Research Proposal

‘To Foresee and Forestall’: History of Statistics in Sustainability Sciences.

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Research goals and existing literature

Sustainability sciences are often said to be fundamentally organized around their ambition to **‘foresee and forestall’** (Schweitzer 1952; Grober 2012). In order to achieve that, they rely on computational techniques – statistical modelling, simulations, multivariate measurements and calculations, which not only shape knowledge-production but also mediate the circulation of findings. Interestingly, this crucial aspect of sustainability research has been largely neglected in the metascientific literature (including history of science), contrary to similar sciences, such as climate science (Edwards 2011; 2013) or ecology (Anker 2011; 2012). Hence, the aim of this work package (WP) is to fill in this gap by scrutinizing sustainability sciences research goals and experimental practices through its quantitative lens. It will utilize methods of integrated history and philosophy of science (Integrated HPS; Shan 2020) – in particular history of measurement and quantification (Kula 1970; Desrosieres 2011, Porter 1986; 1992, Diaz-Bone & Didier 2016) – but supplemented with tools from the digital humanities toolkit, such as simple NLP techniques and quantitative history of concepts.

This two-pronged approach of foreseeing and forestalling will be mirrored by the focus on *predictive power* and *actionable insight* as core features of sustainability research. Both these features are inextricably tied with the usage of numbers. Mathematical modelling is the primary mode of analyzing possible scenarios and assessing their likelihood (Woolf 1961). In other words, statistical methods are used to deal with *complexity* and *uncertainty* (Stigler 1986). I will analyze how sustainability sciences historically emerged in order to explicitly deal with complex macrosystems (ecosystems, trade networks, energy chains), while working on long future timescales and how that crucially relied on such statistical mediation. As a consequence, it will be possible to comparatively assess whether the modes of knowledge-production in sustainability science differ significantly from better-analyzed cases of analogous disciplines, especially systems science and climatology.

Similarly to these other disciplines that also deal with dynamics of complex systems, sustainability scientists faced a problem of dealing with incomplete and inherently *multivariate* data that merged historical records with future projections. But their challenges and specifics were different – sustainability was more geared towards active, pragmatic action and planned replenishment. Statistical practice should plausibly reflect these differing goals and contexts. This suggests that a historical dedicated analysis is required to understand this highly interconnected, yet distinctive scientific endeavour to understand its specificity (Kajikawa 2008).

In their strive for discovering and designing sustainable systems, practitioners of the new field realized that complexity and uncertainty inherent to dynamical systems are exacerbated by the sheer size of diachronic macrosystems, such as ecosystems or globalized economies. Hence, the transformational, but problematic emergence of the need for big data collection and its computer assisted analysis (Beer, 2016_ is especially salient in sustainability research. But whilst the explosion of data-production from the historical standpoint has recently started to be seriously analyzed in history of science literature (both in scientific and public spheres, e.g. Aronova et al. 2017), it has surprisingly not been sufficiently studied in the context of sustainable systems. To remedy that, I will use the existing scholarship from already studied cases (e.g. paleobiology – Sepkoski 2017) to perform comparisons in order to assess the applicability of the received view to the case of sustainability and its potential shortcomings.

For, interestingly, the explosion of number-production is not limited only to the volume of it. What is equally (and arguably *even more*) important is the broadening of the horizon that is admissible for statistical description, a phenomenon sometimes called ‘quantification’ (in history of science, not philosophical logic sense of the word; Ericson 1975). Things that were not deemed to be countable before get subjugated by the numerical description and proper statistical apparatus is devised for them. More often than not, a separate discipline of science grows out of it. The taming of risk (Hacking 1990; Gigerenzer et al. 1990) is a classical example of this historical process. Actuarial science (Porter 1992) and insurance markets are direct consequences of that (Hacking 1990). Risk assessment was of course central in the attempts to conceptualize sustainability through numbers, too (Morgan 2009; Epstein 2014). But, excellent instances of such newly-quantifiable concepts (and problems), such as cost-benefit analysis, welfare measurements or biodiversity metrics are aplenty throughout the history of that field (Ulanowicz et al. 2016) and await careful historical examination.

Invention and introduction of specialized new metrics and indexes, such as ‘carbon footprint’, ‘greenhouse gas index’, ‘Liveable Planet Index’ or the whole family of ‘quality of life’ (QALY) metrics are prime, but underappreciated examples of quantification. There is limited work on the subject (notable exception: Miller 2005; 2007), but it provides rather an invitation to build upon it than anything close to an explored sub-field. One of the aims of this WP is to cover this promising avenue of research with case-studies of sustainability metrics and measurements, such as Brown and Ulgiati’s Sustainability Index (‘SI’; 1997), that can contribute to general debates on history and philosophy of quantification.

Additionally, quantitative tools not only mediate knowledge-production, but also serve an important purpose in unifying interdisciplinary sciences (Kitcher 1999) more pragmatically. When practitioners come from different backgrounds, using differing terminologies, assumptions and frameworks, numbers are often mobilized to provide a universalized method to describe phenomena and make predictions. Conception of a *trading zone* (Galison 2010) is usually conjured in this context, but the relation of interdisciplinary communication and quantification is usually not the crux of these types of analyses. I argue that sustainability sciences as a place of work for specialists haling from various backgrounds and traditions – economy, ecology, physics, earth sciences (and many more) – but all allied in the common goal of numerical forecasting presents a prime opportunity for a historical investigation of the role of quantification in unifying interdisciplinary sciences.

Hence, this WP will be particularly concerned with the role of statistics (figures, visualizations, models) in scientific communication and fact-travelling (Howlett & Morgan 2010) within the sustainability field. Numbers, after all, are used not only for their exactness, but also for their promise of top-tier convincing. At its most extreme forms, statistical demonstration can develop a form of *convincing-without-convincing* (Mamak 2017), where scientific argumentation is presented as unassailable theorem-proving on the basis of authority of statistical models and *hard, cold data*. But more often than not, the construction of statistical description and argumentation is more nuanced (Gitelman 2013) and deserves historical contextualization in order to save verisimilar,
character of science without mythologizing it, that can eventually undermine its authority (Hacking 1982; Salais 2016).

This process can be divided into two phases. First is concerned with the circulation of numerical data within science itself – how datasets are constructed, validated, shared and replicated. *Epistemologies of data* (Leonelli 2014; 2019) are important tools in the possession of metascience to investigate these problems. Not only it positions us to understand why certain explanatory and argumentative strategies are successful, but also can shed light on when and why they break down and degenerate to a form of 'proofiness' or 'mathiness' (Seife 2010).

Similarly to previous aspects, these widely-acknowledged and carefully-studied ideas were so far not applied to sustainability sciences on a regular basis in the literature. It is one of the sub-goals of this WP to conceptualize how sustainability sciences fit into the picture of quantitative standards of rationality of modern science (Renn 1996). A problem that leading early theorists in sustainability research were painfully aware of. To give an example, Ezra J. Mishan lamented that "Some sorts of external diseconomies, manifestly important ones at that, do not lend themselves easily to measurement—no small defect in a society so prone as ours is to *equate relevance with quantification*" (Mishan 1967; Caradonna 2017).

The second aspect of statistics' role in communication and convincing on scientific grounds is the relation between science and the public sphere. Again, figures, visualizations and numerical data are extensively used to get the point across – convey the point in a compressed, digestible and compelling manner. This is especially pressing for sustainability sciences, which are future-looking (*scil. predictive power*) and goal-oriented (*scil. actionable insight)* and geared towards influencing public opinion and laypeople to introduce real-world change to improve certain branches of economic activity – more stable in the long-term (i.e. sustainable). Similarly to work done on IPCC reports already (e.g. Katzav 2014), an analogous argument can (and as I argue – should) be made for cornerstone documents in the history of sustainability: the Brundtland Report, the Rio Summit proceedings or the Kyoto Protocol.

What's more, to perform its practical goals, sustainability science has to ensure its status as an *objective* enterprise. This is especially important for nascent sciences and for sciences that strive to enforce social change in a highly-politicized sphere *via* its findings (Purvis et al. 2019). I argue – similar to Latour in respect to climate science (2018) – that contextualization done by integrated HPS approaches can improve the level of trust and authority of science among the general public (Porter 2014). Hence, the analysis of ideals and practices of objectivity (Daston & Galison 2021) is surely paramount to understand how sustainability researchers tend to achieve its pragmatic societal goals. But more importantly, too, it can help identify how these goals can be achieved more efficiently and systematically.

Source materials

The project will use a wide type and range of sources to track, describe and explain the trajectories of intellectual history of sustainability science. But certain areas will serve as major points of interest. Main focus will lie on the flow of ideas between systems science, ecology, climatology and
sustainability sciences. And particularly, **what role statistical tools, ideas and results played in that process**.

For that purpose, works of scientific personae (Daston & Sibum 2003) in sustainability quantification and their impact on the field will be close-read in order to track the conceptual genealogy of quanatitative ideas about sustainability. The oeuvre of Ludwig van Bertalanffy and his disciples in *systems science* will be set as a starting point for that trajectory. But particular focus will go to Jay Forrester's works, mostly his works on dynamical systems (*Industrial Dynamics, Urban Dynamics, Counterintuitive Behaviour of Social Systems* and others). I will track how Forrester's ideas were used, disseminated and transformed, through examining the writings of second-wave key figures in the sustainability movement, such as Dennis and Daniella Meadows, Amory Lovins, Rachel Carlson or Vaclav Smil.

But publications of key scientists need to be reinforced by analysing the activities and outputs of adjacent instutitions that were also crucial actors in establishing the sustainability agenda among the policy-makers, but also society at large. Especially, Forester's influence on the Club of Rome (via Aurelio Peccei himself) to utilize his simulations and models for forecasting and policy will be analyzed. But what's equally important is the further and non-mainstream receptions of ideas formed at the core – in developing countries, which were thought of as the main recipients of sustainability science's guidelines. For that purpose, I will use materials produced and published by the Balaton Group, a branch organization of Club of Rome's luminaries set up explicitly to export and promote sustainability models, computer simulations and automatized projections outside the G20.

Hence, I will specifically analyze how the statistical tools and results were received also in the Eastern Bloc and in Global South and whether they truly influenced policy-makers and agenda setting. This will grant a better and underexplored perspective on the history of sustainability and the impact of its statistical proceedings. Importantly, I will draw not only on scientific literature (papers, reports and monographs) but will also use overlooked channels of scientific communication – press releases, conference proceedings, newspaper articles and motion pictures (Curtis 2011). Additionally, because of the specificity of the project, also visualizations (graphs, tables, maps), models and simulations will be utilized as supplementary source materials. Models such as World2 or DYNAMO-based simulations in the *Limits of Growth* demonstrate that the classical textual corpus of sources needs to be bolstered for the analysis at hand.

Methods & Outcomes

This WP will primarily use methods from Integrated History and Philosophy and Science approach (Integrated HPS). The main idea within this approach is quite simple. Theoretical problems can be illuminated using historical sources and case-analysis. In turn, theoretical (philosophical) work can help make historical explanations of these cases better. As a whole, it can offer the way to understand how sustainability historically achieved its scientific goals and how it influenced policies. Importantly, it can also describe moments, where sustainability science with its background statistic (simulation, models, projections) failed their promises or when their ambitions backfired. Such complementary study can also help explain causes of such mishaps (Oreskes 2007).
Debates and frameworks particularly applicable to these projects are epistemological contributions of statistical methods and data-production. As such, *historiography and epistemology of data practices* will be used as supplementary methods (Leonelli 2014, Aronova et al. 2017a; 2017b). Another class of problems pertains to the problem of scientific objectivity and its contribution for establishing and communicating scientific facts with authority. Following Ted Porter's, Lorraine Daston's and the Bielefeld School contributions, this WP will investigate how 'trust in numbers' (Porter 1996) is achieved in a particular case of sustainability research. In particular, the context of sustainability as a research object that is politically-involved, value-laden, forward-looking and pragmatically-motivated will offer unique example for long-standing and hotly-debated issues in history of statistics and history of objectivity as a whole (Jukola 2016; Douglas

2004; 2009).

Going in the other direction, careful philosophical inquiry can ameliorate historiographical explanations, too. Examination of several terms critical for quantifying sustainability, such as quality-of-life, growth, scoping, net-zero, circularity, carbon accounting or geological capital will be offered through historical contextualization. To address that, this WP will draw from quantitative history of concepts research (Marjanen 2023) and simple natural language processing (NLP) methods. To do so, I will construct a proof-of-concept corpus of papers, articles and press releases categorized as belonging to 'sustainability science' for a selected period (key two decades between 1968 – establishing the Club of Rome and 1987 – publishing of the Brundtland Report can serve as such demonstrative period).

Corpus-statistics, frequency n-gram analysis and distributional statistics tools will be used in adherence to cognitive metascience principles (Miłkowski 2023). Using specialized software like *Palladio* (Conroy 2021) will help with tracking trajectories of ideas within sustainability science and pin down their semantic evolutions. Two tasks are prime candidates for such work. First, NLP methods will help highlight conceptual connections between terms and semantic shift thereof (using distributional semantics). Secondly, it will help chart the network of actors: scholars and institutions and flow of ideas between them, following the path of successful historiographical research of this kind in the past (e.g. Tuominen et al. 2018).

The contribution to conceptual clarity will not be addressed only through analysis of isolated terms, but also through prying apart conflated terms. For example. HPS was successful in climate science in prying apart the internal and external factors of analysis. Similarly, disentangling *detection* from *attribution* in simulation models is another example of such successful historical/philosophical work with deep empirical consequences (Lloyd & Oreskes 2019; Lusk 2017). Similarly, for sustainability science, careful causal analysis can help illuminate the logic of statistical explanation (Hacking 2016) in the field that might be latent in explicit scientific literature on the subject.

Project will culminate with a series of papers to be published in some of high-impact journals in general history of science (*Isis, Osiris, Philosophy of Science, Metascience*), but also in more targeted outlets, such as *Sustainability Science, Cli*ometrica or *Historical Methods: A Journal of Quantitative and Interdisciplinary History*. Additionally, a monograph on history of quantification, that will include parts on history of statistics in sustainability science, is planned for publication as a part of this project.

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