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SYMPOSIUM ARTICLE

Big Data Enters Environmental Law[†]

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Abstract
Big Data is now permeating environmental law and affecting its evolution. Data-driven innovation is highlighted as a means for major organizations to address social and global challenges. We present various contributions of Big Data technologies and show how they transform our knowledge and understanding of domains regulated by environmental law – environmental changes, socio-ecological systems, sustainable development issues – and of environmental law itself as a complex system. In particular, the mining of massive data sets makes it possible to undertake concrete actions dedicated to the elaboration, production, implementation, follow-up, and adaptation of the environmental targets defined at various levels of decision making (from the international to the subnational level).

This development calls into question the traditional approach to legal epistemology and ethics, as implementation and enforcement of rules take on new forms, such as regulation through smart environmental targets and securing legal compliance through the design of technological artefacts. The entry of Big Data therefore requires the development of a new and specific epistemology of environmental law.

Keywords: Environmental law, Big Data, Innovation, Evidence-based policies, Sustainable development, Environmental goals and targets, Legal epistemology

1. INTRODUCTION

'Big Data' is a trendy expression, as is the word 'innovation'. Beyond the hype, it reveals a reality[1] that is permeating environmental law and affecting its evolution. Data-driven

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[1] N. Savage, 'Big Data Goes Green' (2018) 558(7711), *Nature*, p. S19.

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innovation has been highlighted as a means to address social and global challenges, ranging from climate change, natural disasters, water, energy and food security to research and education. It is described by the Organisation for Economic Co-operation and Development (OECD) as having the potential to significantly enhance social well-being.[2]

The United Nations (UN) considers that the data revolution should help in sharing technology and innovation and use it for the common good and, as such, for the monitoring of Sustainable Development Goals (SDGs).[3] It may thus facilitate integrated action on social, environmental, and economic challenges. In the same vein, the availability of Big Data may further the effectiveness of international environmental law (IEL). Through a multitude of multilateral environmental agreements (MEAs) adopted at the international, regional or transnational level, IEL has developed relatively detailed environmental goals and targets. Although they are not necessarily quantitative, these targets allow the monitoring of the achievement of the commitment of the states parties to the agreement in question.

Indeed, in the run-up to the Second Earth Summit in 2012 in Rio de Janeiro (Brazil) (Rio+20), the United Nations Environment Programme (UNEP) insisted on the need for numbers. It presented an overview of the few existing numerically based environmental goals and targets and highlighted the fact that 'there is no coherent set of quantified goals, targets and indicators that unfold and measure progress toward environmental sustainability or sustainable development'.[4] UNEP also advocated the promotion of evidence-based environmental policies as a way to measure progress.[5] Since then, UNEP has developed platforms to give up-to-date information on the progress towards achieving Global Environmental Goals[6] and SDGs. The organization is in charge of providing coherent evidence-based knowledge and information on the state of the global environment for decision makers and in relation to the development agenda.[7]

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2 OECD, *Data-Driven Innovation: Big Data for Growth and Well-Being* (OECD, 2015), Executive Summary, p. 17, available at: http://dx.doi.org/10.1787/9789264229358-en.

3 See the 2014 Report of the UN Secretary-General's Independent Expert Advisory Group on the Data Revolution for Sustainable Development in 'A World that Counts', Nov. 2014, available at: http://www.undatarevolution.org/wp-content/uploads/2014/11/A-World-That-Counts.pdf.

4 UNEP, 'The Need for Numbers: Goals, Targets and Indicators for the Environment', *UNEP Global Environmental Alert Service*, Mar. 2012, available at: https://unepgrid.ch/storage/app/media/legacy/GEAS_TheNeedforNumbers.pdf.

5 UNEP, *Keeping Track of Our Changing Environment: From Rio to Rio+20 (1992–2012)* (UNEP, 2011), p. vii.

6 Global Environmental Goals are defined as 'internationally agreed environmental goals and objectives, which are part of outcome documents of relevant UN summits and conferences, resolutions of the UN General Assembly, decisions of other global intergovernmental conferences, MEAs and decisions of their governing bodies': see the Global Environmental Goals (GEGs) Live Tracker, available at: http://geodata.grid.unep.ch/gegslive, and the Environmental Data Explorer, available at: http://geodata.grid.unep.ch.

7 UN Environment Assembly (UNEA), Resolution 1/1, Ministerial Outcome Document of the First Session of the UN Environment Assembly of UNEP (26–27 June 2014), available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/17285/K1402364.pdf?sequence=3&isAllowed=y.

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Thus, Big Data and Big Data Analytics call into question the traditional outline of legal epistemology as the design, implementation, and enforcement of rules can take radically new forms. At the same time, the technology fosters the development of new tools and methodologies,[8] such as deep learning and integrative modelling, which are also informing environmental law in a new and better way. Following Atias, we consider that the role of legal epistemology consists of 'tracing the legal knowledge in terms of its scientific formation'.[9] In the field of environmental law, this at least requires consideration of two strongly intertwined aspects of this scientific formation: environmental sciences, and legal knowledge.

Science is fundamental to environmental law[10] and environmental law partly builds on the scientific knowledge of the environment.[11] Ideally, scientific knowledge should inform the content of environmental law norms, contribute to determinations of when these norms have been violated, and also help to monitor their implementation through the realization of environmental goals thanks to targets and indicators. Environmental observations – processed, aggregated, modelled and translated into scientific knowledge – would then be integrated into law and, through this process, become a component of legal knowledge.

Practically, this integration into legal knowledge is not clearly assessed and often remains confined to expert interventions.[12] Big Data gives the opportunity to trace back the process of scientific knowledge integration and analyze how it is transformed into legal knowledge. Thus, the forms of scientific and legal knowledge, and the interaction between them, are questioned and challenged by the production of and access to a huge quantity of data (Big Data) and by new ways of analyzing the data (Big Data Analytics or BDA) and putting it to use (integrative modelling).

Much work is currently being done on the legal implications of access to and use of massive data sets, addressing issues of data integrity, respect for privacy, intellectual property, and so on.[13] These studies, whether scientific or institutional, are motivated precisely by the novelty of the panorama offered by Big Data and the access and interpretation techniques proposed by communication and information technologies. However, these questions are outside the scope of this article.

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8 K.D. Ashley, *Artificial Intelligence and Legal Analytics: New Tools for Law Practice in the Digital Age* (Cambridge University Press, 2017).

9 C. Atias, *Epistémologie Juridique*, coll. Droit Fondamental (Presses Universitaires de France, 1985) cited by M. Galdia, *Legal Linguistics* (Peter Lang, 2009), pp. 282–3.

10 See E. Fisher, *Environmental Law: A Very Short Introduction* (Oxford University Press, 2017), p. 88.

11 When we refer to science and scientific knowledge here, we mean science built iteratively by the scientific community as a whole (as with the Intergovernmental Panel on Climate Change (IPCC)) and not through the intervention of some appointed experts in a specific arena.

12 On the role of science in policymaking, see S. Jasonoff, *Fifth Branch: Science Advisors as Policymakers* (Harvard University Press, 1990), pp. 11–9

13 S. Gutwirth, R. Leenes & P. de Hert (eds), *Data Protection on the Move: Current Development in ICT and Privacy/Data Protection* (Springer, 2016); L. Taylor, L. Floridi & B. van der Sloot (eds), *Group Privacy: New Challenges of Data Technologies* (Springer, 2017); L. Floridi et al., 'AI4People – An Ethical Framework for a Good AI Society: Opportunities, Risks, Principles, and Recommendations' (2018) 28(4) *Minds and Machines*, pp. 689–707; European Economic and Social Committee (EESC), *The Ethics of Big Data: Balancing Economic Benefits and Ethical Questions of Big Data in the EU Policy Context* (European Union (EU), 2017).

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Section 2 considers how the informational content of massive socio-environmental data sets builds environmental knowledge – and, hence, knowledge on environmental law – and nurtures it in an adaptive way. In Section 3 we examine the concrete conditions for the achievement of environmental targets and for the evaluation of associated indicators towards the realization of sustainable development. Section 4 details the foreseeable contribution of Big Data, considering environmental law as a complex system, and Section 5 argues for the necessity of a movement towards a specific epistemology of environmental law in this context. Section 6 concludes.

2. WHEN BIG DATA MEETS LAW

To give a first, broad-brush indication of some issues that are emerging, we consider the example of the legal concept of responsibility from a Big Data perspective. Holding an entity responsible[14] – whether an individual, a social group, an organization, a company, or a state – assumes that an impact or an observed effect (for instance, damage) can be traced back to the author of the action or decision which is the cause of this impact or effect. In the case of environmental matters, this link can be particularly difficult to prove. The traditional scientific concept of causality is turned into an inherently normative notion that makes sense in terms of attribution of responsibility.[15] Humans change their socio-ecological environment via actions or policies supported by political decisions based on plans. These plans reflect their causal understanding of the world. This causal knowledge leads to plans containing a prescription for actions that are supposed to lead to desired outcomes (targets).[16] This assumes an intelligible world that can be understood in terms of simple, isolated and unidirectional causal relations.[17]

Data-driven science challenges this picture in several ways. BDA increasingly replaces the concept of causal relation with that of statistical correlation. Rather than developing a causal hypothesis and then test it against the data, this new method throws a range of machine learning algorithms at large sets of highly varied data and tries to find patterns and connections.[18] The sheer volume of data means that traditional statistical methods are becoming insufficient to unleash the full potential of knowledge discovery. Instead, machine learning and neural networks[19] turn the discovery process into a black box, which, at least initially, adds a level of intransparency and

[14] A. Kiss & D. Shelton, *Guide to International Environmental Law* (Martinus Nijhoff, 2007), p. 20 ('The law of state responsibility requires establishing a link of causality between a culpable act and the damage suffered, and the damage must not be too remote or too speculative').

[15] H.L.A. Hart & T. Honoré, *Causation in the Law* (Oxford University Press, 1985).

[16] In the context of the use of massive data and artificial intelligence (AI), it is interesting to see how AI sciences conceptualize the links between agency, agents' beliefs, goals and preferences, plans and normative systems: see, e.g., G. Boella, L. Lesmo & R. Damiano, 'On the Ontological Status of Plans and Norms' (2004) 12(4) *Artificial Intelligence and Law*, pp. 317–57.

[17] Changing this point of view has important consequences for law, as developed in Y. Halpern, *Actual Causality* (The MIT Press, 2016).

[18] R. Kitchin, 'Big Data, New Epistemologies and Paradigm Shifts' (2014) 1(1) *Big Data & Society*, pp. 1–12.

[19] Y. LeCun, Y. Bengio & G. Hinton, 'Deep Learning' (2015) 521(7553) *Nature*, pp. 436–44.

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unpredictability of outcomes.[20] These approaches allow the identification of many correlations between variables that have not yet been detected or even imagined, and foster the development of decision support tools in various fields such as climate change,[21] environmental change and health,[22] biodiversity,[23] and environmental protection.[24] Increasingly, massive data sets are also being used for the production of environmental indicators,[25] and some of them integrate policy or regulation-related data.[26]

Although brimming with potential, these approaches should not replace conventional analyses. Authors from various scientific disciplines underline the caution that must accompany the interpretation of results obtained through black-box tools[27] and correspondingly insist that the analysis of massive data more than ever requires reliance on solid scientific theories.[28] In terms of socio-environments, a very promising research trend indicates that it should be possible to express the correlations detected by black-box algorithms in the form of testable hypotheses. The processes involved are integrated as components of models simulating the networks of interaction intertwined in socio-environmental systems. Finally, modelling is empirically validated or invalidated by means of comparison with independent data according to rigorous procedures. Thus, the classical conception of simple and unidirectional causality is replaced by the representation of a multitude of causalities more or less local or distant, direct or indirect, immediate or deferred, with diffusing and backscattering effects in networks of resources, agents, and environments. A crucial point here is that this new representation is falsifiable precisely by comparison with empirical data or with information derived in accordance with well-documented and reproducible procedures. This enables an understanding of the world's complexity, which is no longer completely reductionist and which permits the emergence of properties at higher levels of organization that cannot be reduced to properties at the lower levels. The resulting

[20] J. Burrell, 'How the Machine "Thinks": Understanding Opacity in Machine Learning Algorithms' (2016) 3(1) *Big Data & Society*, pp. 1–12.

[21] J.H. Faghmous & V. Kumar, 'A Big Data Guide to Understanding Climate Change: The Case for Theory-Guided Data Science' (2014) 2(3) *Big Data*, pp. 155–63.

[22] L. Fleming et al., 'Big Data in Environment and Human Health', *Oxford Encyclopedia of Environment and Human Health* (Oxford University Press, 2017), available at: http://dx.doi.org/10.1093/acrefore/9780199389414.013.541.

[23] J. Franklin et al., 'Big Data for Forecasting the Impacts of Global Change on Plant Communities' (2016) 26(1) *Global Ecology and Biogeography*, pp. 6–17.

[24] Environmental Law Institute (ELI), *Big Data and Environmental Protection: An Initial Survey of Public and Private Initiatives* (ELI, 2014).

[25] A. Hsu et al., '2016 Environmental Performance Index', Jan. 2016, Yale University, available at: https://epi2016.yale.edu/sites/default/files/2016EPI_Full_Report_opt.pdf.

[26] F. Steves & A. Teytelboym, 'Political Economy of Climate Change Policy', Smith School of Enterprise and the Environment Working Paper 13-06, Oct. 2013, available at: http://www.smithschool.ox.ac.uk/publications/wpapers/workingpaper13-06.pdf.

[27] P.V. Coveney, E.R. Dougherty & R.R. Highfield, 'Big Data Need Big Theory Too' (2016) *Philosophical Transactions of the Royal Society* online articles, A374: 20160153, available at: https://royalsocietypublishing.org/doi/pdf/10.1098/rsta.2016.0153.

[28] A.F. Wise & D.W. Shaffer, 'Why Theory Matters More Than Ever in the Age of Big Data' (2015) 2(2) *Journal of Learning Analytics*, pp. 5–13.

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picture of the world is one of high connectivity leading to unexpected resilience, rapid runaway effects,[29] thresholds or tipping points, and changes trickling through scales.

As this way of thinking begins to dominate scientific epistemology in general, and the socio-environmental sciences in particular, the divergence between legal and scientific epistemology deepens and accelerates. The way in which law tries to conceptualize human agency, reducing events to binary relations between plaintiff and defendant, actions and the harm they have directly caused,[30] and the way in which it ties responsibility to causally predictable outcomes, seems increasingly ill-suited to capture the way in which socio-ecology and environmental sciences increasingly understand the impact and dependence of human societies on the environment. Furthermore, the epistemology of law itself suffers from the same ailment: it assumes that legislators can causally influence human behaviour and hence change the outcomes for society in a predictable manner, with law functioning as a form of mechanical engineering. As Big Data and modelling change our understanding of societal complexity, this conception of law, and what it means to know it and its effects, seems increasingly untenable. System theory had made us aware of the importance of complexity – including feedback loops, self-organization and pattern emergence – in understanding regulatory efforts long before the current interest in data science.[31] Yet what these new techniques allow us to do is to operationalize the insights of system theory and in this way change them from a *post hoc* analysis of systematic failure, formerly of interest mainly to theorists, into concrete tools and methods.

3. ARE LEGAL ENVIRONMENTAL TARGETS REACHABLE?

Particularly important and topical applications of Big Data, artificial intelligence (AI), and integrative modelling concern the construction of legal targets and the evaluation of indicators attached to a multitude of environmental challenges that threaten, among others, the oceans, biological diversity, climate change, water and food security, and health,[32] as well as, and relatedly, sustainable development. Indeed, only the production of indicators which are based on empirical data and which are reproducible, refutable and updated, makes it possible to evaluate the state of the environment, resources, ecosystems, and biodiversity. This need is expressed in a number of high-level political texts. As affirmed by the Executive Secretary to the Convention on Biodiversity

29 T. Elmqvist et al., 'Response Diversity, Ecosystem Change, and Resilience' (2003) 1(9) *Frontiers in Ecology and the Environment*, pp. 488–94.

30 E.J. Weinrib, *The Idea of Private Law* (Oxford University Press, 2012).

31 N. Luhmann, 'Operational Closure and Structural Coupling: The Differentiation of the Legal System' (1991) 13(5) *Cardozo Law Review*, pp. 1419–41.

32 World Economic Forum (WEF) in partnership with PwC and the Stanford Woods Institute for the Environment, 'Harnessing Artificial Intelligence for the Earth', WEF Fourth Industrial Revolution for the Earth Series, Jan. 2018, available at: http://www3.weforum.org/docs/Harnessing_Artificial_Intelligence_for_the_Earth_report_2018.pdf. See also CGIAR Platform for Big Data in Agriculture created in 2017 and applying data-driven solutions to ongoing research for development impact, available at: https://bigdata.cgiar.org.

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(CBD)[33] in July 2018: 'The science is clear and the alarm bells are ringing! The loss of biodiversity and the destruction of ecosystems continue at unprecedented rates'.[34] Yet, although the facts are clear, many questions arise when it comes to deciding the legal and political action to be taken at various spatial and temporal scales to halt the process. This insufficiency, or even failure, is observed in relation to other major environmental issues.[35]

In order to address the continuous environmental degradation of the planet, over 500 MEAs have been signed since 1972, containing an impressive quantity of goals and objectives negotiated through a variety of international and regional forums. Many of these goals are not legally binding but are nevertheless developed in global environmental governance as statements of shared aspiration.[36] The point of developing such environmental targets is to elaborate indicators to inform policy choices at the global level and monitor environmental changes.[37] This aim became a Millennium Development Goal (MDG) in itself – namely, MDG 7 towards 'Ensuring Environmental Sustainability' based on official indicators and data – thereby linking environmental law to the 2030 Agenda for Sustainable Development.

Nevertheless, as underlined in a 2012 UNEP report, '[d]espite the growing body of norms and rules, the overall global environmental situation continues to deteriorate'. When it came to defining the SDGs, the first task was to have a clear knowledge of the already existing environmental goals.[38] Thus, in order to obtain a better view of the fragmented landscape of environmental rules, the UNEP Global Environmental Outlook 5 compiled the various global environmental goals to assess progress towards 90 goals and objectives which are 'specifically geared to respond to some of the world's most pressing environment and development challenges'.[39] As the report stated, there has been little or no progress, or even further deterioration, with regard to about half of the environmental goals and objectives, while more progress has been made on goals that are linked with specific, measurable targets. These findings led to the conclusion that it was necessary to make efforts on the collection and coordination of data and, by the same token, improve scientific knowledge on the issues covered by the targets.

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33 Rio de Janeiro (Brazil), 5 June 1992, in force 29 Dec. 1993, available at: http://www.cbd.int/convention/text.

34 Statement by the Executive Secretary of the CBD, Cristiana Paşca Palmer, at the 22nd Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, 2–7 July 2018, Montreal (Canada), p. 2, available at: https://www.cbd.int/doc/speech/2018/sp-2018-07-02-sbstta22-en.pdf.

35 W.J. Ripple et al., 'World Scientists' Warning to Humanity: A Second Notice' (2017) 67(12) *Bioscience*, pp. 1026–8.

36 L.M. Campbell, S. Hagerman & N.J. Gray, 'Producing Targets for Conservation: Science and Politics at the Tenth Conference of the Parties to the Convention on Biological Diversity' (2014) 14(3) *Global Environmental Politics*, pp. 41–63. For targets in the Kyoto Protocol see United Nations Framework Convention on Climate Change (UNFCCC), *Kyoto Protocol Reference Manual on Accounting of Emissions and Assigned Amount* (UNFCCC, 2008).

37 E. Nicholson et al., 'Making Robust Policy Decisions Using Global Biodiversity Indicators' (2012) 7 *PLoS One*, e41128.

38 UNEP, 'Measuring Progress: Environmental Goals and Gaps', *UNEP Global Environmental Alert Service*, Dec. 2012, available at: https://na.unep.net/geas/archive/pdfs/GEAS_Dec2012_MeasuringProgress.pdf.

39 The choice of these objectives is explained in the report: ibid.

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From a legal perspective, these observations and testimonies point to the need to take action in relation to environmental targets at the different stages of their elaboration, production, implementation, monitoring, targets adaptation, and knowledge integration. Without such action and given the rate of environmental degradation in recent decades, the attainability of environmental targets is doomed to irreversible failure. In order to make ambitious and grounded environmental targets realistically achievable, a number of important factors should be considered. Firstly, we examine the issue of appropriate legal responsiveness, considering that environmental knowledge should be at the core of environmental law conception and development. Secondly, we advocate the development of a specific epistemology of environmental law and suggest some research avenues to pursue.

3.1. *Legal Responsiveness and Involvement*

The elaboration of environmental goals and targets implies access to the best available scientific knowledge,[40] as well as its translation into legal objectives. It calls for association with a wide range of disciplines (social sciences and law included) to determine achievable environmental targets and to define our ultimate aim.

Because of the particularism of environmental law and the intrinsically changing nature of the environment, legal environmental norms should not be disconnected from scientific biological or socio-ecological considerations. One of the problems resides in the adequation between the ecological scales of environmental changes and the administrative level of decision making. In international environmental law, legal researchers usually consider that the implementation of international principles is a national issue and pragmatic questions should be resolved at the national level.[41] Nevertheless, environmental law researchers must consider the continuum between international and transnational environmental law and local regulations and related policies, otherwise the issues of implementation of environmental goals and the efficiency of regulatory measures remains theoretical, disconnected from the complex social and environmental reality.[42]

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[40] See, e.g., CBD COP-10, Decision X/2, 'Strategic Plan for Biodiversity 2011–2020', Annex 3, para. 12 ('sound science').

[41] See, e.g., S.L. Maxwell et al., 'Being Smart about SMART Environmental Targets' (2015) 347(6226) *Science*, pp. 1075–6 ('International signatories readily agree on targets that are ambiguous in definition because a level of increase or reduction required to meet the target is not clearly specified' and 'what is practicable is not defined', which constitutes a real issue for its implementation at the national level).

[42] As sharply pointed out by Philippopoulos-Mihalopoulos, '[n]o longer can the law barricade itself against other disciplines – and if this is true for law in general, environmental law is arguably the most prominent example of such a change. There is no longer a clear-cut boundary between environmental law and, say, science': A. Philippopoulos-Mihalopoulos, *Law and Ecology: New Environmental Foundations* (Routledge, 2011), p. 5. For the various decision-making levels, see International Union for the Conservation of Nature (IUCN), 'World Declaration on the Environmental Rule of Law', IUCN World Congress on Environmental Law, Rio de Janeiro (Brazil), 26–29 Apr. 2016, III, available at: https://www.iucn.org/sites/dev/files/content/documents/english_world_declaration_on_the_environmental_rule_of_law_final.pdf ('Effective implementation is fundamental to achieving the environmental rule of law'. It relies on '[m]echanisms to add procedural strength and help build the procedural and substantive components of the environmental rule of law at national, sub-national, regional, and international levels').

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As highlighted in the 2012 UNEP report, environmental law consists of a complex and fragmented system of rules. Goals are defined in many different settings and not necessarily in a coherent way, even if they respond to a common and clear objective of sustainable development. Although the environmental goals are built on scientific knowledge and rely on various data, this should not prevent legal researchers from actively taking part in the process of construction of environmental targets which will be embedded into legal texts such as MEAs. Legal researchers should become involved in the translation of environmental targets into legal objectives. They should engage in the protection of the environment and stay informed about the progress made in the environmental sciences – both as a source of new operational concepts and as an observation system – and foster a more integrative understanding of multiple interactions within socio-environmental systems.

The lack of legal responsiveness also results from the fact that environmental legal tradition is not contextually grounded into environmental issues. Indeed, considering biodiversity conservation, for instance, the progress of the Aichi Targets[43] at a national level is under-examined and the few analyses conducted are target-specific. This is a real challenge as the CBD, and the Aichi Targets, have to be implemented at the national level and in an integrative manner.[44]

In brief, the importance of dialogue between science and policymakers is often underlined,[45] but the role of jurists or legal researchers in relation to science is almost never mentioned and should be assessed. Jurists indeed have a crucial role to play in better integrating scientific knowledge to build evidence-based indicators in relation to the environmental dynamics and a range of ecological scales.

3.2. *The Process of Designing Targets and Indicators*

The decontextualization of environmental targets is concerning as it can mask the reality of the debates which led to their determination.[46] We should bear in mind the hybrid nature of environmental targets; they are social constructs that contain both scientific and political elements.[47] As underlined by Campbell and her co-authors, targets are far from neutral, but they appear as such as they are being circulated as autonomous objects in different political arenas, all the while '[reflecting] and [reinforcing] configurations of power and knowledge'.[48]

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43 CBD Secretariat, 'Quick Guidelines to the Aichi Biodiversity Targets', Feb. 2013, available at: https://www.cbd.int/doc/strategic-plan/targets/compilation-quick-guide-en.pdf.

44 S.M. Hagerman & R. Pelai, '"As Far as Possible and as Appropriate": Implementing the Aichi Biodiversity Targets' (2016) 9(6) *Conservation Letters*, pp. 469–78.

45 Policymakers or science-policy interface are rarely defined; nevertheless, there is a wide range of policymakers depending on the level of decision examined. The point should also be questioned.

46 See Campbell, Hagerman & Gray, n. 36 above.

47 C. Miller, 'Hybrid Management: Boundary Organizations, Science Policy, and Environmental Governance in the Climate Regime' (2001) 26(4) Special Issue: Boundary Organizations in Environmental Policy and Science, *Science, Technology, & Human Values*, pp. 478–500, at 480; see also T.M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public* (Princeton University Press, 1995) notably Ch. 8 'Objectivity and the Politics of Disciplines', pp. 206–31.

48 Campbell, Hagerman & Gray, n. 36 above.

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Challenges resulting from the ambiguous or poorly operational wording of environmental targets, from the lack of quantified elements,[49] and the difficulties of quantification related to the various temporal and spatial scales[50] have been identified notably in relation to the failure of the implementation of the Strategic Plan for Biodiversity 2002–2010.[51] Recommendations thus led to the adoption of SMART environmental targets (i.e., targets that are Specific, Measurable, Achievable, Realistic, and Time-related),[52] all attributes that Big Data Analytics can make achievable.

The SMARTness of environmental targets is not the only issue. The negotiation process, involving collaboration and consensus to set targets, is also very important. It implies a complex landscape of actors which should be better studied to understand the process of decision making leading to the choice of the targets. Indeed, as underlined by Maxwell and co-authors, '[s]ignatories may find it easier to agree on a target if it is difficult to measure progress toward it'.[53] Targets may be deliberately vague, or a choice may be made in favour of environmental targets that are de facto non-quantifiable and, in the end, unachievable. Accountability in such a context remains difficult to determine.

Technological innovation could foster the development of SMART indicators in relation to environmental targets, help to understand the interactions between actors at various geopolitical scales,[54] and allow better monitoring and adaptation of environmental targets. It might permit consideration of the environmental dynamic and embed it into legal procedures depending on the changing state of the environment, thus responding quickly and appropriately to these changes.

We consider that it is essential to establish information or knowledge systems (supervised or not) to massively integrate data as a basis for quick and appropriate decisions, which must be taken with regard to a set of criteria and values, including those of an ethical nature. In order to succeed in this endeavour, it is important to put environmental knowledge at the core.

3.3. *Environmental Knowledge at the Core*

As stated by McEldowney and McEldowney, '[e]mbracing and working closely with science at the boundaries of knowledge are an essential part of environmental law and may offer environmental lawyers new perspectives and a specific identity within

49 S.H.M. Butchart, M. Di Marco & J.E.M. Watson, 'Formulating Smart Commitments on Biodiversity: Lessons from the Aichi Targets' (2016) 9(6) *Conservation Letters*, pp 457–68, at 458.

50 D.P. Tittensor et al., 'A Mid-Term Analysis of Progress toward International Biodiversity Targets' (2014) 346(6206) *Science*, pp. 241-4.

51 CBD COP-6, Decision VI/26, 'Strategic Plan for the Convention on Biological Diversity'.

52 Campbell, Hagerman & Gray, n. 36 above; Butchart, Di Marco & Watson, n. 49 above.

53 See Maxwell et al., n. 41 above.

54 In the context of the implementation of One Health approaches to environmental, human and animal health see, e.g., P. Mazzega & C. Lajaunie, 'Modelling Organisation Networks Collaborating on Health and Environment within ASEAN', in R.S. Martinez (ed.), *Complex Systems: Theory and Applications* (Nova, 2017), pp. 117–48.

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legal scholarship'.[55] Without going into epistemological considerations about the production of knowledge,[56] two points are essential: (i) data without knowledge is a mere accumulation of observations; and (ii) knowledge without data is speculation. Whatever the field of application, the path from data to knowledge (and back) involves several steps:

- design, acquisition, validation and distribution of data;
- extraction of information useful in and for a given analysis context; and
- possible construction of indicators aggregating and synthesizing a heterogeneous mass of information and designed to be easily understood and used by stakeholders (decision makers, companies, non-governmental organizations (NGOs), local communities, scientists).

The availability and analysis of massive data sets contribute to each of these points. This is particularly because of (i) the masses of informative data solicited; (ii) their heterogeneity and continuous updating, which demonstrate all kinds of connected dynamic processes; (iii) the opportunity to discover unsuspected interdependencies; or (iv) the possibility of providing increasingly relevant syntheses of knowledge from various disciplines. In particular, the design of regulation and environmental public policies must take into account the state of resources and environments, their evolutionary trends, and the natural physical and biogeochemical processes. In the normative sphere of public policy and law, it is also necessary to evaluate the direct or indirect impacts and actual or potential risks related to the implementation of measures. Such research is now developed by various scientific communities using the contributions of agent modelling and software issuing from computer science or AI (such as knowledge representation,[57] data mining,[58] decision-making models[59]). More specifically, the current research on societies of autonomous virtual agents and on self-organized societies[60] brings new points of view to the emergence of collective

[55] J. McEldowney & S. McEldowney, 'Science and Environmental Law: Collaboration across the Double Helix' (2011) 13(3) *Environmental Law Review*, pp. 169–98.

[56] A.F. Chalmers, *What Is This Thing Called Science? An Assessment of the Nature and Status of Science and Its Methods*, 2nd edn (University of Queensland Press, 1982).

[57] M. Chein & M.-L. Mugnier, *Graph-based Knowledge Representation* (Springer, 2009), p. 427; S. Katalnikova & L. Novickis, 'Choice of Knowledge Representation Model for Development of Knowledge Base: Possible Solutions' (2018) 9(2) *International Journal of Advanced Computer Science & Applications*, pp. 358–63.

[58] Science-Metrix: D. Campbell et al., 'Data Mining: Knowledge and Technology Flows in Priority Domains within the Private Sector and between the Public and Private Sectors', European Commission Directorate-General for Research and Innovation, Directorate A – Policy Development and Coordination, Specific Contract No. 30-CE-0677881/00-67, Feb. 2017, available at: https://rio.jrc.ec.europa.eu/en/library/data-mining-knowledge-and-technology-flows-priority-domains-within-private-sector-and.

[59] T. Balke & N. Gilbert, 'How Do Agents Make Decisions? A Survey' (2014) 17(4) *Journal of Artificial Societies and Social Simulation* online articles, p. 13, available at: http://jasss.soc.surrey.ac.uk/17/4/13.html.

[60] H. Aldewereld et al. (eds), *Social Coordination Frameworks for Social Technical Systems* (Springer, 2016); X.A. Ghose et al. (eds), *Coordination, Organizations, Institutions, and Norms in Agent Systems. LNAI 9372* (Springer, 2014); M. Janssen, M.A. Wimmer & A. Deljoo (eds), *Policy Practice and Digital Science* (Springer, 2015).

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behaviour in complex environments, work of primary importance for normative reflection.

The interdisciplinary approaches draw upon increasingly massive heterogeneous sets of data (including observation from instruments aboard satellites or drones, *in situ* data, biological samples, genetic sequencing, administrative data, data from sectoral information systems, surveys, interviews, and textual *corpora*) the analysis of which is based on a range of skills, knowledge and tools (e.g., mechanistic, statistical, or multi-agent modelling), with an expected growth in the contribution from BDA. The integration of knowledge from the humanities and social sciences poses specific difficulties[61] which, in our opinion, show that this integration cannot be established on the same presuppositions and according to the same procedures as those used in natural or formal sciences. Knowledge about the actors' perceptions, intentions, behaviours or decisions, for example, cannot build on the generality of pre-existing laws or benefit from the fixity of natural principles. It rather contributes to answering specific questions in defined contexts, and it is still doing so by privileging the explicit choice of epistemic orientations and methodologies, by specifying the cognitive and cultural framework which shelters the development of knowledge.

One of the primary steps – in terms of time and importance – of analyzing massive environmental data (including societal data) is to produce the most accurate and exhaustive description of the state of an 'ecosystem' (such as a social-ecological system, biome, or a regional sea) at a given date. This description, accompanied by information on the methodology of its construction and on the source data, presupposes the choice of a delimitation of the domain and of the granularities of analysis (spatial and temporal resolutions, biological levels, and so on). It is used as a reference to detect or quantify possible physio-chemical, biological, ecological or societal changes. In stakeholder discussions on potential development scenarios to be considered or promoted, the baseline provided by this description functions as both a cognitive resource and a policy instrument that can drive and guide policy debates, and its mastery provides a competitive advantage in negotiations. The validity and robustness of this description are legitimized by the transparency of the procedures used to develop it and by the possibility for all freely to access the analyzed data. On the other hand, the acceptability of the baseline description for discussion remains a matter of values, ethics, and political balance of power.

4. FORESEEABLE CONTRIBUTION OF BIG DATA

Beyond their use in the environmental sciences, massive data and its analytical techniques have a role to play in understanding the architecture of environmental law and its evolution. By the same token, they contribute to the development of a new environmental law. BDA and some other AI innovations fed by data can be used to anticipate how regulation and scientific knowledge will be integrated and interact in the normative

[61] See, e.g., International Social Science Council (ISSC) and UNESCO, *World Social Science Report 2013: Changing Global Environments* (OECD and UNESCO, 2013), pp. 22 et seq.

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complex system constituted by environmental law. As Lessig, a constitutionalist, stated about cyberspace in his book *Code: Version 2.0*, we need 'an architecture—not just a legal text but a way of life—that structures and constrains social and legal power, to the end of protecting fundamental values'[62] and the environment.

McEldowney and McEldowney underlined that, by definition, environmental law is 'working at the margins of understanding, since environmental science is often uncertain and in continual flux'.[63] While legal complexity has been criticized generally as a threat to legal certainty,[64]as well as a hindrance to real freedom of interaction and social evolution[65] and a source of heavy transaction costs or of high 'delegitimation',[66] this complexity is even more prominent in environmental law because of the uncertainty attached to environmental and legal sciences and knowledge.

4.1. *Environmental Law as a Complex System*

Legal complexity is not a choice but results from legal constructions over long periods of time. Indeed, these constructions are built to address an ever-wider variety of legal issues in different areas,[67] such as human rights, social rights, right to a healthy environment,[68] environmental law – and, more recently, law related to technological innovations[69] (debate about robot law,[70] cyberspace regulation,[71] nanotechnologies, regulations of genetics tools and applications). In each of these domains, the multiplicity of cases induces specific regulations established or implemented by institutions or agents with regulatory powers (states, cities, international organizations, private companies).

Complex systems are characterized by numerous entities or components interacting in a non-linear way.[72] There is such an entanglement of actions and reactions that the analysis of changes affecting entities cannot be described according to linear causality and thus calls for co-evolution[73] between interdependent entities. Analogies with

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62 L. Lessig, *Code: Version 2.0* (Basic Books, Perseus Group, 2006), p. 4.

63 McEldowney & McEldowney, n. 55 above, p. 189.

64 Conseil d'Etat, *Rapport public 2006: Jurisprudence et avis de 2005 – Sécurité juridique et complexité du droit*, Etudes et documents No. 57 (Conseil d'Etat Paris, 2006).

65 R.A. Epstein, *Simple Rules for a Complex World* (Harvard University Press, 1995).

66 P. Schuck, 'Legal Complexity: Some Causes, Consequences, and Cures' (1992) 42(1) *Duke Law Journal*, pp. 1–52.

67 P. Casanovas et al. (eds), *AI Approaches to the Complexity of Legal Systems: Complex Systems, the Semantic Web, Ontologies, Argumentation and Dialogue* (Springer, 2009).

68 N. Bobbio, *L'età dei diritti* (G. Einaudi ed., Torina 1997), pp. xiii–xv.

69 This type of right would probably be included by Bobbio (ibid., p. xiv) into the 'fourth generation rights' together with rights induced by uses of genetic heritage of 'each specific individual'.

70 European Parliament, 'Report with Recommendations to the Commission on Civil Law Rules on Robotics', 2015/2103(INL), 27 Jan. 2017.

71 K. Kittichaisaree, *Public International Law of Cyberspace* (Springer, 2017).

72 D. Bourcier & P. Mazzega, 'Toward Measures of Legal Complexity in Legal Systems' in *Proceedings of the 11th International Conference on Artificial Intelligence and Law*, Stanford, CA (US), 4–8 June 2007, pp. 211–15, available at: https://dl.acm.org/citation.cfm?id=1276359.

73 In a complex system, a same cause may have different effects depending on the state of the system, and the kind of causality link. The predictability of the changes is limited to a finite horizon of prediction intrinsic to the system dynamic.

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complex systems studied in physics or in ecology have opened new research avenues aimed at measuring and monitoring the complexity of constitutive parts of legal systems:[74] networks of citations of legal texts,[75] uses of semantic web technologies applied to the semantic web of legal ontologies,[76] jurisprudence,[77] ratifications of MEAs,[78] and others.

It is stimulating to conceive environmental law as a system comprising all normative texts, legal institutions, decision-making authorities and procedures. Its complexity is instantiated not only in its organizational structure and governance, in the multitude of forms it contains and in its double, semantic and hierarchical interdependency, but even more in the space created by the flexibility of its interpretations and uses. Without objective delimitation, this system opens up through its links and dependencies to other legal fields, themselves in constant evolution (such as criminal law, commercial law). Additionally, the system of environmental law should address new socio-environmental situations (including over-exploitation of resources, pollution, protection and conservation, and patrimonialization) and integrate the production of scientific knowledge.

An example illustrates perfectly the new challenges faced by environmental law. Indeed, one crucial issue comes from the exponentially growing amount of scientific data and the need for new ways and tools to analyze it in order to obtain a clear overview of the literature which can inform policymakers. That difficulty has been underlined in the assessment process conducted by the Intergovernmental Panel on Climate Change (IPCC).[79] The IPCC reports should represent the latest scientific, technical and socio-economic findings and be as comprehensive as possible.[80] As underlined by Minx and his co-authors,[81] to continue to assess the most recent science

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74 J.B. Ruhl & D.M. Katz, 'Measuring, Monitoring, and Managing Legal Complexity' (2015) 101 *Iowa Law Review*, pp. 191–244.

75 P. Mazzega, D. Bourcier & R. Boulet, 'The Network of French Legal Codes', *Proceedings of the 12th International Conference on Artificial Intelligence and Law*, Barcelona (Spain), 8–12 June 2009, pp. 236–37, available at: https://dl.acm.org/citation.cfm?doid=1568234.1568271; D.M. Katz & M. Bommarito, 'Measuring the Complexity of the Law: The United States Code' (2014) 22(4) *Artificial Intelligence and Law*, pp. 337–74.

76 Casanovas et al., n. 67 above; G. Sartor et al. (eds), *Approaches to Legal Ontologies* (Springer, 2011).

77 J.H. Fowler et al., 'Network Analysis and the Law: Measuring the Legal Importance of Precedents at the U.S. Supreme Court' (2007) 15(3) *Political Analysis*, pp. 324–46.

78 R. Boulet, A.F. Barros-Platiau & P. Mazzega, '35 Years of Multilateral Environmental Agreements Ratification: A Network Analysis' (2016) 24(2) *Artificial Intelligence and Law*, pp. 133–48; R. Boulet, A.F. Barros-Platiau & P. Mazzega, 'Environmental and Trade Regimes: Comparison of Hypergraphs Modelling the Ratifications of UN Multilateral Treaties', in R. Boulet, C. Lajaunie & P. Mazzega (eds), *Law, Public Policies and Complex Systems: Networks in Action* (Springer, 2019), pp. 221–42.

79 The role of the IPCC is to assess the thousands of scientific papers published each year to inform policymakers about the risks related to climate change. It thus identifies where there is agreement in the scientific community, where there are differences of opinion, and where further research is needed, available at: https://www.ipcc.ch/organization/organization.shtml.

80 IPCC, 'Appendix A to the Principles Governing IPCC Work: Procedures for the Preparation, Review, Acceptance, Adoption, Approval and Publication of IPCC Reports', Oct. 2013, para. 4.3.4, available at: https://www.ipcc.ch/site/assets/uploads/2018/09/ipcc-principles-appendix-a-final.pdf.

81 J.C. Minx et al., 'Learning about Climate Change Solutions in the IPCC and Beyond' (2017) 77(C) *Environmental Science & Policy*, pp. 252–9.

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in a situation of literature explosion is highly challenging.[82] It requires the development of computer-assisted research tools (including natural language processing and text mining) as well as methods for a transparent use of available research synthesis tools.

Finally, whether it concerns the understanding of socio-environmental evolutions, the multi-scale and refined knowledge of the open system constituted by 'environmental law' (from global to local levels), or the adaptation of this system to environmental changes, the task is completely beyond individual or collective (human) intelligence. In the necessary process leading to the articulation of an epistemology specific to environmental law, Big Data, BDA, AI and modelling software will increasingly contribute to the monitoring of environmental changes and to the synthesis of knowledge necessary for environmental law. Ultimately, they will bring about significant transformations in this very specific branch of law.

4.2. *Big Data and Innovation Transferable to Environmental Law*

It is necessary to explore the application of data analytics to environmental law itself rather than merely to the object of its regulation. A system-theoretical analysis of law provides the theoretical warrant, but only recently do advances in legal AI allow us to operationalize this idea. Besides, integrative models have been explored since the 1990s under the label of 'Artificial Societies', a type of computer simulation based on agent-based computational models in social analysis.[83]

A key theme of artificial society research is the emergence of order through the 'bottom-up' interaction of autonomous and intentional agents. The resulting complexity, the unpredicted system properties, and the insights into the interaction between parts and the whole provide a welcome antidote to the legalism that dominates traditional jurisprudential thought, which sees law as a collection of top-down commands by a sovereign in pursuit of predefined goals, and which in the context of environmental regulation has given rise to the command-and-control model. While artificial societies and multi-agent systems (MAS) research were able to test in new ways assumptions about the way in which cooperation in societies emerges and conflicts are resolved,[84] its ultimate impact on the legislative process so far remains limited.[85]

In marked contrast, the AI and law movement focuses on capturing legal knowledge in a computation and executable form. Where formal legislation remained

[82] The relevant literature to be reviewed for the IPCC's sixth assessment will include between 270,000 and 330,000 publications. This is larger than the entire climate change literature before 2014. Cf Minx et al., n. 81 above.

[83] The consultation of contributions to the *Journal of Artificial Societies and Social Simulation*, for example, gives an overview of the topics discussed and the progress made, available at: http://jasss.soc.surrey.ac.uk/JASSS.html.

[84] S. Ossowski, *Co-ordination in Artificial Agent Societies: Social Structures and Its Implications for Autonomous Problem-Solving Agents* (Springer-Verlag, 1999).

[85] This was partly because the available computational capacity meant that the scenarios that were analyzed remained on the level of 'toy examples' or thought experiments, heavily simplified to test specific hypotheses about the way in which external incentives, disincentives and individual planning interact.

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invisible in MAS research and modelling, legal AI took as definitional the idea that there ought to be an isomorphic relation between computer code and legal code. To count as legal AI, legal provisions have to be explicitly and symbolically represented in such a way that at least some of the key syntactic and semantic aspects of formal legal norms appear.[86] The underlying legal approach remains beholden to legal formalism, law as a system of rules that are applied deductively to a set of facts. Legal knowledge then becomes knowledge of legal rules (which can be statutory or case-based in origin) and the role they play in valid legal argumentation. Legal rules are largely analyzed in isolation, with only a few logical relations between rules and their interaction preserved. What is modelled is not a complex legal system, or even a fragment of a legal system, but (only) the set of rules needed to resolve a legal issue for a specific legal domain.[87] While computational legal knowledge representation of this type was successful in reducing costs, increasing consistency and, at times, the speed of decision making, it suffers from a number of shortcomings. Logic-based systems with formal representations of rules and cases are time-consuming to build and update, so seem prima facie unsuitable to address problems that are caused by the speed of change in both environmental conditions and our knowledge of them, which is the result of the velocity of Big Data. They also struggle with the ability to cope with unforeseen circumstances and conditions, and work best in highly repetitive and standardized tasks.

Several advantages of machine learning over more traditional approaches have already been mentioned. In sum, they relate mainly to the ability to automatically discover new underlying rules structuring large sets of data, and apply them in return to masses of data, including legal data.

So far, we have seen how computational approaches to legal regulation reflect and build upon a variety of legal considerations which, in past times at least, often marked the opposite ends of the spectrum of jurisprudential thought. At the same time, they all address in various ways pertinent concerns for environmental law and regulation – issues such as noticeable enforcement deficits, regulation lagging behind scientific and technological developments, regulation that is insufficiently responsive to particular situations and contexts, and the general limits to rule-based interventions in complex and interconnected systems.[88] Ideally, therefore, these approaches would be combined to harness their respective advantages, while avoiding any normative or philosophical conflict between their underlying epistemological assumptions and jurisprudential commitments.

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86 So, canonically, T.J. Bench-Capon & F.P. Coenen, 'Isomorphism and Legal Knowledge-based Systems' (1992) 1(1) *Artificial Intelligence and Law*, pp. 65–86.

87 A classic example from that time: see M.J. Sergot et al., 'The British Nationality Act as a Logic Program' (1986) 29(5) *Communications of the ACM*, pp. 370–86 (e.g., a set of rules that determine if someone is eligible for citizenship).

88 For a discussion of the problems of legislative intervention in networked, complex environments see, e.g., A.Guadamuz-González, 'Scale-Free Law: Network Science and Copyright' (2006) 70 *Albany Law Review*, pp. 1297–322.

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4.3. *Technical Innovation and New Legal Findings*

Data-driven approaches to legal AI emerged at the turn of the millennium, partly in response to the perceived failure to develop suitable practical applications, partly in rejection of the underlying formalist epistemology of law. Rather than formally representing legal sources such as statutes and precedent-setting appeal court cases, data-driven systems began to use machine learning and neural networks to extract information from less authoritative but more plentiful data sets. A typical early example was SplitUp, a neural network-based approach that mined information from first instance family courts in Australia, and from this predicted the likely distribution of assets in divorce cases.[89] It is this type of approach which has more recently captured the legal imagination, and which feeds into the discussion on the future – if there is one – of the legal profession. Examples include the prediction of court decisions based on machine learning not just from past published decisions, but also from party submissions and docket files, or the analysis of the correlation between severity of punishment and distance to lunch.[90] The last example, in particular, indicates the shift from the previous, rule-based paradigm: knowing the law now means having the ability to predict the outcome of specific court cases, and if non-legal factors help with this prediction, then this is to be welcomed.

While this approach to legal AI is arguably the one most closely aligned to Big Data and has garnered the most recent interest in the field, for the purpose of this discussion it suffers from a litigation-centric view. Indeed, it is at its strongest when the decision in a new case can be predicted on the basis of past events. However, if our aim is to design better legislation, or to predict how a legislative proposal will impact on the environment, this approach has less to offer in itself, but it is very promising when it is combined with integrative modelling.

Finally, we should mention the 'regulation by design' movement, an approach that has given a new lease of life to the aforementioned formalist legal expert systems. We have already mentioned Lessig's work, which presents as a central tenet of his argument that 'internet law' should be understood not just as a distinctive branch of law but one with its own and unique epistemology.[91] While law had been traditionally understood as the domain of the 'ought' – things we should be doing but often do not, or should omit but often do – and embodies a regulatory ideal that relies on punishment after a rule violation has occurred, the ontological malleability of cyberspace allowed it to 'design in' legal norms directly into the computational infrastructure and to merge legal code and software code into a unity that pre-empts norm violation.

An interesting situation arises when older ideas about legal knowledge representation and rule-based expert systems are combined with code-based law enforcement.

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89 J. Zeleznikow, A. Stranieri & M. Gawler, 'Project Report: Split-Up – A Legal Expert System which Determines Property Division upon Divorce' (1995) 3(4) *Artificial Intelligence and Law*, pp. 267–75.

90 S. Danziger, J. Levav & L. Avnaim-Pesso, 'Extraneous Factors in Judicial Decisions' (2011) 108(17) *Proceedings of the National Academy of Sciences*, pp. 6889–92.

91 L. Lessig, 'Law Regulating Code Regulating Law' (2003) 35(1) *Loyola University Chicago Law Journal*, pp. 1–14.

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In this case, the contextual environment does not just prevent rule-violating behaviour; it moreover reasons in the process of application of rules, rules which are formally represented in a way that again isomorphically matches the text of the statutes or cases. In this situation, we have what Hildebrandt calls 'ambient law', a world where the environment increasingly takes decisions that ensure our behaviour is compliant with norms.[92] Design choices on the technological level can now be traced back to the relevant legislation that they embed, and the correspondence between technological normativity and legal normativity becomes a formally provable relation within the system. Those, and only those, constraints on behaviour through technological tools that are authorized by formal laws are permitted. Furthermore, the correspondence, or isomorphism, between the two types of normativity becomes a formally provable characteristic of the system as a whole.

An interesting example, which combines the advantages of a multi-agent system with those of a formal representation of legal norms, comes from an application that is relevant for environmental protection. Imagine a smart city environment where cars, energy providers, and payment systems are in a constant bi-directional exchange of data, electricity, and money. Sensors and measuring on the side of the energy providers ensure that electricity is optimized for changing demands, and also allow cars to feed back excess energy into the grid. This is the scenario that the SmartPrivacy initiative tried to emulate. For the purpose of this example, it combines a formal ontology which represents the flow of data, energy, and money as the object of regulation with a separate formal ontology which represents the applicable data protection law. The legal regulation module automatically generates policies for the smart grid which are turned into design constraints for the grid engineers. The engineer works in a software design environment with its own ambient legal intelligence, and guides and restricts design choices.

Now, we will factor in some more overtly environmental legislation. Our fictitious legal measure has two components. Firstly, it prescribes maximum levels of air pollution that the city is allowed to experience at any given point in time. Secondly, it obligates the energy providers to nudge drivers towards achieving this goal through a flexible pricing system: whenever pollution increases towards problematic levels, the price for energy increases in turn, disincentivizing drivers from unnecessary travel until such time as air pollution levels have improved. In this scenario, cars, which report about their energy status, are additionally fitted with sensors that detect air pollution, turning them into a network of mobile, ground-level surveillance devices for compliance with environmental law. The information they gather about local air pollution is centrally collected and analysed, and, once the resulting model reaches a certain value, electricity prices automatically increase.

In this context we should insist on the importance of being aware of the many challenges raised by the use of Big Data. Indeed, the uncontrolled utilization of Big Data can come into conflict with fundamental legal principles and social values and, as such,

[92] M. Hildebrandt & B.J. Koops, 'The Challenges of Ambient Law and Legal Protection in the Profiling Era' (2010) 73(3) *The Modern Law Review*, pp. 428–60.

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constitute 'the greatest peril of our times'.[93] Ultimately, these uses should be debated and result from collective and political choices.[94]

In the preceding example, we developed an account of environmental law compliance by design that is open to Big Data. It reflects the complexity, interconnectedness and feedback loops within the legal system in the same way in which they are represented in environmental science disciplines. This exercise constitutes a first step towards a potential realignment of scientific and legal epistemologies.

5. TOWARDS A SPECIFIC EPISTEMOLOGY OF ENVIRONMENTAL LAW

In 1987, the Brundtland Report stated that '[h]uman laws must be reformulated to keep human activities in harmony with the unchanging and universal laws of nature'.[95] It is now time to deliver on that statement and to explore the specificities of environmental law and, particularly, the necessity to rely on environmental knowledge, and to consider together the environmental dynamic and the complexity of the environmental legal system.

The reflection starts with the realization that what has been analyzed as a legal regime fragmentation is in fact attributable to different regimes and layers of decision making, and also to lawyers' fragmented vision of scientific issues. Of course, environmental law has developed instruments to combat the fragmentation or even contradictions between the objectives of MEAs. This holds true particularly for the three Rio Conventions and the biodiversity-related conventions, which contain mechanisms that aim to enhance coherence and cooperation in implementation, and which favour synergy and coordination.[96] Nevertheless, the fragmentation of environmental law remains an issue. A 2017 UNEP report highlights the gap in collaboration between scientists and policymakers.[97] Among the key elements for an effective science-policy interface, it mentions the availability of the appropriate data and expertise to provide the right evidence. It also identifies as hurdles the divergent viewpoints of decision makers on the importance of the environment and the necessity to deal with complexity, whether it concerns the various and dynamic environmental interactions or the complexity of law and policy processes.

A specific epistemology of environmental law could help to really embrace these two forms of complexity. To be useful, a legal norm must be conceived generically with regard to the question to be regulated, each case corresponding ontologically with an

93 C. Devins et al., 'The Law and Big Data' (2017) 27(3) *Cornell Journal of Law and Public Policy*, pp. 357–413, at 357.

94 J.R. Gil-Garcia, 'Towards a Smart State? Inter-Agency Collaboration, Information Integration, and Beyond' (2012) 17(3) *Information Polity*, pp. 269–80, at 276; W.B. Boyd, 'Environmental Law, Big Data, and the Torrent of Singularities' (2016) 64 *UCLA Law Review*, pp. 544–70, at 544.

95 Report of the World Commission on Environment and Development, *Our Common Future* (United Nations and Oxford University Press, 1987) (Brundtland Report), p. 330.

96 With the creation respectively of the Joint Liaison Group and of the Biodiversity Liaison Group.

97 UN Environment, *Strengthening the Science-Policy Interface: A Gap Analysis* (UNEP, 2017).

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instance of the norm applied to the empirical situation being considered.[98] The particularity of environmental law lies in the fact that the empirical situation – an ecological system, the state of a certain environment or resources – evolves according to endogenous dynamic processes which for the most part are subject to natural laws. This simple remark nevertheless has two major consequences: firstly, the environmental legal norm best can be designed generically on the basis of a precise knowledge of the environmental state and dynamics; and, secondly, the instantiation of the generic norm – for example, to move from global objectives to national goals, taking into account country-specific context – must follow the evolution of the environment as it is observed.[99]

Another key concern resides in the choice of the scientific knowledge to be integrated into environmental law. Thus, law should be adaptive to take into account the environmental dynamic.[100] It means that, with the development of SMART environmental targets, we should elaborate 'smart' procedures capable of putting into action innovative methods (machine assisted, or machine-based), translating environmental or socio-ecological systems changes into related updates of obligations, legal measures, or policy incentives.

To ensure the appropriate legal responsiveness to environmental changes and to development objectives, environmental law should be built as a co-evolutive normative system. In order to reach that goal, we could develop at least three types of tool, relying on opportunities provided by Big Data and AI:

- smart targets;
- smart indicators;
- smart legal procedures.

As with any legal instrument, these tools should be conceived in a manner that ensures their relevance (ability to respond in an appropriate manner to a specific issue),

98 In modelling language, an instance is 'a concrete manifestation of an abstraction': J. Booch, J. Rumbaugh & I. Jacobson, *The Unified Modelling Language User Guide*, 2nd edn (Addison-Wesley, 2005). Instantiation is the process of associating such concrete manifestation (e.g., specific targets for a particular context, a set of empirical data, etc.) with the abstraction (e.g., the generally defined target, the corresponding general type of data, etc.).

99 When it comes to the implementation of generic international norms into national law, the environmental or ecological context should be taken into account. For instance, in the case of Good Environmental Status in the European Union (EU), 'descriptors' are detailed to help Member States in implementing a Directive, as in the case of the Marine Strategy Framework Directive adopted on 17 June 2008 (Directive 2008/56/EC establishing a Framework for Community Action in the Field of Marine Environmental Policy, [2008] OJ L 164/19). The European Commission has also produced a set of detailed criteria and methodological standards to help Member States, which have been modified by Commission Decision (EU) 2017/848 of 17 May 2017, [2017] OJ L 125/43. Interestingly, preambular para. 20 of the Decision states: 'Criteria, including threshold values, methodological standards, specifications and standardised methods for monitoring and assessment should be based on the best available science. However, additional scientific and technical progress is still required to support the further development of some of them, and should be used as the knowledge and understanding become available'. The European Commission translates the generic character of the norm into criteria which help to instantiate the norm at the national level according to the specific socio-ecological context.

100 S. Morand & C. Lajaunie, *Biodiversity and Health: Linking Life, Ecosystems and Societies* (Elsevier ISTE Press, 2017), Ch. 13 'The Role of Law, Justice and Scientific Knowledge in Health and Biodiversity', pp. 209–18.

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feasibility (susceptibility to production and implementation), transparency (understandability and traceability), and robustness (contribution to legal security). Nevertheless, the notion of smartness is justified in order to address specific challenges: (i) to ensure intersectoral consistency; (ii) to integrate in a harmonious way the objectives of environmental protection and conservation with those of sustainable development; (iii) to adapt to evolution of environmental and social systems in a responsive, clear, traceable and predictable way; (iv) to ensure a continuum of environmental governance and environmental goals through ecosystem and social scales, as well as at various legal and political levels.[101]

The exploitation of massive data sets leads to precise descriptions of the present state of a socio-ecosystem or of an environment. In addition, integrative modelling makes it possible to explore various likely trajectories of socio-ecological changes that help to reach not one but a set of prescribed targets (for example, linking environmental and sustainable development targets). The conditions for achieving these trajectories are documented, as are the direct and indirect changes and trends. By allowing the advantages and disadvantages of several scenarios to be compared and evaluated, this modelling approach provides a base of evidence for discussing the desirability or acceptability of a particular policy or regulatory option. Indicators can also be diversified at the request of stakeholders and according to the context. The use of a variety of models and the exploration of many scenarios offer a plurality of development perspectives from the current empirical situation. This approach seems qualified to be part of the systems to be put in place to 'prevent the manipulation of indicators and the assessments on which they are based, to ensure that the information they provide is objective and reliable'.[102]

These basic components provide a way to overcome the fragmentation of environmental law and to reduce the gap between science and policy for an effective implementation of an adaptive environmental law. They can be operationalized through the use of Big Data or BDA, or models and scenarios associating environment and legal systems as coupled systems.

The challenge of choice of the appropriate scientific knowledge, as illustrated by the role of the IPCC, comes from the multiple interactions in an open system, operating at various temporal and spatial scales, as well as from the fact that recommendations from science on global environmental issues cannot be separated from the fundamental issues of fairness, equity and social justice.[103] The use of Big Data and AI-based software raises various intertwined ethical issues to be considered carefully in the elaboration of a specific epistemology for environmental law.[104] AI and Big Data represent

[101] See Campbell, Hagerman & Gray, n. 36 above.

[102] A.C. Newton, 'Implications of Goodhart's Law for Monitoring Global Biodiversity Loss' (2011) 4(4) *Conservation Letters*, pp. 264–68.

[103] UN Environment, n. 97 above.

[104] See, e.g., J. van den Hoven, 'Moral Methodology and Information Technology', in K.E. Himma & H.T. Tavani (eds), *The Handbook of Information and Computer Ethics* (Wiley, 2008), pp. 49–67; M. Anderson & S. Leigh Anderson (eds), *Machine Ethics* (Cambridge University Press, 2011); European Commission, High-Level Expert Group on Artificial Intelligence, 'Draft Ethics Guidelines

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not only an opportunity but also a risk: their use necessitates an evaluation of the way in which and the purpose for which the information and knowledge are produced and operated. Similarly, the collection and production of environmental knowledge, as well as the design and monitoring of legal knowledge (and specifically environmental goals and targets), should be considered in the specific context of their implementation.[105] Moreover, in addition to the need for transparency and accessibility of acquired knowledge (and data), its various potential uses are at the heart of sustainable development debates, since these uses have serious and differentiated societal impacts. The analysis of the ethical implications of these issues is, in itself, an essential research avenue that is of increasing interest not only to ethicists but to environmental researchers more broadly.[106]

6. CONCLUSION

This world requires 'a novel approach to law making which addresses the challenges of technology, legitimacy, and political-legal theory'.[107] It also requires a rethinking of the very notion of normativity, contrasting legal and technological normativity. A shift to technological normativity not only creates practical dangers but also the potential to radically alter our understanding of legal legitimacy.[108] On the other hand, it is aligned with the move towards 'proactive law' which, from its origin in Scandinavian legal thought,[109] increasingly influences technology regulation in the European Union[110] and also environmental regulation.[111]

If the effects of laws were perfectly foreseeable and possible to plan, and if the software engineer could not but faithfully implement the legal directive into code, this might indeed be the end of the story. In reality, of course, a different outcome is likely.

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for Trustworthy AI', Apr. 2019, available at: https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai.

105 For environmental knowledge as well as legal knowledge see the analysis of general knowledge versus particular knowledge and the way to apply a rule of 'local and situated knowledge' in settings that are mutable, undetermined (some facts are unknown), and particular: see J.C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (Yale University Press, 1998), pp. 311–21.

106 N. Tuana, 'Leading with Ethics, Aiming for Policy: New Opportunities for Philosophy of Science' (2010) 177(3) *Synthese*, pp. 471–92, available at: https://doi.org/10.1007/s11229-010-9793-4. For a study of the ethical side of interdisciplinary research on the environment cf. C. Lajaunie & P. Mazzega (invited eds), 'The Ethics of Biodiversity Conservation' (2018) 10(4) *Asian Bioethics Review*, Special Issue.

107 Hildebrandt & Koops, n. 92 above, p. 428. See also R. Leenes, 'Framing Techno-Regulation: An Exploration of State and Non-State Regulation by Technology' (2011) 5(2) *Legisprudence*, pp. 143–69.

108 B.J. Koops, 'Law, Technology, and Shifting Power Relations' (2010) 25(2) *Berkeley Technology Law Journal*, pp. 973–1035; M. Hildebrandt, 'Legal Protection by Design: Objections and Refutations' (2011) 5(2) *Legisprudence*, pp. 223–48.

109 See, in particular, P. Wahlgren (ed.), *A Proactive Approach* (Stockholm Institute for Scandinavian Law, 2006); H. Haapio (ed.), *A Proactive Approach to Contracting and Law* (International Association for Contract and Commercial Management and Turku University of Applied Sciences, 2008).

110 Preliminary Draft Opinion dated 14 May 2008 of the European Economic and Social Committee (EESC) on 'The Proactive Law Approach: A Further Step towards Better Regulation at EU Level', EESC INT/415.

111 G. Berger-Walliser & P. Shrivastava, 'Beyond Compliance: Sustainable Development, Business, and Proactive Law' (2014) 46 *Georgetown Journal of International Law*, pp. 417–74.

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Even though there is now a direct connection between formal law and software implementation, law will never conclusively determine engineering solutions, leaving a range of design choices to the engineer. A range of choices remain within the parameters described by the legislation, but each of them differs in the detail with which the meaning of the natural language legislation is reduced to formally executable code. The result is a variety of implementation options, which are all consistent with the law but are mutually inconsistent with each other.

Ultimately legal regulation itself should be treated as a complex dynamic system that explicitly links environmental legal provisions with other relevant legal provisions, and that can be modelled through data. In such an approach, 'legal objects' such as statutes, court decisions or even individual legal arguments are not just constraints on the behaviour of actors, but are, themselves, actors. They interact with other legal objects in complex and not always intentionally planned ways, which gives rise to emergent properties of the legal system as a whole, such as efficiency, legitimacy or regulatory density. Text analysis, data visualization and network analysis, as well as integrative modelling, are among the tools that can be harnessed to give such a formal account of a legal system which lays bare the interconnection between different parts of the legal system[112] and also with knowledge about socio-environments.

Although we are far from thinking that Big Data can, in any way, be a panacea for the empirically well-attested degradation of the environment and the exhaustion of natural resources, these developments open new perspectives and call for a re-foundation of the epistemology of environmental law.

[112] For examples see, e.g., R. Winkels & A. Boer, 'Finding and Visualizing Dutch Legislative Context Networks' (2014) 3 *Diritto, Scienza, Tecnologia*, pp. 157–82; R. Boulet, P. Mazzega & D. Bourcier, 'Network Approach to the French System of Legal Codes, Part II: The Role of the Weights in a Network' (2018) 26(1) *Artificial Intelligence and Law*, pp. 23–47.

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