Is Ecosystem Health a Useful Metaphor? Towards a Research Agenda for Ecosystem Health Research

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Abstract. The term ecosystem has been widely adopted outside its original domain in biology, for example in business and engineering studies. Ecosystem health is a derivative metaphor used to describe the success of the ecosystem. In this paper, we describe the key shortcomings of ecosystem health research. We put forward two key postulates of ecosystem health. Based on these postulates we present a research agenda for ecosystem health.

Keywords: Business ecosystem · Software ecosystem · Ecosystem health

1 Introduction

The term 'ecosystem' has been widely adopted outside its original domain in biology, for example in business and engineering studies. Prior studies have introduced terms including 'business ecosystems' (Peltoniemi and Vuori 2004), 'innovation ecosystems' (Oh et al. 2016), 'mobile application ecosystems' (Hyrynsalmi et al. 2016), 'service ecosystems' (Vargo and Lusch 2011), 'product ecosystems' (Frels et al. 2003), among others. The widespread use implies that the ecosystem analogy has been viewed to provide value-added for research. At the same time, the use of ecosystem analogy has also been criticized (see for example Oh et al. 2016; Hyrynsalmi et al. 2015a, Mäntymäki and Salmela 2017).

In biology, an ecosystem, or ecological system, typically denotes a unit of biological organization made up of all the organisms in a given area, thus forming a "community". Organisms within a community interact with the physical environment so that the flow of energy leads to characteristic trophic structure and material cycles within the system (Odum 1966). *Ecosystem health* is an analogy used to describe business ecosystems. According to Ianisiti and Levien (2004a, p. 5), ecosystem health is a crucial concept in business ecosystem research: *"if the ecosystem is healthy, individual participants will thrive; if the ecosystem is unhealthy, individual participants will suffer"*.

Up to date, with one notable exception (Hyrynsalmi et al. 2018), very few studies have critically evaluated applicability of the ecosystem health analogy outside the biological domain, for example with respect to business or software. To address this

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void in prior literature, this study aims to concretize the critique presented by Hyrynsalmi et al. (2018) towards a research agenda. As a result, the purpose of this paper is to *(i)* critically discuss the applicability of the ecosystem health analogy in business research, *(ii)* address the key challenges related to the use of the ecosystem health analogy, and *(iii)* put forward a research agenda to address these challenges.

The remaining of the study is structured as follows. Section 2 previews the extant literature on software ecosystem health. Section 3 defines the starting hypotheses and drivers for the ecosystem health research renewal. In addition, it discusses on various countermeasures against the seen issues. Section 4 lists the research actions proposed and Sect. 5 concludes the study.

2 Ecosystem Health as a Metaphor

In addition to different biology inspired analogies such as rainforest or jungle, research on business networks has used the 'business ecosystem' analogy by Moore (1993, 1996), and its derivatives—such as 'software ecosystem'—as a crucial conceptualizations for today's business networks. A key characteristic that distinguishes natural ecosystems from artificial ecosystems such business ecosystems is actor's consciousness of the existence of the ecosystem and the actors involved in the ecosystem ecosystems (Moore 1993). The fact that actors are conscious of the ecosystem allows then to also evaluate the health of the ecosystem and adapt their behaviour intentionally.

In this paper, we view software ecosystem as a subset of the more generic business ecosystem concept (Hyrynsalmi et al. 2015a). There are several different kinds of software ecosystems (SECO) focusing on the software producing companies and their networks (Jansen et al. 2009; Manikas and Hansen 2013a), mobile ecosystems formed by the companies producing hardware and software for new era smartphones (Basole 2009), and even mobile application ecosystems comprise the relationships of mobile application marketplaces, their content producers i.e. application developers, and users (Hyrynsalmi et al. 2014; Suominen et al. 2014). Furthermore, the software ecosystem concept includes non-commercial open-source ecosystems built on shared code repositories (e.g., OSGi ecosystem), commercial open-source projects (e.g., WebKit) as well as platform ecosystems revolve around global players such as Amazon, Facebook, and Alibaba and utilize the focal company's interface to customers and brand.

To illustrate the difference between business and software ecosystem, Manikas and Hansen (2013) pointed out that in a software ecosystem, the relationships between the actors are based on a shared software technology or a software platform (Manikas and Hansen 2013a). Based on these considerations, we conceptualize, software ecosystems are business ecosystems where software constitutes a focal part of the unit of exchange.

Software ecosystem as research area is relatively young, first publications dating back to the first decade of the 2000s (Jansen and Cusumano 2013). The term and conceptualization emanate from Moore's (1993, 1996) work on business ecosystems. According to Moore (1993), a business ecosystem is a complex network of organizations and individuals that are involved in the creation or delivery of a service or a product. The business ecosystem concept has hitherto become critical for both scholars as well as for practitioners to understand and describe today's business networks. Due to the potentially simultaneous cooperation and competition as well as abundance of organizations involved in the network (cf. Mäntymäki and Salmela 2017; Hyrynsalmi et al. 2017), business ecosystem are often complex systems.

It is not surprising that business ecosystems are nowadays seen everywhere, from retail (Moore 1993) to telecommunication (Basole 2009), and from small ecosystems orchestrated by a single company to massive software-based value-chains consisting of hundreds of thousands of independent vendors (Hyrynsalmi 2014). According to Moore (1993) a key characteristic of a business ecosystem is the survival of an individual actor depends on the whole network. The survival of the ecosystem is turn contingent upon the individual actors' own choices and agency (Moore 1993). Since then, the literature has examined and put forwards conceptualizations for the well-being of business ecosystems (e.g. Iansiti and Levien 2004a, b; Hyrynsalmi et al. 2015; da Silva Amorim et al. 2017; Alves et al. 2018).

Iansiti and Levien (2004a) derived three health measures from biological ecosystems for business ecosystems: *productivity*, *robustness* to external shocks, and *niche creation* that helps the ecosystem to renew. Iansiti and Levien are (2004a) describe these three measures as follows:

> **Productivity** of business ecosystems can be measured as e.g. return on capital invested or economic value-added created from tangible and intangible assets in producing goods or services. This refers to a biological ecosystem's ability e.g. create biomass from inputs such as sunlight.
>
> **Robustness**, in its simplest form, refers to the survival rate of ecosystem's members, either in relation to other ecosystems or over time. Robustness means that the ecosystem can face and survive from the changes of the environment.
>
> **Niche Creation** in the context of business ecosystems refers to ability to create value by putting new functions into operation and increasing meaningful diversity in ecosystem through that. Diversity gives ecosystem potential for productive innovation and indicates its ability to absorb shocks from outside.

In his analysis of ecosystem health literature, Jansen (2014) noted the lack of operationalisations for ecosystem health. To address this issue, Jansen (2014) presented the OSEHO, a health model for open-source ecosystems. It is based on health characteristics defined by Iansiti and Levien (2004a). However, while Jansen's approach is holistic, the model is only applicable for the open-source software ecosystem and thus it cannot be used to evaluate the multitude of different types of software ecosystems.

Ben Hadj Salem Mhamdia (2013) extended the Iansiti's and Levien's (2004a) model and measured the health of an ecosystem with *robustness*, *productivity*, *interoperability*, *satisfaction of stakeholders* and *creativity*. However, the model is built on an interpretation that only firms located in the same country would create a business ecosystem or a software ecosystem. Similarly, den Hartigh, Tol and Visscher (2006) presented a model and measured well-being of an ecosystem based on their co-location in the same country. These interpretations and measures presented for the health of an ecosystem are not compatible with the more traditional interpretation where businesses are required to cooperate instead of being nearly located.

In addition, Hyrynsalmi et al. (2015) as well as Manikas and Hansen (2013b) have presented models for ecosystem health assessment. Hyrynsalmi et al. (2015) adapted a process-like view on ecosystem health assessment. However, the work is based on summarizing extant literature and did not presented any empirical validation to support the models.

Manikas and Hansen (2013b) divided software ecosystem health into three components: the health of software, actors and orchestration. This approach diverges from other conceptualizations and thus provides a novel perspective to study ecosystem health but lacks operationalization and thus also empirical validation. Furthermore, the model measures the health of software through the healthiness of components and platforms. However, instead of a shared platform, software ecosystem can be based on a common standard (cf. Jansen and Cusumano 2013; Knodel and Manikas 2015).

Finally, some existing critique have presented towards the current models. For example, Hyrynsalmi (2016) presented a critique towards unclear terminology and required redefining the concept. Hyrynsalmi et al. (2018) continue the critique by noting that *(i)* it is not clear for whom ecosystem health measures are meant to (e.g., should they be used by ecosystem orchestrators or customers), *(ii)* whether the measures are proactive or only reactive, and *(iii)* emphasizing that the natural evolution of an ecosystem (c.f. Plakidas et al. 2016; Teixeira et al. 2017) has not been taken into account in most of the ecosystem health metrics. However, neither of those works proposed any concrete steps to improve the current status quo.

3 Key Shortcomings of Prior Ecosystem Health Literature

In this section, we elaborate on the key issues related to ecosystem health that, in our view, prior research has not sufficiently addressed. To this end, we put forward two key postulates of ecosystem health.

> *Key postulate 1: Due to the scattered use of the terms 'ecosystem' and 'ecosystem health' both concepts have become muddled and meaningless.*

The concepts *business ecosystem* and *business ecosystem health* are often used as labels for systems or networks under empirical investigation without sufficient consideration and argumentation whether the entity under investigation is an ecosystem. With respect to this issue, Hyrynsalmi et al. (2015) claim that after the labelling has been done, the ecosystem or ecosystem health aspect is often forgotten. This in turn has led to a situation where a multitude of easy-to-collect measures are proposed for assessing the ecosystem health. Thus, in the current discourse, a very diverse set of entities are labelled and empirically treated as ecosystems. Consequently, more or less every aspect of the so-called ecosystem can be used to measure ecosystem health. (Hyrynsalmi et al. 2015b; Seppänen et al. 2017.)

As an example of the easy-to-collect measures for ecosystem health, a number of prior studies have proposed using lines of code as a productivity measure of a software ecosystem (cf. Hyrynsalmi 2014 for a summary). However, the number of code lines has been considered an insufficient metric of productivity for decades (Jones 2000). For example, comparing different programming languages is hard and work needed to write a single line of code varies a lot between different kinds of tasks as well as environments. Moreover, productivity should capture an ecosystem's ability to *"transform technology and other raw materials of innovation into lower costs and new products"* (Iansiti and Levien 2004a, p. 3). It is thus questionable whether the number of source code lines meaningfully captures the productivity of an ecosystem.

To address these issues, we hold it is important to move towards establishing a baseline for ecosystem health, i.e. defining what being healthy means in the context of software ecosystems. A potential step to this direction would be to study major software ecosystems—such as Google Play ecosystem and Symbian ecosystem—that exist currently and have already become extinct. The extant literature has focused only on the existing software ecosystems and omitted the studies of departed ecosystems, i.e. *ecosystem post-mortems* (c.f. Hyrynsalmi et al. 2015a; da Silva Amorim et al. 2017). This could potentially help better understand what *health* means and whether absence of health leads into ecosystem death.

Key postulate 2: Existing frameworks to analyse software ecosystem health have been designed to describe certain ecosystem sub-types but have limited value for identifying general properties of business or software ecosystems.

According to (Hyrynsalmi et al. 2015a), current research has treated different software ecosystems as a homogenous group and omitted the rich diversity of different ecosystem types. For example, when Wnuk et al. (2014) tested the ecosystem health framework by Jansen (2014), they used a tool designed for general type open-source ecosystems while their case study focused on a hardware-dependent software ecosystem.

4 Towards a Research Agenda for Software Ecosystem Health

In this section, we build on our two key postulate and move towards putting forward a research agenda for software ecosystem health. To this end, we describe four directions for future research activities.

Study of extinct and dying ecosystems. We propose future research taking a life-cycle perspective to ecosystem health. While there are studies analysing the reasons for the fall of the Symbian mobile ecosystem (e.g. West and Wood, 2013), there is a lack of research examining specifically how ecosystem health measures evolved during the ecosystem life. To address this void, future research could look into other ecosystems potentially approaching the terminal stage and examine how the situation look like through the current measures of ecosystem health and what kind of weak signals, if any, might predict the decline of an ecosystem. This type of research could be conducted e.g. with case study methodology.

Study of healthy ecosystems. We propose an analysis of software ecosystems that are in the different phases of their lifecycles while still considered to be growing. The focus of the research is specifically on existing health measures as well as identifying signals, incidents, and contingencies that may predict the success of an ecosystem. This would help to create a more comprehensive picture of the usefulness of different ecosystem health metrics. In addition, by combining the results of this line of inquiry with insights from the studies of extinct ecosystems, it would be possible to evaluate the usability and relevance of different metrics in different stages of ecosystem lifecycle.

Conceptualization of ecosystem health. We propose conceptual research focusing on ecosystem health. As pointed out by Hyrynsalmi et al. (2015a, 2018), there is an evident need for increased conceptual clarify with respect to business ecosystems and ecosystem health.

Ecosystem taxonomy construction. As discussed in Sect. 3, we propose building a general business ecosystem taxonomy. This would help to make sense in the vast field of ecosystems as well as to characterize relationships and connections between different types of ecosystems. The underlying idea behind the taxonomy is that that there are certain characteristics that are similar between certain types of ecosystems. Thus, by creating the ecosystem taxonomy and identifying measures that can be applied to study the health of different ecosystems, the taxonomy could help select the most usable health measures for each type of ecosystem. Figure 1 below provides an illustrative example of an ecosystem taxonomy.

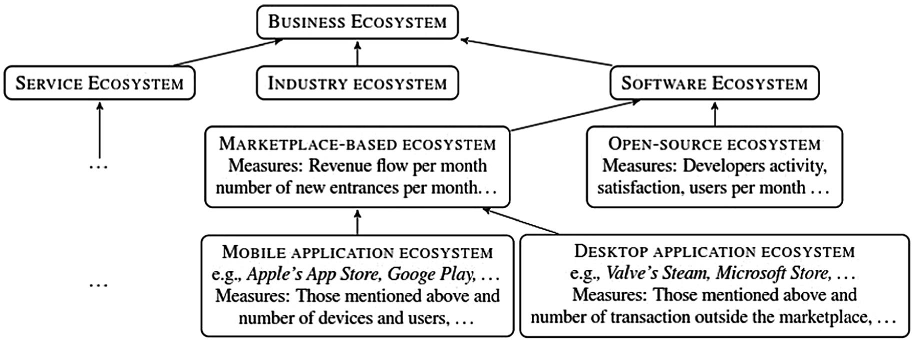

Fig. 1. A partial, simplified, example of an ecosystem taxonomy.

Figure 2 summarizes the proposed research lines as well as their expected impacts to the redefining the field of ecosystem health research. The present study is subject to a number of threats. First, it is possible that each ecosystem should be treated as a snowflake. That is, each ecosystem is unique enough that no common characteristics can be identified. Keeping in mind that there is a limited number of ecosystems available – and the number of competitive ecosystems that a single market support is limited (Hyrynsalmi et al. 2015a) plausibility of the snowflake hypothesis needs to be carefully evaluated.

Second, it is not clear whether the current or even new metrics have predictive or only explanatory value. That is, software ecosystem metrics might turn out to be useful tools for explaining the past issues but lack have predictive power to evaluate the possible future development. Therefore, it is important for the ecosystem health research field to focus also on empirical studies exploring the limits of different metrics.

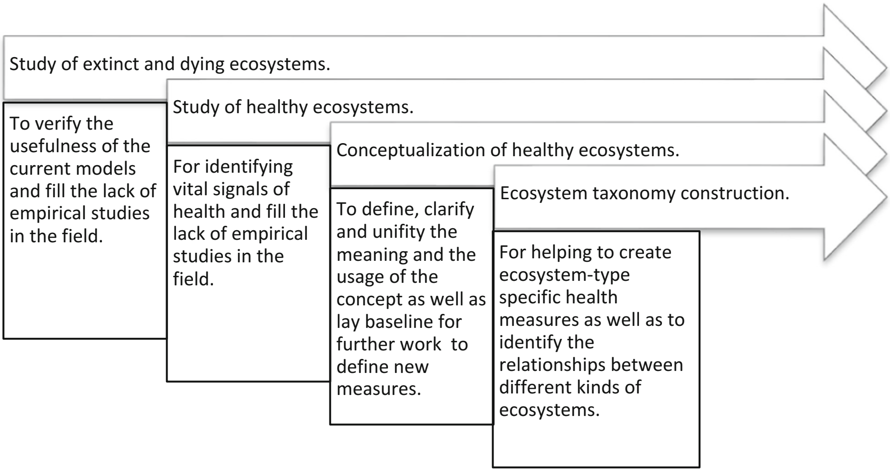

Fig. 2. Proposed four directions and their expected impacts for advancing ecosystem health research

5 Conclusions

This study has presented two key postulates of ecosystem health research and put forward a research agenda to study ecosystem health. To this end, we have put forward two key postulates:

- *#1: Due to the scattered use of the terms 'ecosystem' and 'ecosystem health' both concepts have become muddled and meaningless*, and
- *#2: Existing frameworks to analyse software ecosystem health have been designed to describe certain ecosystem sub-types but have limited value for identifying general properties of business or software ecosystems.*

In addition, based on those two postulates, we proposed four research directions that should be advanced in order to restart ecosystem health research. Our points of departure to the most of the previous studies are our proposals to focus on ecosystem-type specific health measures, and to study also extinct ecosystems. The former would help us to define better-fitting measures for a case at hand. The latter would help us to evaluate whether the proposed measures are useful for predicting the future development and forecasting the fate of an ecosystem based on the health measures.

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