Function and normativity in social-ecological systems

Nei de Freitas Nunes-Neto [*]
Cristian Saborido [#]
Charbel N. El-Hani [δ]
Blandina Viana [ϕ]
Alvaro Moreno [γ]

Abstract: We all live in social-ecological systems. Farms, fisheries, gardens, small towns and big cities are examples of hybrid systems that result from tight interactions between social human components and strictly ecological components. The contemporary literature on social-ecological systems has focused on many different features of them, such as resilience and adaptability, governance, trust relations, measurements of resilience. In this paper, our focus lies in three aspects of social-ecological systems: functionality, organization and normativity. Our central aim in this paper is to discuss the concepts of function and norm in social-ecological systems, inspired by organizational

[* δ # ϕ γ] National Institute of Science and Technology in Interdisciplinary and Transdisciplinary Studies in Ecology and Evolution (INCT IN-TREE).

[* δ] Laboratório de Ensino, Filosofia e História da Biologia (LEFHBio), Instituto de Biologia, Universidade Federal da Bahia. Rua Barão do Geremoabo, s/n, Campus Universitário de Ondina, Salvador, Bahia, Brazil, 40170-115. E-mails: nunesneto@gmail.com, charbel.elhani@gmail.com

[#] National University of Distance Learning, Department of Logic, History and Philosophy of Science. Facultad de Filosofía, Edificio de Humanidades. Avenida Senda del Rey 7, 28040 Madrid, Spain. E-mail: cristian.saborido@fsof.uned.es

[ϕ] Laboratório de Biologia e Ecologia de Abelhas. Instituto de Biologia, Universidade Federal da Bahia. Rua Barão do Geremoabo, s/n, Campus Universitário de Ondina, Salvador, Bahia, Brazil, 40170-115. E-mail: blandefv@ufba.br

[γ] Department of Logic and Philosophy of Science, University of the Basque Country. Avenida de Tolosa 70, 20080, Donostia, San Sebastián, Spain. E-mail: alvaro.moreno@ehu.eus

approaches from philosophy of biology and ecology. Moreover, we also briefly discuss about the need to integrate ethical considerations to the epistemological ones, towards a more complete philosophical approach of social-ecological systems. According to the approach we draw in this paper, there is a double normativity linked to social-ecological systems. These are the natural norms (by and for ecological systems, such as ecosystems, wild bees, crops and wild plants), identified with basic functions (or constraints); and social norms (by social subsystems in social-ecological systems, such as farmers, beekeepers, governments, for themselves or for ecological items), identified with regulatory functions (or regulatory constraints). Based on this distinction we elaborate on the complex relationships one kind of norm establish to the other. We hope with this paper also to stimulate more participation of philosophers of ecology as well environmental philosophers on epistemological and ethical reflections on social-ecological systems.
Key-words: organization; regulatory functions; natural norms; social norms; social-ecological systems

Função e normatividade em sistemas sócio-ecológicos

Resumo: Todos nós vivemos em sistemas sócio-ecológicos. Fazendas, comunidades de pesca, jardins ou parques, pequenas e grandes cidades são exemplos de sistemas híbridos que resultam de interações estreitas entre os componentes sociais humanos e componentes estritamente ecológicos. A literatura contemporânea sobre os sistemas sócio-ecológicos tem se concentrado em muitas de suas diferentes características, tais como a resiliência e a adaptabilidade, governança, relações de confiança e as medições da resiliência. Neste artigo, nosso foco reside em três aspectos dos sistemas sócio-ecológicos: funcionalidade, organização e normatividade. O nosso objetivo central neste trabalho é discutir os conceitos de função e norma em sistemas sócio-ecológicos, inspirados nas abordagens organizacionais da filosofia da biologia e ecologia. Além disso, nós também discutiremos brevemente sobre a necessidade de integrar considerações éticas às questões epistemológicas, no sentido de uma abordagem filosófica mais completa de sistemas sócio-ecológicos. De acordo com a abordagem que esboçamos neste trabalho, há uma dupla normatividade nos sistemas sócio-ecológicos. Estas são as normas naturais (por e para os sistemas ecológicos, tais como os ecossistemas, abelhas e plantas selvagens), identificadas com as funções básicas (ou restrições); e as normas sociais (por subsistemas sociais dos sistemas sócio-ecológicos, como agricultores, apicultores, governos, atuando sobre si mesmos ou sobre componentes naturais, ecológicos), identificados com funções de regulação (ou restrições regulatórias). Com base nesta distinção elaboramos sobre as relações complexas que um tipo de norma estabelece com o outro tipo. Esperamos

com este trabalho também estimular maior participação dos filósofos da ecologia, bem como filósofos ambientais, em reflexões epistemológicas e éticas sobre sistemas sócio-ecológicos.

Palavras-chave: organização; funções regulatórias; normas naturais; normas sociais; sistemas sócio-ecológicos

1 INTRODUCTION

We all live in social-ecological systems. Farms, fisheries, gardens, small towns and big cities are examples of hybrid systems that result from tight interactions between social human components and strictly ecological components.

Paradigmatic examples of very well-studied social-ecological systems (hereafter SES) are fisherman communities and fisheries (Ostrom, 2007), farmers, the cattle and the pastures used by them Berkes, Colding & Folke, 2003), or pollination systems and farmers who produce pollination-dependent vegetables (Kremen, Iles & Bacon, 2012).

SES have been extensively studied in recent years (e.g., Berkes, Colding & Folke, 2003; Abel, Cumming & Anderies, 2006; Ostrom 2007, 2009; Norberg & Cumming 2008; Halliday & Glaser 2011; Kerner & Scott Thomas 2014; Schewenius, McPhearson and Elmqvist, 2014; Kelly *et al.*, 2015), as a consequence of the increasing recognition that many systems – particularly in the contemporary world – are so tightly connected to human societies that they cannot be understood only in terms of ecological theory, but need also a complementary perspective from the social or human sciences (Bennett & Roth, 2015). Moreover, neither can we understand the dynamics and maintenance of human social systems without taking in due account their dependence on ecological systems and processes.

On the one hand, SES are not strictly ecological systems, such as those traditionally investigated by ecologists (e.g., an ecosystem where the sociocultural human presence can be neglected, say, a bromeliad ecosystem in the middle of the Amazon rainforest, far from any human presence). By definition, SES have some social or cultural human presence. On the other hand, SES are not strictly social systems (e.g., a network communication system in the internet, where "natural" or "ecological" components can arguably be neglected), since SES also contain natural components (such as biological populations or communities or, yet, abiotic natural components) as a necessary part. Despite the difficulties faced when proposing any sharp distinction between social and ecological systems, precisely because they are intermingled in SES, it is sufficient in terms of clarity to conceive a SES as encompassing, necessarily some kind of cultural and/or technological structure that makes possible the integration of human societies to the natural environments. Moreover, and obviously, we can say that the strictly ecological systems are all becoming SES, more and more, with the ubiquitous and increasing human influence on the natural world, on Earth (Allen & Hoekstra [1992], 2015), mainly in the last decades (MA, 2005). After all, even remote ecological systems have been suffering the impact of human societies, for instance, due to climate change, as our species have changed Earth to such an extent that it has been proposed that we live in a new geological era, the Anthropocene (Crutzen, 2002; Steffen, Crutzen & McNeill, 2007; Steffen *et al*., 2011).

The contemporary literature on SES has focused on many different features of them, such as resilience and adaptability (Berkes, Colding & Folke, 2003; Norberg & Cumming, 2008), governance (Ostrom, 2009), trust relations (Stern & Baird, 2015), measurements of resilience (Kerner & Scott Thomas, 2014; Scheffer, Carpenter & Dakos, 2015), among other aspects. In this paper, our focus lies in three aspects of SES: functionality, organization and normativity.

This perspective is a legitimate one for scientific and social reasons. A philosophical work on organization, normativity and functionality of SES is relevant because it contributes to a more precise conceptual representation and modelling of the studied systems (a more epistemological contribution), but also because it raises – in a clear manner – relevant ethical and political concerns related to social normativity in SES, which only in part can be dealt with from a purely scientific or epistemological perspective (being necessary also a more ethical-political contribution, built from a philosophical point of view).

If we look at the current scientific literature on the subject, we notice, indeed, that different authors have been using some kind of functional, organizational or normative discourse related to SES. Here are some examples:

> We first define Diversified Farming Systems (DFS) as farming practices and landscapes that intentionally include *functional* biodiversity at multiple spatial and/or temporal scales in order to maintain ecosystem services that provide critical inputs to agriculture, such as soil fertility, pest and disease control, water use efficiency, and pollination. […] We explore to what extent DFS overlap or are differentiated from existing concepts such as sustainable, *multifunctional*, organic or ecoagriculture. (Kremen, Iles & Bacon, 2012, p. 44, emphasis added)

> From a *functionalist* perspective a social-ecological system is a complex system whose goal is the well-being of a community of humans and non-human life forms and their geophysical environment. […] That is, from a management perspective, the aim is to understand the *functioning* of the system as the basis for interventions oriented towards the achievement of 'whole system goals'. (Halliday & Glaser, 2011, p. 4, emphasis added)

> In a complex SES, subsystems such as a resource system (e.g., a coastal fishery), resource units (lobsters), users (fishers), and governance systems (*organizations* and *rules* that govern fishing on that coast) are relatively separable but interact to produce outcomes at the SES level, which in turn feed back to affect these subsystems and their components, as well other larger or smaller SESs. […] The prediction of resource collapse is supported in very large, highly valuable, open-access systems when the resource harvesters are diverse, do not communicate, and fail to develop *rules* and *norms* for managing the resource. (Ostrom, 2009, p. 419, emphasis added)

In the first excerpts, from Kremen, Iles & Bacon (2012) and Halliday & Glaser (2011), we can notice the use of the concept function or derivatives, while in the last one, by Ostrom (2009), we can notice the use of the concepts of organizations, rules and norms. One thesis we support here is that these terms convey something important about the scientific and philosophical perspectives assumed by these authors in the study of SES, although they do not point directly to the philosophical perspectives on which we will base our approach.

We think that we can consistently discuss, at least in part, the use of a functional and organizational language about these systems on the organizational approach to biological and ecological systems (Mossio, Saborido & Moreno, 2009; Nunes-Neto, Moreno & El-Hani, 2014), because the functional ascriptions to the social and ecological subsystems of SES have a normative character that can be clearly defined from the point of view of these approaches. Importantly, the contributions from the point of view of organizational approach (from epistemology of science) will need a complementary point of view, from ethics. This complementary, ethical, point of view will be only briefly developed here. We point out that it is still needed a clear conceptual integration between the organizational point of view, on the SES, by one hand, with the ethical considerations, by the other, based on some approach of debates in moral philosophy (such as the debate about moral ontology and the debate between the moral theories; see Singer, 2004; Warburton, 2004), as we will explain better below.

Based on the context discussed above, as well as in previous works on functionality and organization of biological and ecological systems (Mossio, Saborido & Moreno, 2009; Saborido, Mossio & Moreno, 2011; Nunes-Neto, Moreno & El-Hani, 2014), our central aim in this paper is to discuss the concepts of function and norm in SES, inspired by organizational approaches from philosophy of biology and ecology, leaving the deeper ethical and political considerations for further works. Our elaboration on these concepts here will constitute a step towards a more integral scientific and philosophical perspective on SES, which should account also for the concepts of malfunction, regulation, resilience and values, for instance.

To achieve this aim, the structure of the argument will be the following. In section 2 we will characterize in more detail the normative notion of function in the contemporary philosophy of biology and introduce the recent organizational approach to biological organisms and ecological systems. In section 3 we develop a theoretical approach to the notion of function in SES explicitly based on the Organizational Approach to ecological functions. From this point of view, we will present a general theoretical proposal for SES, with an emphasis on the concepts of function and norm. We will use as an example one particular SES, a system of fruit production dependent on pollination activity performed by wild bees. Finally, in section 4, we present our final remarks.

2 THE ORGANIZATIONAL APPROACH IN PHILOSOPHY OF BIOLOGY AND ECOLOGY

2.1 Biological functions and living normativity

In the contemporary philosophy of biology, there are two main ways to ground the kind of disposition that can be interpreted as a function. On the one hand, the different causal-role approaches (*e.g.* Cummins, 1975; Craver, 2001; Boorse, 2002) base the theoretical grounding of functions on the disposition of a specific trait to contribute to achieve a concrete systemic goal or capacity. On the other hand, evolutionary approaches interpret that a biological trait's effect is a function if it entails a disposition to contribute, either in past instances or in current organisms, to the selection of the trait via natural selection (as defended by the Selected Effect Theories put forward, among others, in Wright, 1973; Millikan [1989], 1998; Neander [1991], 1998) or to the fitness of the past (Weak Etiological Theories such as Buller, 1998) or present organisms (Propensity View of Bigelow & Pargetter, 1987).

The causal-role approach, both in the classical systemic definitions (Cummins, 1975; Davies, 2001; Craver, 2001) and in the more specific formulations of the so called Goal Contribution Approach (Nagel [1977], 1998; Boorse, 2002), defines functions as current means-end relationships, and more specifically as current contributions of components to the emergence of a specific capacity of the containing system. Therefore, according to this view, functions do not refer to any causal process that would explain the existence of the function bearer. We claim that this interpretation has many virtues for the scientific practice but in the end fails to provide a fully satisfactory ground for the normativity of functional ascriptions because it underdetermines the conditions for functional ascriptions. Avoiding any teleological interpretation, causal role approaches subsume the concept of function under the notion of cause. According to most of these accounts, a function is simply a particular causal relation among components of a system that is set apart from other causal relations only because of scientific or pragmatic interests (see Cummins, 1975). And this is problematic since, as McLaughlin (2001; 2009) has pointed out, functions seem to show a particular type of relationship between certain means and goals in a system, which go beyond the standard concept of causality and have a normative flavor. When a function is ascribed a certain rule is postulated at the same time, a rule that is applicable to the behavior of what we consider as functional.

Although the causal-role theorists use to deny it (see, for instance, Cummins, 2002 or Davies, 2001), there is a general assumption in the philosophy of biology that biological function is a normative concept, and not just a descriptive notion, because it refers to some effect that *should take place*, not only that *it takes place* (Price, 1995, 2001, p. 12-15; Hardcastle, 2002, p. 144). For example, saying that the heart's function is pumping blood is equivalent to stating that tokens of the type "heart" should pump blood.

Clearly, the normative dimension of functions requires an appropriate theoretical justification of the criteria under which the functional relationships are identified as such and distinguished from all the other causal relations in the activity of a system. If functions are normative and, accordingly, they should be understood as norms that must be satisfied, an adequate approach should explain why there are some causal relations that must be accomplished whereas others (the non functional or "accidental" effects) simply occur, only casually happen. Causal role definitions turn out to be systematically under-determined: and they do not restrict functional ascriptions to the relevant classes of systems, traits and goals, because there is no difference among causal relations in terms of an intrinsic normativity. In contrast to this view, the evolutionary approaches are able to avoid the problem of the under-determination of the causal-role theories, because they address normativity by appealing to teleological dimension of the concept of function: evolutionary view tries to answer teleological questions such as "why does a trait exist?" or "why a trait will exist in the future?" providing a characterization of a "causal loop" that appeals to relevance of the functional effect for the evolutionary preservation across generations (through the action of the natural selection) of the functional bearer. This allows us to offer a suitable characterization of normative function: a function is an effect of a biological trait that had been evolutionarily selected precisely due to that functional effect. Consequently, that trait should do what it was selected for (Millikan [1989], 1998; Neander [1991], 1998).

The main problem of the evolutionary perspective is that every evolutionary account is *epiphenomenal*: functional ascriptions have no relation to the current contribution of the trait to the system, since they point solely to the selective history of the trait (see Christensen and Bickhard, 2002; Mossio, Saborido & Moreno, 2009). And this epiphenomenal character is at odds with the fact that, in order to be explanatory and relevant as a scientific tool, a function of a trait is expected to have a relation – captured by the causal role approaches – to what that function bearer currently does (and should do), and not only to the causes of its current existence.

In conclusion, the causal-role approach is, on the one hand, unable to adequately ground the normative dimension of functional explanations because underdetermines the conditions for the ascription of biological functions. And, on the other, the evolutionary accounts cannot offer a tenable formulation of normative function for current organisms since their approach is problematically epiphenomenal.

The organizational approach we endorse in this paper aims to overcome those limitations by combining both approaches in a systemic, teleological and non-epiphenomenal account of biological functions. This approach is at the same time a causal-role and an etiological approach. In this way, it is able to provide clear criteria for the ascription of functions in a normative way that appeals to a causal-loop that explains the current existence of the functional bearer. However, unlike the evolutionary approaches, the organizational approach avoids the problem of epiphenomenalism, since that causal-loop is found in systemic features of living beings, focusing therefore on the biological properties of current biological organizations.

2.2 The organizational approach to functions in biological organisms

Different formulations of organizational approach have been recently proposed, among others, by Schlosser (1998), Collier (2000), Bickhard (2000; 2004), McLaughlin (2001), Christensen & Bickhard (2002), Delancey (2006), Edin (2008), and Mossio, Saborido & Moreno (2009). They ground functional ascriptions in the fact that biological systems realize a specific kind of causal regime in which the actions of a set of parts are a condition for the persistence of the whole organization through time. Organizational theories argue that there is a causal loop, based in the self-maintenance of organisms, that allows us to state that a trait has (or serves) a specific function when that trait contributes to the maintenance of the biological organization to which it belongs through the performance of an specific effect (which will be the trait's function). Consequently, organizational theorists claim that the functional effect has an explanatory relevance to account for the very existence of the functional bearer. A function is, at the same time, an effect and a cause of the current presence of a functional trait, according to a causal-loop that is accessible from a systemic frame. Therefore, the organizational approach accounts for the reasons for the existence of a functional trait, as it endorses a teleological interpretation of functionality, and, since it also assumes a systemic view, does not fall in the problem of epiphenomenalism.

Moreover, the organizational approach claims that the effect of a trait that contributes to the self-maintenance of the organization is a normative function. Organizational functions are biological performances necessary for the persistence of the system in which the functional trait exists. If a functional trait fails to produce its function, then it will not be around for very long, because it cannot be re-produced by the system and, in the last term the biological system won't be capable of self-maintenance (see Schlosser 1998; McLaughlin, 2001, p. 191). That particular interpretation of normativity presumes that norms can be interpreted as conditions of existence: a trait effect is a normative function iff that effect is a condition of existence of the trait. In Christensen & Bickhard's words: "[a functional trait] can succeed or fail in supporting the system, and this makes a distinct difference to the system, and to the world" (Christensen & Bickhard, 2002, p. 16). Accordingly, in organisms, functional norms are not external "observer-dependent" values because they appeal to the *conditions of existence* of a living organization. Organizational functions are norms *imposed by the system itself*.

Biological self-maintenance implies integration among the different processes and structures involving the traits of an organism. If we consider, for instance, the classical example of the function of the heart, this definition would imply that the heart has the function of pumping blood since pumping blood contributes to the maintenance of the organism by allowing blood to circulate, which in turn enables the transport of nutrients to and waste away from cells, the stabilization of body temperature and pH, and so on. At the same time, the heart is produced and maintained by the organism, whose overall integrity is required for the ongoing existence of the heart itself. Lastly, the organism realizes *organizational closure*.

The organizational closure is realized when a network of material structures is able to exert mutual constraining actions on its boundary conditions, such that the whole network is collectively self-maintaining[1]. Whereas each constraint - that is, the local and contingent causes, exerted by specific structures or processes, which reduce the degrees of freedom of the system on which they act (Pattee, 1972; Moreno & Mossio, 2015, p. 4) – is not *per se* able to achieve self-maintenance, the whole network of constraints, insofar as it is subject to organizational closure, can avoid its own decay due to its far-from-equilibrium nature, by constraining its own surroundings in such a way as to recursively assure the replacement of the different components. Thus, the close association between complexity and integration accomplished by organizational closure is a mark of biological self-maintenance.

In sum, organizational approaches claim that organizational closure of constraints constitutes the relevant causal regime in which the teleological and normative dimensions of functions of organismic traits

[1] For a detailed theoretical characterization of the crucial notion of "closure of constraints", see Moreno & Mossio (2015). In their words:
"Closure is a specific mode of dependence between a set of constraints. In very general terms, it refers to all those cases in which, instead of having a linear chain of dependence relationships between constraints, the chain folds up and establishes *mutual* dependence. In formal terms, a set of constraints C realises closure if, for each constraint C*i* belonging to C:
1. C*i* depends directly on at least one other constraint of C (C*i* is de-pendent);
2. There is at least one other constraint C*j* belonging to C which depends on C*i* (C*i* is enabling).
Closure refers then to an organisation in which each constraint is involved in at least two different dependence relationships, in which it plays the role of enabling and dependent constraint, respectively. The network of all constraints, which fit the two requirements, is – we hold – collectively able to self-determine (or, more specifically, self-maintain […]) through self-constraint" (Moreno & Mossio, 2015, p. 20-21).

can be adequately grounded. An organizational function is a constraining action that is an effect of and a condition for the self-maintenance of the organism. Moreover, such mutual dependence between existence and activity provides an intrinsic and naturalized criterion to determine what norms an organism and its traits are supposed to follow.

2.3 The organizational approach to functions in ecological systems

The organizational perspective was applied to ecological systems by Nunes-Neto, Moreno and El-Hani, who defined an ecological function as "a precise (differentiated) effect of a given constraining action on the flow of matter and energy (…) performed by a given item of biodiversity, in an ecosystem closure of constraints." (Nunes-Neto, Moreno & El-Hani, 2014, p. 131). The main element here is the idea of an ecosystem closure of constraints, which is the basis to ground the teleology and normativity of functions, from a naturalized organizational perspective.

We can explain the basic idea further by considering the example of a minimal ecosystem with three functional groups: producers, consumers, and decomposers of organic matter; and two hierarchical levels (i.e., in a hierarchy of control, cf. Ahl & Allen, 1996): the level of the items of biodiversity (which act as the constraints) and the level of the flow of carbon atoms (the processes). In our minimal ecosystem, the items of biodiversity are the functional groups. The producers of organic matter (plants) constrain the flow of carbon atoms, reducing its degrees of freedom, through the absorption of carbon dioxide and carbon fixation in photosynthesis. The flow of carbon atoms becomes more determinate, more harnessed, as those atoms become part of the plant biomass. Part of this biomass (leaves, fruits, sprouts, etc.) is eaten by the consumers (herbivorous animals), which further channel the flow of carbon, when carbon atoms become part of their biomass. When the consumers and producers die, the animal carcasses and plant leaves, fruits, and twigs constitute the organic matter that is further processed by decomposers, transforming it into available nutrients for plants and, thus, closing the cycle.

There is a mutual dependence between these constraints. The consumers, for example, constrain the flow of matter in a way that reduces its degrees of freedom, and, with this effect in the ecosystem as a whole, they create enabling conditions to the existence of the decomposers. Thus, on the one hand, they are enabling conditions to the decomposers, while, on the other, they are dependent on the producers of organic matter and on the very decomposers that mobilize nutrients to the producers.

The producers, consumers, and decomposers play functions that contribute to the self-maintenance of the ecological system and these functions correspond to their constraining action on the flow of matter and energy within the ecosystem closure of constraints.

3 TOWARDS AN ORGANIZATIONAL APPROACH TO SES

We suggest that the idea of organizational closure of constraints (already applied to organisms and ecosystems) can, at least in principle, be applied to SES, following an earlier suggestion by Velasco (2008).

In order to try to extend the organizational approach to SES we will consider a specific kind of SES, namely, that of a food production system based on bee pollination. A concrete instantiation of this kind of SES is the *apple production system in an agricultural pole and a National Park* [c. 200.000 ha] in Chapada Diamantina, Bahia, Brazil (Viana *et al.*, 2014; see Fig.1).

For the sake of the argument, let us first consider a two-level ecological system (following our previous organizational approach in ecology, explained above) composed by a flow of matter (at level L_1) and by ecological entities acting as constraints on this flow of matter (at level L_2).

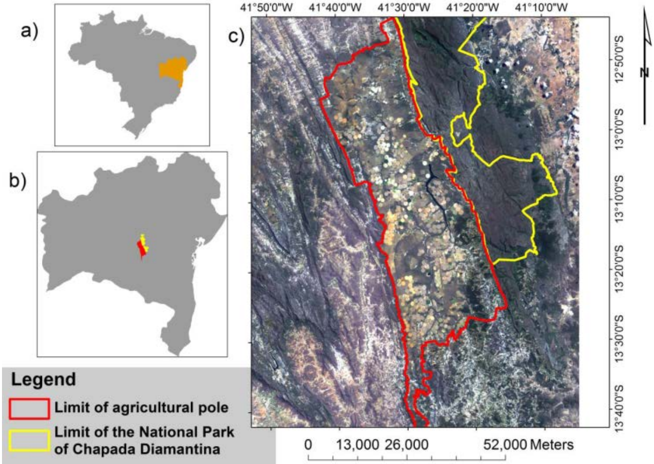

Fig. 1. A specific kind of SES, a food production system based on bee pollination. This is a concrete instantiation of a SES for apple production which integrates an agricultural pole and a National Park [c. 200.000 ha], in the region of Chapada Diamantina, Bahia, Brazil. (from: Viana *et al.*, 2014)

In our case study, the flow of matter can be instantiated in the flow of carbon atoms present in the fruits produced by the system, whereas the ecological constraints can be identified with actions of the items of biodiversity[2], more specifically, the apple trees (the producers of organic matter), the wild bees (the pollinators), and the soil organisms (decomposers of organic matter in soils). The entities and processes in these two levels integrated in a control hierarchy (Ahl & Allen, 1996)

[2] An item of biodiversity is "a biological entity or activity directly relevant for the maintenance of an ecosystem, by actively participating in, at least, one constraining action within this same ecosystem". This concept does not simply refer to species composition, but also to entities or activities that are considered – by contemporary ecology (mainly BEF) – biodiverse. Hence, this concept – which is hierarchical and scale-free (just as the ecosystem concept) – "includes in its domain (…) the following items: morphological or physiological traits, organisms, populations, species and functional groups" (Nunes-Neto, Moreno & El-Hani, 2014, p. 132; see also Cooper, El-Hani, Nunes-Neto, 2016). We could identify a number of different items of biodiversity in the SES we are analyzing, using a series of different criteria, but for the sake of simplicity we will consider only three items in our analysis.

constitute the natural ecological subsystem of the SES in our case study.

The constraints found in this SES harness in a functional way the flow of matter (producing, consuming, storing or degrading it), and they contribute in this way to the maintenance of the whole SES. It is important to understand that these constraints are mutually dependent, and this mutual dependence embeds them in an ecological closure of constraints. For instance, the apple trees are, on the one hand, *dependent* on the regeneration of organic matter in soils (since the plants demand nutrients, such as N, P and K available to absorption by the roots, in the soil) and they are, on the other hand, *enabling* for the wild bees (since they are flowering plants, and the flowers are conditions of possibility for pollination). The wild bees, in turn, are *dependent* on the apple trees, but are *enabling* to the soil organisms, which decompose the fruits or other organic matter in the soils, since there would be no fruits without pollination. This decomposition of organic matter by soil organisms contributes to the fertility of soils, which, in turn, creates conditions for the growth of apple trees. The soil organisms are *dependent* on wild bees, but also *enabling* to apple trees.

Having made this description, let us take into account now that, in our case study, this ecological system is in interaction with social systems (as subsystems of the SES) and, for the sake of simplicity, that there are two levels in the social systems, with their respective functions and norms.

One level is composed by social agents and norms that interact more closely with the ecological systems. In our case study, let us consider the farmers, the (sub)systems involved in the transportation and distribution of the fruits, the fruit consumers as well as the (sub)systems that are responsible for the collection and treatment of organic wastes. Further, we will elaborate more on this, building a more precise representation, but now a coarse representation is enough. Thus, we can say that these social agents and norms (at level L_3) act on the ecological constraints (at level L_2), constraining or modulating them.

Another level of the social subsystems is composed by agents or norms (in a more political level of action, which we call here level L_4) which act by modulating the behavior of the other – abovementioned – social agents or norms (at level L_3).

In sum, the result is a four-level hierarchical system composed by the flow of matter (L_1), the ecological constraints (L_2), the social agents or norms, which have a more direct contact with the natural subsystems (L_3) and the social agents or norms, which act in a more political level (L_4), all related to each other, directly or indirectly, in complex ways.

3.1 Normativity in social-ecological systems

Since function is a normative concept, it is necessary to explain what we understand by norm here. This clarification of the meaning of norm and the normative dimension of the concept of function will be at the same time a more precise elaboration on the organization (maybe an ontology) of SES we have proposed above.

First of all, let us clarify that in our approach there are two main kinds of norms: 1) *natural norms* (*by* and *for* ecological systems, such as ecosystems, wild bees and wild plants), identified with basic functions (or constraints); and 2) *social norms* (*by* social subsystems in SES, such as farmers, beekeepers, governments, *for* themselves or *for* ecological items), identified with regulatory functions (or regulatory constraints). Let us now explain them, illustrating with our case study.

The natural norms (of strictly ecological systems) are linked to a natural and intrinsic normativity of such systems. In general, they could be identified with the fulfillment of a global capacity of these systems, such as cohesion (Collier, 2000), resilience (Holling, 1973, 1996; Folke *et al.*, 2004; Gunderson, Allen & Holling, 2010; Curtin & Parker, 2014), or simply the self-maintenance of the whole system (Mossio, Saborido & Moreno, 2009), etc. To our understanding the concept of ecosystem closure of constraints (Nunes-Neto, Moreno & El-Hani, 2014; Cooper, El-Hani, Nunes-Neto, 2016) is an adequate representation of the natural ecological norms. The ecosystem closure of constraints (which can be characterized in terms of mutual dependence relationships between constraints, as we have explained above) with the entanglement of the flow of carbon atoms and the apple trees, the wild bees and the soil organisms constitute an example of the natural norm of the ecological (sub)system of the particular SES we are examining.

The social norms, in turn, can be split up in two kinds. The first, which we call the 1st order social norms, are *directed towards* ecological items. They are the *presuppositions of what the ecological items in SES should do* (e.g., wild bees in SES *should pollinate flowering plants in a given rate*; wild plants in SES *should produce fruits in a given rate*, etc.). Commonly, but not necessarily, these norms are presuppositions made by the agents that more directly interact with the ecological systems. For instance, an apple producer assumes a presupposition about the amount of fruits he or she will need in order to keep a given pattern of production. And this will indirectly refer also to the pollination rates, since fruit production depends on pollination in this case.

The second kind of social norms are the 2nd order social norms, or as we prefer to call them, the social metanorms. These are norms about *what the social agents should do in terms of their own behaviors and value systems, having direct influence on the 1st order social norms* (and, indirectly – but quite significantly – also on some of the natural norms of SES). While the 1st order social norms are related to the direct design and intervention on SES, and as such they *target* the very ecological items constituting the SES and their respective normativity, by its turn, the social metanorms are *reflexive*, in the sense they are by human agents towards – or *targeting* – other or the same human agents. In this sense, social metanorms target, specifically, the issues related to the *role of science in the social and environmental problems*, the *laws* related to environment, the *value systems* (epistemic and moral) that guide our interactions among ourselves and with nature, as well as the *educational processes* in science, technology, society and environment, for instance. As an example, we can treat the role of public banks in funding agriculture in a given region as a social metanorm. Depending on the pattern of funding, a given kind of agriculture (such as agroecological; see Altieri, 1999) will be more supported than another (such as agribusiness), having a direct influence on the apple producers, for instance, but also, indirectly and significantly, on the natural (sub) system of the SES (for a schematic representation, see Figure 2).

Here a qualification is necessary: why have we pointed out to *norms* and not *agents*, when it comes to the predominantly social subsystems of SES? For us, it seems more adequate to think about the social subsystem of a SES in terms of *norms* and not *entities*, such as *agents*. We suggest that a representation in terms of norms, present in all social agents (although in different degrees, combinations or emphases) is more precise than a representation in terms of types of agents (although that discourse in terms of agents seems easier to understand). This is the case because the kind of normativity in the social subsystem is more important than the kind of entities or social groups that perform it. In other words, once we go to a description of the social norms, we will see that both social norms (1^{st} and 2^{nd} order) are present – more or less – in all social agents or systems, in a complex pattern. For instance, a farmer, who is an agent usually characterized – *qua* farmer, that is, according to his/her social (main) function – by the performance of 1^{st} order social norms (because of his/her more direct interactions with the natural systems of SES, such as plant trees or other organisms), performs also 2^{nd} order social norms (because of his/her role as a political agent – for instance, through his/her participation in social movements, social organizations, legal and political discussions about the agricultural laws, educational processes involving his/her own child – able to modulate the 1^{st} order social norms). Interestingly, this representation in terms of norms and not agents allows us to notice a feature of social functions – which, as pointed out by Jax (2005) is similar to ecological functions – that is, the fact that one given agent can perform different roles depending on his/her context. For instance, one given person can assume the social function of teacher in her school, while – in a different moment – that of a mother at home. So, since, one given agent assumes different roles in society, depending on the particular context of social living, a characterization in terms of the norms guiding the specific interactions seems a more precise one.

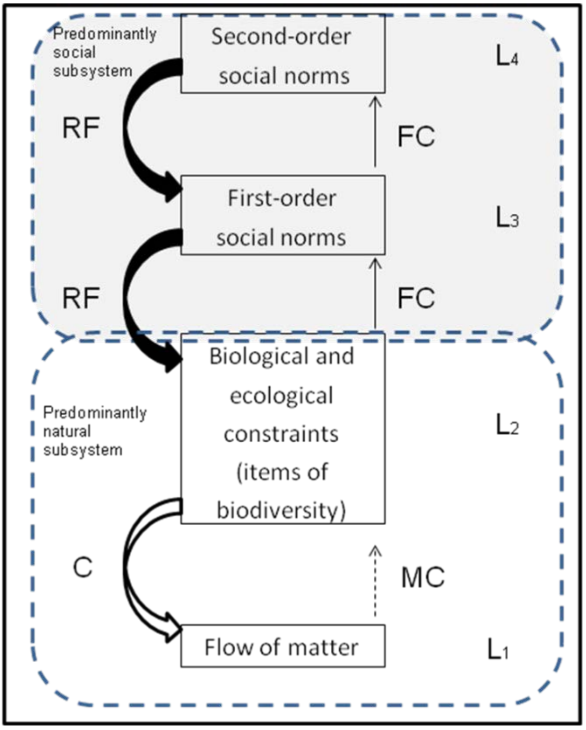

Fig 2. Abstract/general scheme of four non-nested levels in a control hierarchy (sensu Ahl & Allen, 1996) of a SES. L_1 is the level of the flow of matter (e.g., the flow of Carbon, which traverses and is constrained through the bodies of producers, consumers and decomposers of organic matter in an ecosystem); L_2 is the level of the biological and ecological constraints (e.g., the items of biodiversity, the producers, consumers and decomposers of organic matter; which act constraining through their own metabolic, physiological and ecological actions the flow of matter); L_3 is the level of the first-order social norms (which are embodied, for instance, by agricultural practices, directly acting on the items of biodiversity); L_4 is the level of the second-order social norms (which are embodied, for instance, in agricultural laws, value systems, political settings etc). RF indicates a Regulatory Function; C, a Constraining action; FC, a Functional Contribution (analogous to a formal cause); and MC, a material contribution (analogous to a material cause). The predominantly social part of the system is represented within the grey box, while the predominantly natural part is within the white box.

The relationships between natural and social norms constitute a central and complex issue. It seems that, in SES, some natural norms of ecological systems need to be maintained in the biological or ecological structures (the items of biodiversity, for instance), whereas other natural norms are effectively harnessed or modulated by human actions (following social purposes). And here we reach a central question for the understanding and design of SES, for which an organizational perspective (both scientific and philosophical) can contribute to answer: how is it possible for a SES to accommodate both natural and social norms, in a way that the higher level social norms does not undermine the lower level, natural, norms?

Let us now explain this issue through our case study. For this, imagine two extreme states of affairs or conditions. One is a pure natural condition (where there are only natural norms at work, with no social norms). This situation is simply not problematic because there are no humans involved at all. It is however, an idealized situation, which is patently false in the current state of affairs, where the human presence on Earth is ubiquitous. We could even say that once human species appeared on Earth, ecological systems in interaction with human beings could not anymore be considered "purely ecological", but had to be considered as SES. At the other extreme, let us focus on a situation of a purely social/cultural world. This is also clearly an idealized situation, since social norms are embodied and grounded, in some degree, in biological, natural organizations and also dependent on ecological organizations. So we are always somewhere in between the two extremes.

In spite of being always somewhere in between the middle, the problem, however, is that in the current environmental crisis we are all facing (MA, 2005), the social norms are superimposing themselves on the natural norms, in a way that may cause the collapse of many SES in the future (or are already causing). For instance, taking our case study, the 1^{st} and 2^{nd} order social norms – associated respectively to the agricultural practices and public policies in agriculture, among others – are impacting the maintenance of the wild bee communities as well as the flowering plants, mainly the wild species, and as a consequence, are affecting the very flow of carbon harnessed by them.

If, on the one hand, social norms need to modulate the natural norms in order to ensure the maintenance of the human society (which could be identified with human well-being or with environmental services (see Nunes-Neto, Carmo & El-Hani, 2016), according to this particular scientific-ideological perspective), on the other these social norms cannot exceed some limits, since otherwise the social norms will destroy the cohesion, resilience, or simply the capacity of self-maintenance of the natural (sub)systems.

Of course, the natural systems we are examining – as well as many other cases of SES – are not autonomous in relation to the human social (sub)system. For instance, the domesticated apple trees cannot reproduce by themselves, directly depending on 1st order social norms to be reproduced. By no means this is an exception, seeming, rather, to be a general rule for domesticated animals and plants: since these organisms were – at least in part – a result of a human creation – many along millennia of coevolution, artificial selection and domestication – it is more precise to qualify them as hybrid, both biological and cultural, objects (we can call them biocultural objects).

It is important to highlight that this, in our view, should not lead us to a denial of nature or "naturalness", as sometimes Latour (1999) alluded. It is not neglecting nature – both in our scientific understanding as well as in our social practices toward it – that we, as social agents, will be able to establish adequate social norms, targeting the maintenance of SES for large – ideally infinite – time-horizons (for critiques on Latour's position, see Larrere, 2013 and Nunes-Neto, 2015). Also, it is not pure technology that will save us from the environmental crisis[3]. Rather on the contrary: we need to adequately recognize the natural norms that underlies the collective maintenance of these hybrid objects within an ecological system, hence, not designing social norms which could violate their natural norms, because this violation of biocultural objects' natural norms (such as it happens, sometimes, with domesticated animals or plants) is a destruction of the conditions of possibility of the very social purposes – seek when the social norms are designed, ultimately fixed in the 2nd order social norms – and as a consequence affects the viability of the whole SES. This means that, for

[3] Such as robot bees, for the case of colony collapse disorder, associated to pollination deficits (see http://robobees.seas.harvard.edu/).

instance, "some norms of an apple tree" should be maintained inviolable ("such as the biological closure of constraints of the apple tree on the flow of matter that traverses it"; which presupposes a mutual dependence relationship between constraints, such as the roots, the trunk and the leaves/canopy), while others, inevitably should be modulated, in order to increase fruit production, such as flower and fruit production by the apple tree or the reproduction of the apple tree, which is strongly dependent on agricultural practices, developed along history.

The recognition of natural norms in SES is somewhat the recognition of those natural norms or dimensions of the biocultural objects that are *inviolable*, although they *should* be modulated in order to reach social purposes. And here it is the hard question: is it possible for social norms to *modulate* natural norms (in order to reach social purposes, such as fruit production for human beings) but *without violating* the natural norms themselves (which would imply a destruction of the whole system)? If yes, *how* would that be possible? This question seems central to an understanding of the complex relationships between natural and social norms in SES. Although we raise it here, we leave it open for further investigations.

However, before finishing this section, it is important to say some words on the role of ethics in connection with the social norms. Among the elements composing the social norms (of 1^{st} and 2^{nd} order) it is worth mentioning the ethical perspectives one could assume in his/her actions. We propose to organize these elements in two main groups: 1) the moral ontology, that is the definition of those who are worth of moral consideration. For instance, what are the ones morally considered? Some human beings, all human beings, all non-human animals, communities, ecosystems? and 2) the normative moral theories (virtue ethics, utilitarian ethics, deontological ethics), which, in turn offer the criteria to justify a moral act, with a relative independence from the moral ontology assumed (Warburton, 2004). More specifically: to what trend in moral philosophy would the organizational approach in epistemology of biology and ecology be closer?

Although we point to these elements here a more elaborated approach integrating the organizational approach in philosophy of biology and ecology (an epistemic perspective), by one hand, and the debates and contributions from moral ontology and the ethical theories (an ethical perspective), by the other, needs a more careful consideration in the future.

4 CLOSING REMARKS

In this paper we examined the concepts of function and norm in SES from the point of view of organizational perspectives from philosophy of biology and ecology.

Our main conclusion is that an adequate understanding of SES require a double normativity: natural and social norms related to each other in complex ways. Seemingly, the social norms should adequately modulate, but not violate, the natural norms of ecological systems, if they are designed to contribute to the sustainability of the whole SES. But how to do that is a hard issue.

Different questions can be raised for future investigations, in order to reach a more complete and satisfactory framework for SES. For instance, we can ask:

1) What is the role of functional regulation, as a social norm, in SES?
2) How could we define malfunction in SES? More specifically, we could ask: how could a definition of malfunction be applied for the case of colony collapse disorder or pollination deficit, which are currently affecting wild bees?
3) How can we understand the first and second-order social norms, in terms of ethics (moral ontology and ethical theories)? In order to reach a more complete understanding of SES, how is it possible to connect epistemological perspectives on the organization of SES with ethical considerations coming from debates in moral philosophy and environmental ethics?

These are socially, environmentally and politically relevant questions for further research in philosophy of ecology and environmental ethics, to which the work of philosophers can shed some light.

Acknowledgments

Nei de Freitas Nunes-Neto thanks to CNPq (National Council for Scientific and Technological Development, Ministry of Science and

Technology, Brazil) for the post-doctoral research Grant number 201618/2014-1. Charbel N. El-Hani is indebted to CNPq for the research support through Grant number 301259/2010-0 and CNPq and FAPESB (State of Bahia Foundation for the Support of Research) for funding of project PNX0016_2009. Alvaro Moreno acknowledges aid from the Research Project IT 505-10 of the Gobierno Vasco and FFU2009-12895-CO2-02 and FFI2014-52173-P of the Spanish Ministerio de Economia y Competitividad.

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Data de submissão: 01/06/2016
Aprovado para publicação: 02/08/2016