters arising from corporate ecological management accounting and ecosystem-centric management accounting

Developments in corporate ecological management accounting could help corporations from different sectors define and implement strategies that facilitate reconciling transformation of their business models and production modes in a way that reduces their impact on biodiversity, while at the same time guaranteeing their corporate economic viability. From this point of view, links to ecosystem-centric management accounting expansion are considered necessary so that corporate strategic management is broadened and: (1) impact assessments are rewritten, as are

expectation definitions and descriptions of what is appropriate for clearly defined ecosystem re-evaluation. This all takes place within the framework of collective agreement with other users of the same ecosystem; (2) the company can invest in the construction of a shared repository for assessing and monitoring ecosystem-centric environmental results (for example, inventory procedures and ecological indicators for monitoring biodiversity quality of the river mentioned above); (3) gauge as well as possible and have other stakeholders recognize the relative value of specific contributions made to delivering these environmental results (for example, by estimating action values in the reduction of pollutant discharge and desired outcomes of mortality rates within an amphibian population; or by estimating the value of river bank restoration measures in relation to increasing an aquatic bird species habitat, etc.); (4) thought is given to the cost of making these specific contributions, to assessing possible benefits which result from improving ecosystem function (for example, avoided cost of water purification) and negotiation on counterparts becomes possible with other involved public or private organizations (see work on the “Ecological contributions accounts” model, Feger 2016; Feger and Mermet 2018).

5) Corporate ecological balance sheet accounting: being accountable for pledges made to ecosystem preservation

The second business-level field we identify is corporate ecological balance sheet accounting. The proposal is to classify all research in this category that seeks to extend the scope of responsibility to natural capital. This comprises corporate accountability by including components relating to impact or to good corporate biodiversity management in balance sheet accounting practice. Jones' ground-breaking work reflects this outlook well (1996, 2003) in terms of developing a natural inventory, a monitoring and a reporting model sought to provide oversight of stewardship within a biodiversity enterprise subjected to the model: *"Organizations are stewards for the assets which they control, whether these assets be financial or non-financial. There is an underlying premise that organizations are accountable to society at large as well as to stakeholders for their stewardship of the environment.* (Jones 2003, p. 764).

Developments in corporate ecological balance sheet accounting aim to answer questions which differ from those arising from corporate management accounting, given that in this instance they are not determined at a project dimension or on any particular scale of activity, but are raised at an organization's absolute scope level. How then are absolute scope and scope points defined for business biodiversity and ecosystem responsibility? How are regular

assessments of corporate natural capital made and what efforts does a corporation make to manage it sustainably? What accountability is there to corporate stakeholders on the topic: public authorities, non-financial rating agencies, investors and civilians? Of greater concern is that these questions and this area of development are intrinsically linked to the challenge of standardizing extra-financial ecological accounting practice and revisiting the role, purposes and modes of governance of companies.

Developments in this field may be categorized in relation to two basic contentions: (1) methods and recommended integration magnitude within the same standardized report between non-financial accounting and financial accounting, and the varying degree to which these standards are legally constraining for the corporation's accountability to its external stakeholders (this deliberation relates to "integrated reporting": Eccles and Saltzman 2011; Busco et al. 2013 IIRC 2013; Rambaud and Richard 2015; Rambaud 2018; Richard et al. 2018, c. 18); (2) the significance given to wanting to maintain natural capital versus wanting to maintain financial capital (it is here that the debate on weak sustainability arises — where displacement between capitals is possible. Indeed, strong sustainability requires separate preservation of each asset: Gray 1992, 2010; Richard 2012, p. 209-225; Altukhova 2013, p. 83-87; Rambaud and Richard 2015; Rambaud 2018; Richard et al. 2018, c. 18).

In addition, the stakes in corporate ecological balance sheet accounting are more crucial than in other spheres, ie, formalizing new standards and accounting principles, notwithstanding prevailing standards. It seems to be a matter of fact that conservation sciences and understanding acquired from that and other disciplines do nonetheless allow partial overlap for uniformity and regulation. Consequently, there is greater intelligibility within reporting formats with regard to impacts on and dependence upon ecosystems in other business sectors (Kareiva et al. 2015); conversely, mainstreaming the implementation of these new accounting practices could be made mandatory to promote their adoption. This would apply also to corporations which do *not have a* specific interest in reporting poor natural capital management performance.

Here we set out two main developmental areas. Firstly, there is growing research which relates to non-financial reporting, a main theme in social and environmental accounting texts (Gray 1994, 2007; Cho and Patten 2007; Cho et al. 2015), and its development into biodiversity. Many different approaches have been put forward to absorb biodiversity indicators into corporate Sustainable Development or Environmental reports, such as procedures for systematic natural world quality oversight, of habitats and of well-functioning ecosystems under corporate control or which are affected by an organisation's activity (Jones 1996; Jones

2003; Jones 2010; GRI 2011, 2016; Jones and Solomon 2013; Jones 2014b; Thomson 2014b), or metrics designed to show the link between a company's conduct and the extinction of certain species (Atkins and Maroun 2018).

However, recent critical worldwide research or conversely, interrogation centered upon a given country or sector of activity, highlight diversity and qualify the strength of current non-financial biodiversity reporting by pioneering companies. Generally speaking, they demonstrate that biodiversity data and detail have until now been quite broad and have offered scant quantifiable facts in Sustainable Development large corporation reports. The one exception comes from one of the most well-reported sectors — mining (Van Liempd and Busch 2013; Rimmel and Jonäll 2013; Atkins et al. 2014; Samkin et al. 2014; Boiral 2016; Adler et al. 2017; Addison et al. 2019; Adler et al. 2018). This not only reflects the still relatively low levels of commitment and accountability on the subject, but it also demonstrates the real difficulties that currently exist when measuring whether promises made — which are frequently unspecified and non-timebound, actually yield positive effect on nature or not (Addison et al. 2019) (See Text box 3).

Further research yields an additional line of investigation — wanting to factor in management-related components and maintenance and/or enhancement of ecological systems, which are seen as natural capital, in financial accounting. The challenge is therefore to define, measure and report (*via* balance sheet accounting) the contribution (positive or negative) made by natural capital to a corporation's assets and to delivering its economic and financial results over a given period (*via* its income statement).

For example, some of this field's schemes embrace the inclusion of physical elements related to dependence and impact of corporate activity on ecosystems in specifically designed natural capital accounts. These “mirror” current convention in financial accounting practice, and monetary items are then derived from these biophysical accounts for integration within its core (Houdet 2012; Houdet et al 2014). Others have developed practices designed to integrate natural capital value into the balance sheet, where natural capital is conceptualized as a current or future flow of ecosystem services subject to monetary valuation. To demonstrate this, reference is made to proposals to integrate avoided costs assessment by dint of ecosystem services provided by “green infrastructures”, in particular for water sector industries (Pickle et al. 2014); or to Koshy's (2020) and Nicholls and Koshy's (2020) systematic schemes in the recent report that the Capitals Coalition (2020) instigated: *Improving nature's visibility in financial accounting*.

Research on the CARE-TDL model (*Comprehensive Accounting in Respect of Ecology-Triple Depreciation Line*) (Richard 2012; Rambaud 2015a; Rambaud and Richard 2015)

develops an alternative approach to this notion of natural capital. It extends the logic of strong sustainability by giving the same importance to financial, human and natural capital and by calling as a consequence for fundamental changes in terms of models of corporate governance and power relations that underpin them. Its advocates define corporate natural capitals as a set of natural entities which correspond to a particular application within the corporate activity framework and which must then be preserved in the same way as the other types of capital used (Rambaud 2015b Rambaud and Richard 2015; Richard et al. 2018, c.18). As such, the CARE-TDL model suggests entry of natural capitals as liabilities (subsequently considered as ecological debts to be repaid). With balance sheet financial accounting, application of natural capitals should be entered as assets. The value of such natural capitals is then determined by assessing costs associated with ecological conservation and regeneration action needed to preserve them over time. Consequently, advocates suggest an integrated definition of financial result and therefore of profit also, the calculation of which could be carried out only once depreciation expenses for the uses of natural capitals (i.e. the costs of maintenance) are taken into consideration. This approach reflects the spirit of previous research on "Environmental Sustainable Costs accounting" (Gray 1992; Gray and Bebbington 2001). It is important here also to underline the challenges linked to development of ecosystem-centric accounting (see Text box 3).

Text Box 3: Matters arising from corporate ecological balance-sheet accounting and ecosystem-centric management accounting

Corporate environmental balance sheet accounting can address challenges of delivering environmental ecosystem preservation goals where underlying logic is regulation and redefinition of the remit of the collective — the corporation — and of the power dynamic and accountability that are part of its foundation (Segrestin and Hatchuel 2012; Caron 2014). Consequently, development of ecosystem-centric management accounting can produce the essentials to better respond to current corporate challenges in terms of reporting precisely and conventionally on the efficacy of biodiversity pledges made (Addison et al. 2019). Such developments also represent an important adjunct to the development of the CARE-TDL model (Rambaud and Feger 2020). This would certainly bestow a strong accounting basis upon each ecosystem with which a corporation interacts (a biodiversity habitat area; water quality in a lake; fluvial biodiversity, etc). In addition, this would yield a diversity of activity contexts and stakeholder relations (or “representatives of natural capital” to use CARE-TDL's terminology): (1) in the scientific definition and collective negotiation of the expected extent of preservation

of natural capitals; (2) in monitoring corporation-initiated environmental activity performance to cushion natural capitals usage; (3) in budgeting and monitoring costs and expenses needed to carry out these actions and finally accounted for in the corporate balance sheet and income statement as part of integrated accounting provided by CARE-TDL.

Figure 2: Discussion and debate in literature specific to each area of development in accounting for biodiversity and ecosystems

Underlying discussion and contentions

- Interdisciplinary dialogue between accounting researchers and conservation scientists
- Support for the strategic use of existing ecological information systems
- Definition of appropriate scope and ecological results and values to be created
- Design of new accounting models dedicated to the collective ecosystem management

Ecosystem-centric management accounting

e.g. Dey and Russell, 2014; Feger, 2016; Feger and Mermet, 2017; Feger et al., 2018; Cuckston, 2017, 2018; Tregidga, 2013; Ionescu, 2016, etc.

Government natural capital accounting

e.g. Weber, 2014; Vanoli, 2015; Waves, 2014; BoM, 2013; UNEP-WCMC, 2016; Edens and Hein, 2013; Hein et al., 2015, 2020; Mäler et al., 2008; Gundimeda et al., 2007; Borucke et al., 2013, etc.

- Aggregation and representation conventions for ecosystem values
- Weak sustainability (monetary evaluation of ecosystem services) vs strong sustainability (biophysical assessment and/or debts and ecosystem regeneration costs)
- Degree of integration into the national accounting vs autonomous satellite accounting
- Decision-making application drafting of public policy, and accountability of those in power

Corporate ecological management accounting

e.g. Houdet, 2010; Houdet and Germaneau, 2014; TEEB, 2012. NCC, 2016; Green et al., 2017; Efec, 2015; Waage and Kester, 2015; Davies, 2014; Kering, 2015; Zhang et al., 2010a, 2010b; Lammerant et al., 2018, etc.

Corporate ecological balance sheet accounting

e.g. Jones, 1996, 2003, 2010; GRI, 2016; Rambaud and Richard, 2015; Rambaud, 2018; Kareiva et al., 2015; Thomson, 2014; Adler et al., 2017; Addison et al., 2018; Atkins and Maroun, 2018; Capitals Coalition, 2020, etc.

- Extra-financial biodiversity reporting vs incorporation with financial accounting
- Weak sustainability (fungibility of capital) vs strong (conservation of each type of capital)
- Harmonization of ecological reporting standards
- Degree of transformation of existing accounting standards
- Considerations on corporate governance, goals and accountability

Discussion and conclusion

One of the major challenges in the discussion of social and environmental accounting literature is predominantly the expression of obligatory corporate shift for factoring in natural capital and for directing operations toward delivering environmental outcomes. Secondly, there is the definition and representation at societal, national or even global level of environmental and sustainable development goals. These have to underpin collective effort and must work toward collective modes of organizing socio-economic activity in order to ensure the protection of the biosphere (Gray 1992, 2010; Milne 1991; Milne 2007; Milne et al. 2009; Milne and Gray 2013). How indeed can a corporation be held accountable for its attempts to protect ecosystems at a micro level, if at the same time we do not define the basis for assessment of these efforts in the delivery of environmental results at a macro level? Conversely, why deliberate and

suggest at a macro level, accounting illustrations of the overall value of ecosystems, their degradation and environmental boundaries that must be respected in order to deliver territorial or planetary sustainability, if we also fail to translate this into responsibility for and contribution to tangible steps via properly identified organizations which operate within one or more individual ecosystems?

Through suggesting a framework for joint visualization of research domains and practice, which is more often than not addressed separately, we have sought clarity about concerns on elementary political and organizational discussion of accounting practice. Consequently, our typology highlights current differences between two major developmental areas of biodiversity accounting focused on private organizations on the one hand, and two major series of developments in accounting for biodiversity which focus upon collective entities (public and interorganizational), on the other. However, without claiming to redress differences here, our typology has allowed us primarily to underline areas of developmental diversity, challenges, debate and current argument which each distinguish the four major biodiversity and ecosystems accounting areas identified (see Figure 2). We have also demonstrated how each of these areas represents a specific view of what constitutes the fundamental driver of environmental change. Nevertheless, if each of these fields of thought and development can legitimately claim to possess transformative ideals, then ultimately none of them can achieve it by itself, and the four areas seem ultimately and extremely reciprocal and mutually dependent. They contribute to the increasing importance of biodiversity responsibility.

The arrival of ecosystem-centric management accounting practice in the wider national and corporate environmental accounting landscape has enabled differential discussion of such mutual dependence and of the viability of and necessity for progress within these different domains (see Text boxes 1, 2 and 3). Firstly, this makes it possible to create a new tier within accounting and collective organization practice. This then offers an essential addition to excessively linear links between government and corporate biodiversity accounting. Currently, these attempts have yielded no results owing mainly to the multiplicity of ecosystem types involved and metrics used for their assessment. This is also because of the great diversity of collective action contexts where ecological responsibilities are to be negotiated, assigned and controlled. It becomes impossible for a general equivalence to materialize that "would facilitate comparison of the multiplicity of human actions which affect [biodiversity]" (Godard 2005, p. 7) (see Figure 3, nexus-D). Secondly, focusing on conditions vital for achieving environmental results within each ecosystem or ecological entity which characterizes the field of ecosystem-centric accounting does invite particular reflection upon possible links this field has with developments in other fields, in particular those developments that focus on achieving key ecological performance indicators and on accounting for the essential expenditure and

resources to achieve them. These all form part of strong sustainability (Text boxes 1, 2 and 3; Figure 3).

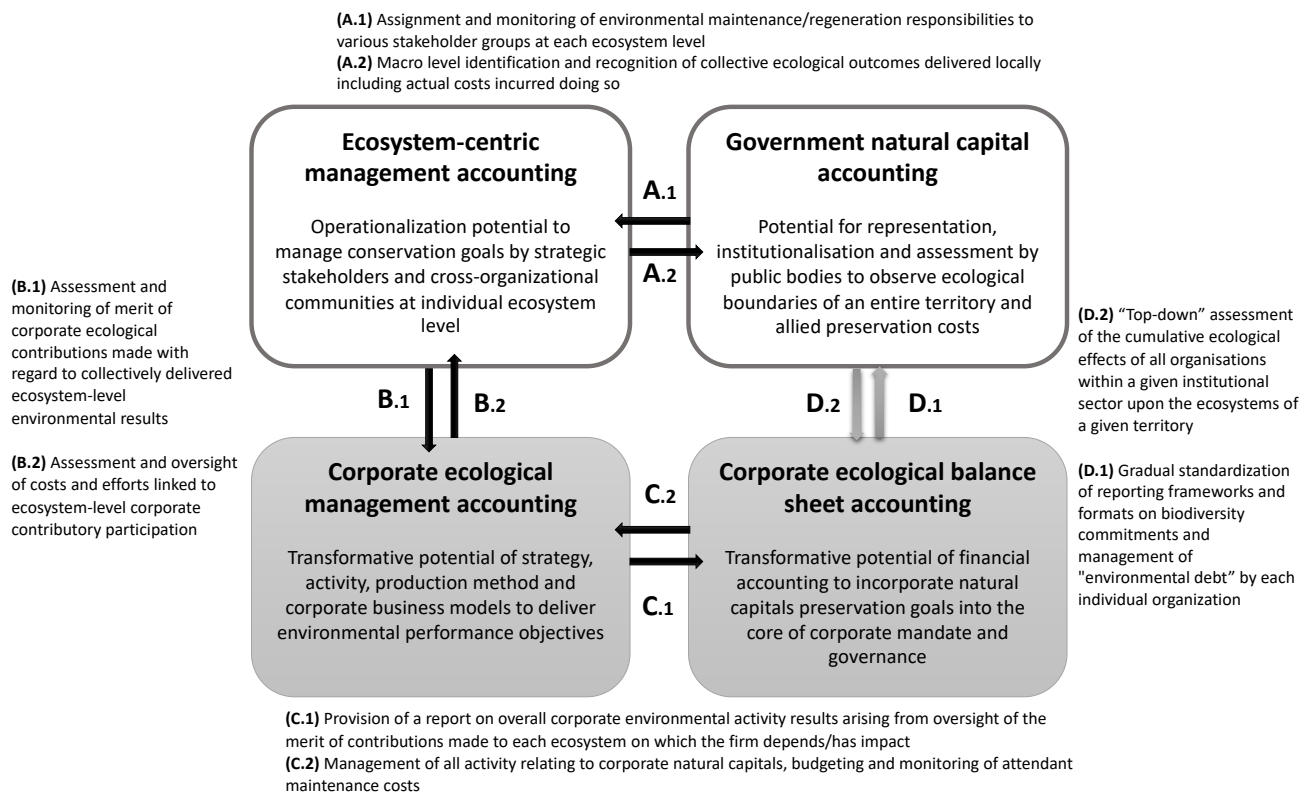
However, progress towards greater linkage or indeed potential harmonization between these areas of accounting development will firstly require an intensification of research into conceptual and epistemological explanation within and between different domains (by carrying out, for example, a more perfected method for grading all definitions and methods which measure biodiversity, ecosystems and natural capital maintenance, and for classifying underlying philosophies, etc.). Secondly, there will be a need to advance in terms of developing greater theoretical understanding and experimentation with some of the State-level accounting models mentioned. This will apply also for corporations and interorganizational ecosystem management so as to stimulate deliberation of tangible compatibility requirements. Thirdly, this will require more empirical research tailored to each domain and which focuses upon i) change instigators, their social anthropology and their ability to promote and/or adopt these accounting developments for biodiversity (accounting professionals, managers, business leaders, national accountants and public policy decision-makers, scientists and conservation practitioners from NGOs or otherwise etc.), ii) scrutiny of resistance encountered,

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iii) possible alliances between these different communities of “biodiversity conservation accountants”, and iv) a solid base for their successful implementation in addition to or in lieu of current accounting practice.

Finally, this paper has focused on mere performative potential of biodiversity accounting developments. However, it is clear that developments in accounting alone will not provide an answer to the question of how to organize preservation of planetary ecosystems. Its reliance upon bona fide change in corporate accounting law seems unavoidable (see Section 5). This applies as much at a national level as it does for collective ecosystem management, where development of new accounting practices must be backed by strengthening environmental law. In many circumstances, regulatory measures and developments in this field are still a vital source of underscoring realization of environmental performance objectives (via prohibitive action or via enactment of law on environmental thresholds, for example), and are critical to give value to i) certain land zones, ii) practices supporting biodiversity, or iii) the preservation of entire ecosystems through recognition of new areas such as non-human entities’ rights (Cabanès 2016).

Figure 3: Major challenges in interlinking the four areas of accounting for biodiversity and ecosystems development (in a strong sustainability perspective)



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