Big data enters environmental law

Citation for published version:
Lajaunie, C, Schafer, B & Mazzega, P 2019, 'Big data enters environmental law', *Transnational Environmental Law*, vol. 8, no. 3, pp. 523-545. https://doi.org/10.1017/S2047102519000335

Digital Object Identifier (DOI):
10.1017/S2047102519000335

Published In:
Transnational Environmental Law

Big Data × Environmental Law: Massive Data Technologies Enters Environmental Law

Journal:	*Transnational Environmental Law*
Manuscript ID	TEL-074-2018.R1
Manuscript Type:	Article
Keywords:	Environmental law, Big Data, innovation, evidence, goals and targets, legal epistemology
Number of Words Including Footnotes:	10821

Big Data × Environmental Law

Massive Data Technologies Enter Environmental Law

Abstract.

Big Data expresses a reality that is permeating the evolution of environmental law. Data-driven innovation has been highlighted as means to contribute to addressing social and global challenges.

We present various perspectives on Big Data and artificial intelligence and show how they transform our knowledge and understanding of domains that should be regulated by environmental law - environmental changes, sustainability of natural resources, dynamics of socio-ecological systems.

The same technology also leads to new tools and methodologies that are informing environmental law in a new and better way and contributing to reshaping it in its full complexity.

This development questions the traditional approach to legal epistemology and ethics, as implementation and enforcement of rules can take new forms such as smart environmental targets, indicators and regulations or the law compliance by design of technological artefacts. It calls for a specific epistemology of environmental law.

Keywords. Environmental law; Big Data; innovation; evidence; goals and targets; legal epistemology.

1. Introduction

Big Data is a trendy expression, as is the word innovation. Beyond the hype, it expresses a reality that is permeating the evolution of environmental law. Data-driven innovation has been highlighted as means to contribute to addressing social and global challenges (climate change, natural disasters, water, energy and food security, research and education …). It is described by the Organisation for Economic Cooperation and Development as having the potential to significantly enhance social well-being[1]. It questions the traditional outline of legal epistemology as the design, enforcement and implementation of rules can take radically new forms. At the same time, the very same technology also leads to new tools and methodologies - e.g. deep learning, integrative modelling - that are also informing environmental law in a new and better way and contributing to reshape it. Following Atias, we consider that the role of legal epistemology consists in 'tracing the legal knowledge in terms of its scientific formation'. Regarding environmental law, we should examine at least two strongly intertwined aspects of the scientific formation that are giving flesh to that specific branch of law: environmental sciences and legal knowledge.

Environmental law, obviously, builds on the scientific knowledge of the environment. This knowledge informs the content of environmental law norms, contributes to establishing when these norms have been violated but also and finally, helps to monitor their implementation through the realization of environmental goals thanks to targets and indicators. Environmental observations, processed, aggregated and translated into scientific knowledge, are then integrated into law and, through this process, become a component of legal knowledge.

These two forms of knowledge, scientific and legal, and their interaction are questioned and challenged by the production and access to a huge quantity of data (Big Data) and by new ways of analyzing (Big Data Analytics or BDA) and using the data (integrative modelling). The informational content of massive socio-environmental data sets builds knowledge on the environment and thus on environmental law and nurture it in an adaptive way (Section 2).

The United Nations considers that the data revolution should help to share technology and innovation and use it for the common good and as such for the monitoring of Sustainable

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

Development Goals[2] (SDGs) and facilitate the integrated action on social, environmental and economic challenges International environmental law, through a multitude of multilateral environmental agreements, whether international, regional or transnational, has developed more or less detailed environmental goals and targets, not necessarily quantitative, allowing monitoring the achievement of the commitment of the States parties to an environmental agreement.

In the run-up of the Second Earth Summit in Rio (Rio+20, 2012), the United Nations Programme for the Environnement (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 in general'[3]. UNEP also advocated for the promotion of evidence-based environmental policies as a way to measure progress[4]. Since then, the UNEP developed platforms to give up-to-date information on the progress towards achieving Global environmental Goals[5] 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[6].

---

[2] See the 2014 Report of the UN Secretary-General's Independent Expert Advisory Group on the Data Revolution for Sustainable Development at http://www.undatarevolution.org/wp-content/uploads/2014/11/A-World-That-Counts.pdf Accessed 24 Jan. 2019

[3] UNEP, 'The need for numbers - goals, targets and indicators for the environment' (2012) *Global Environmental Alert Service bulletin*, United Nations Environment Programme.

[4] UNEP, '*Keeping Track of Our Changing Environment: From Rio to Rio+20 (1992-2012)*' (United Nations Environment Programme, 2011), p. vii.

[5] Global Environmental Goals are defined as 'internationally-agreed environmental goals and objectives, which are part of outcome documents of relevant United Nations summits and conferences, resolutions of the General Assembly, decisions of other global intergovernmental conferences, multilateral environmental agreements and decisions of their governing bodies', see Global Environmental Goals (GEGs) Live Tracker http://geodata.grid.unep.ch/gegslive/ and Environmental Data Explorer http://geodata.grid.unep.ch/

[6] United Nations Environment Assembly, Resolution 1/1. Ministerial outcome document of the first session of the United Nations Environment Assembly of the United Nations Environment Programme (2014), Nairobi, available at https://wedocs.unep.org/bitstream/handle/20.500.11822/17285/K1402364.pdf?sequence=3&isAllowed=y

In section 3 we examine the concrete conditions for the achievement of these targets and for the evaluation of associated indicators. Section 4 details the foreseeable contribution of Big Data considering environmental law as a complex system. Section 5 argues about the necessity of a movement towards a specific epistemology of Environmental Law in this context. Section 6 presents the conclusion.

2. When Big Data Meets Law

To give a first board-brush indication of some of the issues that we see emerging, let us consider the example of the legal concept of responsibility from a Big Data perspective. Charging a responsibility[7], especially in environmental matters, to an agent - an individual, a social group, an organization, a company, a state ... - assumes that an impact or an observed effect (e.g. damage) is traced back to the author of the action or decision which is the cause of this impact or effect. The traditional scientific concept of causality is turned into an inherently normative notion that makes sense in terms of attribution of responsibility[8]. In this view, 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[9] set as prescription for actions supposed to lead to desired outcomes (targets). This assumes an intelligible world that can be understood in terms of simple, isolated and unidirectional causal relations.

Data-driven science challenges this picture in several ways. Basically, BDA replaces the concept of causal relation increasingly with that of statistical correlation. Rather than developing a causal hypothesis and then test it against the data, the new method throws a

[7] A. Kiss & D. Shelton, *Guide to International Environmental Law* (Martinus Nijhoff Publishers, 2007) at 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.' The authors insist on the doubts about the causal link while physicists have techniques to identify the multiple causalities in such a context.
[8] H.L.A. Hart & T. Honoré, *Causation in the Law* (OUP Oxford, 1985).
[9] In this context of use of massive data and artificial intelligence, it is interesting to see how AI sciences conceptualizes the links between agency, agents' beliefs, goals and preferences, plan and normative system: e.g. G. Boella, L. Lesmo & R. Damiano, 'On the ontological status of plans and norms' (2004) 12 *Artificial Intelligence and Law*, at p. 317-357.

range of machine learning algorithms at large sets of highly varied data and tries to find patterns and connections.[10] The sheer volume of data means that traditional statistical methods are becoming insufficient to benefit from the full potential of knowledge discovery. Instead machine learning and neural networks[11] turn the discovery process into a black box, which at least initially adds a level of in-transparency and unpredictability of outcomes.[12] These approaches allow the finding of many correlations between variables that have not been detected or even imagined so far, but also the development of decision support tools in various fields such as climate change[13], environmental change and health[14] or biodiversity[15], environmental protection[16]. But already increasingly massive data sets (see Box 1) are being used for the production of environmental indicators[17], some of them also integrating policy or regulation-related data[18].

[Box 1. What does environmental Big Data look like?]

However, these approaches should not replace or supplant conventional analyses. Many authors from various scientific disciplines warn about the caution that must accompany the

[10] R. Kitchin, 'Big Data, new epistemologies and paradigm shifts' (2014) 1(1) *Big Data & Society* 2053951714528481

[11] Y. Le Cun., Y. Yoshua Bengio & G. Hinton, 'Deep learning' (2015) vol. 521 *Nature* at p. 436-444. doi:10.1038/nature14539

[12] J. Burrell, 'How the machine 'thinks': Understanding opacity in machine learning algorithms' (2016) 3 (1) *Big Data & Society* 2053951715622512.

[13] 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* at p. 155–163.doi: 10.1089/big.2014.0026

[14] L. Fleming, N. Tempini, H. Gordon-Brown, G.L. Nichols, C. Sarran, P. Vineis, G. Leonardi, B. Golding, A. Haines, A. Kessel, V. Murray, M. Depledge, & S. Leonelli, 'Big Data in Environment and Human Health'in Oxford Encyclopedia of Environment and Human Health (OUP Oxford, 2017). Available at: http://dx.doi.org/10.1093/acrefore/9780199389414.013.541, 1

[15] J. Franklin, J.M. Serra-Diaz, A.D. Syphard & H.M. Regan, 'Big data for forecasting the impacts of global change on plant communities' (2016) 26(1) Global Ecology and Biogeography at p. 6-17. https://doi.org/10.1111/geb.12501

[16] ELI, *Big Data and Environmental Protection: An Initial Survey of Public and Private Initiatives* (Environmental Law Institute®, 2014), 32 p.

[17] A. Hsu et al., *Environmental Performance Index* (Yale University, New Haven CT, 2016) https://issuu.com/rodrigovelasquezangel/docs/epi2016_final_report Accessed 21 Janv 2019

[18] F. Steves & A. Teytelboym, *Political Economy of Climate Change Policy* Working paper 13-06 (Smith School of Enterprise and the Environment, Oxford 2013) http://www.smithschool.ox.ac.uk/publications/wpapers/workingpaper13-06.pdf Accessed 21 Janv 2019

interpretation of the results obtained through black-box tools[19] and correlatively insist that the analysis of massive data requires more than ever to rely on solid scientific theories[20]. In terms of socio-environments, according to a very promising research trend, it is possible to express the correlations detected by box-black algorithms in the form of testable hypotheses. The processes involved are integrated as components of models simulating the networks of interactions intertwined in socio-environmental systems. Finally, modelling is empirically validated or invalidated by comparison with independent data according to rigorous procedures. Thus, the classical conception of simple and unidirectional causality mentioned above is replaced by the representation of a multitude of causalities more or less local or distant, direct or indirect, immediate or deferred, diffusing and backscattering effects in networks of resources, agents and environments. This enables an understanding of the world complexity that is not any longer completely reductionist, permits the emergence of properties on higher levels of organization that cannot be reduced to properties on the lower levels. The resulting picture of the world is one of high connectivity leading to unexpected resilience, rapid runaway effects[21], 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 law tries to conceptualize human agency, reducing events to binary relations between plaintiff and defendant, actions and the harm they have directly caused,[22] and the way in which it ties responsibility to causally predictable outcomes seems already ill suited to capture the way in which socio-ecology and environmental sciences increasingly understand the impact and dependence of human

[19] P.V. Coveney, Dougherty E.R. and R.R. Highfield, 'Big data need big theory too' (2016) 374 Philosophical Transactions of the Royal Society A: 20160153. http://dx.doi.org/10.1098/rsta.2016.0153

[20] 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*, at p. 5–13. http://dx.doi.org/10.18608/jla.2015.22.2

[21] T. Elmqvist, C. Folke, M. Nyström, G. Peterson, J. Bengtsson, B. Walker, & J. Norberg, 'Response diversity, ecosystem change, and resilience' (2003) 1, no. 9 *Frontiers in Ecology and the Environment* at p. 488-494.

[22] E. J. Weinrib, *The idea of private law* (Oxford University Press 2012).

societies on the environment. Furthermore, the epistemology of law itself suffers from the same issue: it assumes that legislators can causally influence human behaviour and in that way predictively change the outcomes for society, law being seen as a form of mechanical engineering. As Big Data and modelling change our understanding of societal complexity, this understanding of law, and what it means to have knowledge of 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.[23] But 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, of interest mainly to theorists, into concrete tools and methods.

Particularly important and topical applications of Big Data, AI and integrative modelling, concern the construction of legal targets and the evaluation of indicators attached to a multitude of environmental challenges faced by the planet whether they concern the ocean, the biological diversity, climate change, water and food security or health for instance[24], but also and in a related way, sustainable development.

3. ARE LEGAL ENVIRONMENTAL TARGETS REACHABLE?

'The science is clear and the alarm bells are ringing! The loss of biodiversity and the destruction of ecosystems continue at unprecedented rates'[25] stated the executive secretary of the Convention on Biodiversity in July 2018. Nevertheless, beyond the clarity of that fact, many questions arise when it comes to deciding which legal and political action to be taken at

[23] N. Luhmann, 'Operational closure and structural coupling: the differentiation of the legal system' (1991) 13, *Cardozo Law Review* 1419.
[24] World Economic Forum in partnership with PwC and the Stanford Woods Institute for the Environment, *Harnessing Artificial Intelligence for the Earth* (World Economic Forum, Fourth Industrial Revolution for the Earth Series, 2018).
[25] Statement by the Executive Secretary of the Convention on Biological Diversity, Ms. Cristiana Paşca Palmer, at The Twenty-Second Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, 2-7 July 2018, Montreal, Canada, 2.

various spatial and temporal scales to halt the process. This insufficiency, or even failure, is observed in relation to other major environmental issues such as containing of global warming, sustainability of terrestrial and marine natural resources, quality of air, water and soil.[26]

In order to address the continuous environmental degradation of the planet, over 500 international environmental agreements have been signed since 1972 with an impressive quantity of goals and objectives negotiated through a variety of international and regional forums. Many of these goals are non-legally binding but are nevertheless developed in global governance as statements of shared aspiration[27]. The point of developing such environmental targets whether they concern biodiversity in general or trade in endangered species, hazardous wastes, climate change or desertification, is to elaborate indicators to inform policy choices at a global level[28] and monitor environmental changes. It became a Millennium Development Goal (MDG) in itself, the MDG 7 'Ensuring Environmental Sustainability', based on official indicators and data, therefore linking environmental law to the Agenda of Global Development.

Nevertheless, as underlined in a report of the UNEP in 2012, 'Despite the growing body of norms and rules, the overall global environmental situation continues to deteriorate'. Thus, acknowledging the complexity and fragmented landscape of environmental rules and in the perspective of the definition of the Sustainable Development Goals (SDGs), the main

[26] W. J. Ripple, C. Wolf, T. M. Newsome, M. Galetti, M. Alamgir, E. Crist, M. I. Mahmoud, W. F. Laurance & 15,364 scientist signatories from 184 countries, 'World scientists' warning to humanity: a second notice' (2017) *Bioscience* doi:10.1093/biosci/bix125

[27] 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*, doi:10.1162/GLEP_a_00238 ; targets in the Kyoto Protocol see United Nations Framework Convention on Climate Change, Kyoto Protocol Reference Manual on Accounting of Emissions and Assigned Amount, (2008) UNFCCC.

[28] E. Nicholson, B. Collen, A. Barausse, J. L. Blanchard, B. T. Costelloe, K.M. E. Sullivan, F. M. Underwood, R. W. Burn, S. Fritz, J.P.G. Jones, L. McRae, H. P. Possingham, E. J. Milner-Gulland, 'Making Robust Policy Decisions Using Global Biodiversity Indicators' (2012) 7, *PLoS One*, e41128.

challenge appeared to have clear knowledge about what goals exist[29]. In order to get a better view, the Global Environmental Outlook 5 compiled the various global environmental goals to assess progress towards 90 goals and objectives 'specifically geared to respond to some of the world's most pressing environment and development challenges'[30]. As the report stated there has been little or no progress, or further deterioration, on about half of the environmental goals and objectives while more progress has been made on goals that are linked with specific, measurable targets. It led to the conclusion that it was necessary to make efforts on the collection and coordination of data and by the same token improve knowledge on the issues covered by the targets.

From a legal perspective, there is a need for action in relation to environmental targets at different stages of elaboration, production, implementation, monitoring, targets adaptation and knowledge integration. Without such an action and given the environmental degradation of recent decades, the attainability of environmental targets is questionable. We identify important elements that should be considered in order to be able to reach ambitious and grounded environmental targets. First, we examine the issue of appropriate legal responsiveness, considering that environmental knowledge should be at the core of environmental law conception and development. Second, we advocate for the assessment of elements constituting a specific epistemology of environmental law and suggest some research avenues to pursue.

3.1 An Issue of Legal Responsiveness and Involvement

The elaboration of environmental goals and targets implies to have access to the best scientific knowledge possible[31] but also to translate it into legal objectives. It implies to

[29] United Nations Environment Programme (UNEP), *Measuring Progress: Environmental Goals & Gaps*, (Nairobi, UNEP, 2012)
[30] The choice of these objectives is explained in the report UNEP 2012 above.
[31] See for instance the CBD COP 10, Decision X/2. Strategic Plan for Biodiversity 2011-2020, Annex 3, §12 'sound science'
.

associate a wide range of disciplines (social sciences and law included) to determine the environmental targets and to define what we are ultimately aiming at.

Due to the particularism of environmental law and to the intrinsic changing nature of the environment, legal environmental norms should not be disconnected from scientific (biological, or socio-ecological) considerations. The problem resides in the administrative level of decision-making. In international environmental law, legal scientists usually consider that the implementation of international principles is a national issue and pragmatic questions should be solved at the national level[32]. 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 and efficiency of environmental goals remains at a theoretical level.

As highlighted by the UNEP report of 2012 and by the process leading to the choice of goals to be assessed, the environmental law is a complex and fragmented system of rules. Goals are defined in many different settings and not necessarily in a coherent way, responding to a common and clear objective of sustainable development. Even though the environmental goals are built on scientific knowledge relying on various data, it should not prevent legal scientists from actively taking part into the process of construction of environmental targets that will be anyway embedded into legal texts such as international environmental agreement. Legal scientists should get involved into the translation of environmental targets into legal objectives through different legal means and should be enterprising in the protection of the environment and stay informed about the progress made by the environmental sciences and the more integrative understanding of multiple interactions within socio-environmental systems.

[32] See for instance S. L. Maxwell, E. J. Milner-Gulland, J. P. G. Jones, A. T. Knight, N. Bunnefeld, A. Nuno, P. Bal, S. Earle, J. E. M. Watson & J. R. Rhodes, 'Being smart about SMART environmental targets' (2015) 347 (6226) *Science* 1075-1076. '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.

The lack of legal responsiveness also results from the fact that classic culture in environmental law is not contextually grounded into environmental issues. Considering biodiversity conservation for instance, the progress of Aichi Targets at a national level is under-examined and the few analyses conducted are target-specific: this is a real challenge since the CBD, and the Aichi targets, have to be implemented at the national level[33] and in an integrative manner.

Legal scientists have a crucial role to play in better integrating scientific knowledge to build evidence-based indicators in relation with the environmental dynamics and a range of ecological scales. The importance of the dialogue between science and policy-makers[34] is often underlined but the role of jurists or legal scientists in relation to science is almost never mentioned and should be assessed.

3.2 The Process of Designing Targets and Indicators

The decontextualization of environmental targets is also a real concern as it can mask the reality of the debates which led to the final definition of the targets[35]. We should bear in mind the hybrid nature of these targets, that is to say the fact that they are social constructs that contain both scientific and political elements[36]. As underlined by Campbell, they are far from neutral but they appear as such as they are circulated as independent objects in different political arenas while they 'reflect and reinforce configurations of power and knowledge.[37]'

[33] S.M. Hagerman & R. Pelai, '"As Far as Possible and as Appropriate": Implementing the Aichi Biodiversity Targets' (2016) 9(6) *Conservation Letters*, at p. 469–478

[34] Policy-makers or science-policy interface are rarely defined nevertheless there is a wide range of policy-makers depending on the level of decision examined. The point should also be questioned.

[35] See L.M. Campbell et al., n. 36, above.

[36] 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*, at p. 480.

[37] Campbell et al. 2014, above.

Challenges resulting from the ambiguous or poorly operational wording of the targets, the lack of quantified elements[38] or the difficulties of quantification related to the various temporal and spatial scales[39] have been identified notably in relation to the failure of the implementation of the Strategic Plan for Biodiversity 2002-2010. Recommendations thus led to the adoption of SMART environmental targets, targets that are specific, measurable, achievable, realistic, and time-related[40].

But the SMARTness of the environmental targets is not the only issue, the negotiation process involving collaboration and consensus to set targets is very important. It implies a complex landscape of actors that should be better assessed to understand the decision in relation to the choice of the targets. Indeed, as underlined by Maxwell, 'Signatories may find it easier to agree on a target if it is difficult to measure progress toward it'[41]. The vagueness of targets could be decided on purpose, environmental targets being *de facto* non-quantifiable and, in the end, unachievable. The accountability in such a context remains difficult to determine.

Technological innovation could serve as means to build SMART indicators in relation to environmental targets, help to understand the interactions between actors at various geopolitical scales and allow a better monitoring and adaptation of environmental targets. Of course, we could insist on other important elements such as the necessity to consider the environmental dynamic and embed it into legal procedures depending on the changing state of the environment (or to the main trends), at different scales and according to the regions and ecosystems considered or the fact the legal process is too slow to respond quickly and appropriately to the environmental changes, especially when they are abrupt and need an instantaneous reaction.

[38] S. H. M. Butchart, M. Di Marco and J. E. M. Watson, 'Formulating Smart Commitments on Biodiversity: Lessons from the Aichi Targets' (2016) 9(6) *Conservation Letters*, 458.
[39] D.P. Tittensor et al., 'A mid-term analysis of progress toward international biodiversity targets', (2014) 10;346(6206) *Science* 241-4. doi: 10.1126/science.1257484. Epub 2014 Oct 2
[40] Campbell et al. 2014, above; Butchart et al. 2016 above.
[41] See S. L. Maxwell et al. p. 1075-1076, n. 41 above.

We consider that it is essential to establish information or knowledge systems (supervised or not) to massively integrate these data and quickly take the most appropriate measures, with regard to a set of criteria (and values, including ethical ones). In order to succeed, it is important to put environmental knowledge at the core.

3.3 Environmental Knowledge at the Core

As stated by McEldowney and McEldowney, 'Embracing and working closely with science at the boundaries of knowledge is an essential part of environmental law and may offer environmental lawyers new perspectives and a specific identity within legal scholarship.[42]' Without going into epistemological considerations about the production of knowledge[43], two points are essential: data without knowledge is a mere accumulation of observations; knowledge without data is speculation. Whatever the field of application (climate change, biodiversity conservation, management of marine resources and areas, health and environment, etc.), 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; 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, NGOs, local communities, scientists). The design of regulations and environmental public policies (i.e. targeting environmental objectives, dependent on natural resources and environmental services, or having environmental impacts) must take into account the state of resources and environments, the trends of these states' evolution, 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

[42] J. McEldowney & S. McEldowney, 'Science and Environmental Law: Collaboration across the Double Helix' (2011) 13(3) *Environmental Law Review*, pp. 169-198.
[43] A. F. Chalmers *What is this thing called science? An assessment of the nature and status of science and its methods* (University of Queensland Press, 1982), 2d ed., St Lucia.

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 issued from computer science or artificial intelligence (knowledge representation[44], data mining[45], decision-making models[46], ...).

The interdisciplinary approaches resort to increasingly massive heterogeneous sets of data (observation from instruments aboard satellite or drones, *in situ* data, biological samples, genetic sequencing, administrative data, data from sectoral information systems, surveys and interviews, textual corpora, ...) whose analysis is based on a range of skills, knowledge and tools (e.g. mechanistic, statistical or multi-agent modelling) with an expected growth of the contribution from BDA. The integration of knowledge from the humanities and social sciences poses specific difficulties[47] which, in our opinion, reveal, above all, the fact 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 and benefit from the fixity of natural principles. It rather contributes answering specific questions in defined contexts, and 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 tasks - in order of time and importance - of analyzing massive environmental data (including societal data) is to produce the most accurate and exhaustive

[44] M. Chein & M.-L. Mugnier, *Graph-based knowledge representation*(Springer, London, 2009) xiv+427 pp.; Katalnikova S. & L. Novickis 'Choice of knowledge representation model for development of knowledge base: possible solutions' (2018) 9(2) *International Journal* of *Advanced Computer Science* & *Applications*:358-363.

[45] Science-Metrix: D. Campbell, C. Tippett, B. Struck, C. Lefebvre, G. Côté, B. St-Louis Lalonde, A. Ventimiglia, G. Roberge and E. Archambault, *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 n° 30-CE-0677881/00-67, 2017 Brussels), 176 pp.

[46] T. Balke & N. Gilbert 'How Do Agents Make Decisions? A Survey'. (2014) 17 (4) *Journal of Artificial Societies and Social Simulation* 13 http://jasss.soc.surrey.ac.uk/17/4/13. html> DOI: 10.18564/jasss.2687

[47] See e.g. ISSC/UNESCO *World Social Science Report 2013: changing global environments* (OECD Publishing and UNESCO Publishing 2013), Paris, p. 22 *sq.*

description of the state of an 'ecosystem' (social-ecological system, biome, regional sea, etc.) 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 granularities of analysis (spatial and temporal resolutions, biological levels, etc.). It is used as a reference to detect or quantify possible physicochemical, biological, ecological or even societal changes. In stakeholder discussions on potential development scenarios to be considered or promoted, the baseline provided by this description is both a cognitive resource and a policy instrument that can drive and guide policy debates, and whose 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 to freely 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, as we have just seen, massive data and their analytical techniques have a role to play in understanding the architecture of environmental law and its evolution and by the same token contribute to the development of a new environmental law. BDA and some other AI's innovations fed by data can be used to anticipate how regulation and scientific knowledge are integrated and interact in the normative complex system constituted by environmental law. As stated about cyberspace in its book Code 2.0 by Lessig, a constitutionalist, 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'[48] 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

[48] L. Lessig, *Code, version 2.0* (Basic Books, Perseus Group, 2006), p.4.

continual flux'.[49] While the legal complexity has been highlighted and criticized as a threat for legal security[50], hindrance for a real freedom of interactions and social evolutions[51], source of heavy transaction costs, or high '*delegitimation*'[52], the complexity is even stronger in environmental law due to the uncertainty attached to environmental and legal sciences and knowledge.

4.1 Environmental Law as a Complex System

Legal complexity is not a choice. It results from legal constructions over long periods of time to address an ever-wider variety of legal issues in many different areas[53] -human rights, social rights, right to a healthy environment[54] or environmental law- and more recently law related to technological innovations[55] (debate about robot law[56], cyberspace regulation[57], nanotechnologies, regulations of genetics tools and applications). In each of these domains, there is a multiplicity of specific cases inducing specific regulations established or implemented by institutions or agents with regulation powers (states, cities, international organizations, private companies...).

Complex systems are characterized by numerous entities or components interacting together in a non-linear way[58]. There is such an entanglement of actions and reactions than the analysis of changes affecting entities cannot be described according to linear causality and thus calls

[49] McEldowney and McEldowney, 2011, above.
[50] Conseil d'Etat, *Rapport public 2006 - Sécurité juridique et complexité du droit.* Jurisprudence et avis de 2005, n. 57, (Etudes et documents du Conseil d'Etat Paris 2006).
[51] R.A. Epstein, *Simple rules for a complex world* (Harvard University Press 1995)
[52] Schuck P. 'Legal complexity: some causes, consequences, and cures' (1992) 42(1); Duke Law Journal, 1-52.
[53] P. Casanovas, U. Pagallo, G. Sartor, G. Ajani, *AI Approaches to the Complexity of legal systems. Complex systems, the Semantic Web, Ontologies, Argumentation and Dialogue* (Springer, 2010).
[54] N. Bobbio *L'étà dei diritti* (G. Einaudi ed., Torina 1997), pp. xiii-xv.
[55] This type of right would probably be included by N. Bobbio into the 'fourth generation rights' together with rights induced by uses of genetic heritage of 'each specific individual' (ibid. p.xiv).
[56] European Parliament Report with recommendations to the Commission on Civil Law Rules on Robotics (2015/2103(INL)), (2017) and see also (accessed: 27 August 2018), http://www.europarl.europa.eu/RegData/etudes/ATAG/2017/599250/EPRS_ATA(2017)599250_EN.pdf
[57] K. Kittichaisaree, *Public international law of cyberspace* (Springer, Law, Governance and Technology Series 32, Switzerland 2017).
[58] D. Bourcier & P. Mazzega 'Toward measures of legal complexity. (2007) *Artificial Intelligence and Law', Stanford Law School,* ACM Press, New York, 211-215. doi>10.1145/1276318.1276359

for co-evolution[59] between interdependent entities. Analogies with complex systems studied in physics or in ecology opened research avenues on the rise, aiming at measuring and monitoring the complexity of constitutive parts of legal systems[60]: network of citations of legal texts[61], uses of semantic web technologies applied to the semantic web of legal ontologies[62], jurisprudence[63], multilateral environmental agreements ratifications[64], etc.

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 in its organizational structure and governance, in the multitude of forms it contains and in its double interdependency, semantic and hierarchical but even more in the space created by the flexibility of their interpretations and uses. Without objective delimitation, this system opens up through its links and dependencies to other legal fields, themselves in constant evolution (e.g. criminal law, commercial law). Besides, it should address new socio-environmental situations (use of resources, pollution, protection and conservation, patrimonialisation...) or political situations (agreements negotiations, priority given to non-sustainable development projects) and integrate the production and actualization of scientific knowledge.

An example illustrates perfectly the new challenges faced by environmental law. Indeed, one crucial issue comes from the exponential growing amount of scientific data and the need for

[59] In a complex system, a same cause may have different effects depending on the state of the system, causality links nature, geometry or intensity can change et the predictability of state changes is limited to a finite timeline intrinsic to the system dynamic (the timeline presenting itself a temporal variability).

[60] J. B. Ruhl & D. M. Katz 'Measuring, monitoring, and managing legal complexity' (2015) 101 *Iowa Law Review*:191-244.

[61] P. Mazzega, D. Bourcier & R. Boulet 'The Network of French Legal Codes' (2009) *Proceedings 12th International Conference on Artificial Intelligence and Law (ICAIL)*, Barcelona – Spain, 8-12 June, 236-237. doi : 10.1145/1568234.1568271; Katz D.M. and M. Bommarito 'Measuring the Complexity of the Law: the United States Code' (2014) 22(4) *Artificial Intelligence and Law* 337–374.

[62] P. Casanovas, U. Pagallo G. Sartor & G. Ajani (eds) *AI approaches to the complexity of legal systems* (Springer LNAI (2009) 6237; G. Sartor, P. Casanovas, M.A. Biasiotti & M. Fernandez-Barrera (eds) *Approaches to legal ontologies.* (Springer, Law Governance & Tech; Series, Dordercht, 2011).

[63] J.H. Fowler, T.R. Johnson, II J.F Spriggs. S. Jeon & P.J. Wahlbeck 'Network Analysis and the Law: Measuring the legal importance of precedents at the U.S. Supreme Court' (2007) 15 *Political Analysis* 324–346. doi:10.1093/pan/mpm011

[64] R. Boulet, A. F. Barros-Platiau and P. Mazzega '35 years of Multilateral Environmental Agreements ratification: a network analysis' (2016) 24 *Artificial Intelligence and Law*, 133-148. DOI 10.1007/s10506-016-9180-7; R. Boulet, A. F. Barros-Platiau and P. Mazzega 'Environmental and trade regimes: comparison of hypergraphs modelling the ratifications of UN multilateral treaties' in R. Boulet, C. Lajaunie and P. Mazzega (eds) *Law, Public Policies and Complex Systems: Networks in Action* (Springer 2019), *in press*.

new ways and tools to analyze it and get a clear overview of the literature which can inform policy-makers. That difficulty has been underlined regarding the assessment process of the Intergovernmental Panel on Climate Change (IPCC)[65]. The IPCC Reports should represent the latest scientific, technical and socio-economic findings and be as comprehensive as possible[66]. As underlined by Minx et al.[67] (2017), to continue to assess the most recent science in a situation of literature explosion is highly challenging[68]. It requires the development of computer-assisted research tools 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 an individual or collective (human) intelligence. In the necessary process leading to the definition of an epistemology specific to environmental law, Big Data, BDA and Artificial Intelligence and modelling software will increasingly contribute to the monitoring of environmental changes and to the synthesis of knowledge necessary to environmental law. Ultimately, they will participate to the mastering and to the transformation of 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

[65] 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 https://www.ipcc.ch/organization/organization.shtml

[66] IPCC, 'Appendix A to the Principles Governing IPCC, Work Procedures for The Preparation, Review, Acceptance, Adoption', Approval and Publication of IPCC Reports, 4.3.4.

[67] J. C. Minx, M. Callaghan, W. F.Lamb, J. Garard & O. Edenhofer 'Learning about climate change solutions in the IPCC and beyond' (2017) 77 *Environmental Science & Policy*, 252-259.

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

theoretical warrant, but only recently advances in legal AI allow us to operationalize this idea. Integrative models of the type described above 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[69].

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 insight into the interaction between parts and the whole provided a welcome antidote to the legalism that dominates traditional jurisprudential thought, an approach that sees laws as top-down commands by a sovereign in pursuit of predefined goals, and which in the context of environmental regulation gave rise to the command and control model. While artificial societies and multi-agent systems (MAS) research was able to test in new ways assumptions about the way in which cooperation in societies emerges and conflicts are resolved,[70] its ultimate impact on the legislative process remained limited so far[71].

In marked contrast, the Artificial Intelligence and Law movement focussed on capturing legal knowledge in a computation and executable form. Where formal legislation remained 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 had 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.[72] The underlying legal approach remained beholden to legal formalism, law as a system of rules that are applied deductively to a set of facts. Legal knowledge then becomes a knowledge of legal

---

[69] 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. See: http://jasss.soc.surrey.ac.uk/JASSS.html

[70] S. Ossowski, *Co-ordination in artificial agent societies: social structures and its implications for autonomous problem-solving agents* (Springer-Verlag, 1999).

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

[72] So canonically T. J. Bench-Capon, & F. P. Coenen, Isomorphism and legal knowledge based systems (1992) *1*(1) *Artificial Intelligence and Law*, 65-86.

rules (which can be statutory or case-based in origin) and the role they play in valid legal argumentation. Legal rules are largely analysed 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[73]. While computational legal knowledge representation of this type was successful in reducing costs, increasing consistency and sometimes speed of decision-making, they suffered 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 the 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.

So far, we have seen how computational approaches to legal regulation reflect and build on a variety of legal considerations which, in the past at least, often marked the opposite ends of the spectrum of jurisprudential thought. At the same time, they all address in various ways concerns pertinent 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 that rule based interventions have in complex and interconnected systems.[74] Ideally therefore, we would want to combine these approaches to benefit from their respective advantages, while avoiding any normative or philosophical conflicts between their respective underlying epistemological assumptions and jurisprudential commitments.

---

[73] A classical example from that time. See M.J. Sergot, F. Sadri, R. A. Kowalski, F. Kriwaczek, P. Hammond, & H. Terese Cory, 'The British Nationality Act as a logic program' *Communications of the ACM* (1986): 29, no. 5 370-386. e.g. a set of rules that determine if someone is eligible for citizenship.

[74] For a discussion on the problems of legislative intervention in networked, complex environments see e.g. A.G. González 'Scale-free law: network science and copyright' (2006) 70 *Albany Law Review* at p.1297.

4.3 Technical Innovation and New Legal Findings

Partly in response to the perceived failure to develop suitable practical applications, partly in rejection of the underlying formalist epistemology of law, data-driven approaches to legal AI emerged at the turn of the millennium. Rather than formally representing legal sources such as statutes and precedent-setting appeal court cases, these 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 likely distribution of assets in divorce cases.[75] It is this type of approach that has more recently recaptured the legal imagination, and 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 party submissions and docket files, or the analysis of the correlation between severity of punishment and distance to lunch.[76] The last example in particular indicates the shift from the previous, rule-based paradigm: knowing the law now means ability to predict the outcome of specific court cases, and if nonlegal 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 the one most prominent in the recent interest in the field, for our purposes it suffers from the litigation-centric view: it is at its strongest when the decision for 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.

Finally, we should mention the 'regulation by design" movement, an approach that gave a new lease of life to the aforementioned formalist legal expert systems. We already mentioned

[75] 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*, at p. 267-275.

[76] S. Danziger, J. Levav, & L. Avnaim-Pesso, 'Extraneous factors in judicial decisions' (2011) 108 (17) *Proceedings of the National Academy of Sciences*: 6889-6892.

Lawrence Lessig's work, who made it 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.[77] While law had been traditionally understood as the domain of the 'ought' – things we should be doing or omitting, but often do – and a regulatory ideal that relies on punishment after a rule violation 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 prevents norm violation.

An interesting situation arises if the older ideas about legal knowledge representation and rule-based expert systems are combined with code-based law enforcement. In this case, the contextual environment does not just prevent rule violating behaviour, it reasons in the process of the applicable 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 called 'ambient law", a world where increasingly the environment takes decisions that ensure our behaviour is compliant with norms.[78]

Design choices on the technological level can now be traced back to the relevant legislation that they embed, 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 within this approach. Furthermore, the correspondence, or isomorphism, between the two types of normativity becomes a formally provable characteristic of the system as a whole.

One interesting example that combines the advantages of a multi-agent system with that of a formal representation of legal norms comes from an application that is connected to the issues of environmental protection. Imagine a smart city environment where cars, energy providers and payment systems are in constant bidirectional exchange of data, electricity and money.

[77] L Lessig, 'Law regulating code regulating law' (2003) 35 *Loyola University Chicago Law Journal*, p.1.
[78] M. Hildebrandt, & B. J. Koops 'The challenges of ambient law and legal protection in the profiling era' (2010) *73*(3), *The Modern Law Review*, 428-460.

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 SmartPrivacy initiative tried to emulate. For this purpose, it combines a formal ontology that represents the flow of data, energy and money as the object of regulation with a separate formal ontology that represents the applicable data protection law. The legal regulation module automatically generates policies for the smart grid that are turned into design constraints for the grid engineers. The engineer works in a software design environment that has its own ambient legal intelligence, and guides and restricts their design choices.

Now, let us add some more directly environmental legislation. Our fictitious law has two components. First, it prescribes maximum levels of air pollution that the city is allowed to have at any given point in time. Second, 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, disincentive drivers from unnecessary travel until such a time that air pollution levels have improved. In this scenario, cars, in addition to reporting about their energy status, are also 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, the electricity prices automatically increase.

We have developed an account of environmental law compliance by design that is open to Big Data in particular represented the complexity, interconnectedness and feedback loops within the legal system in the same way in which we represent them in environmental science disciplines. This means a first step towards a realignment between 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"[79]. It is now time to give flesh to 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 analysed as a legal regime fragmentation is in fact coming from the different regimes and layers of decision-making but also from the fragmented vision of scientific issues by lawyers. Of course, instruments have been developed in environmental law to combat the fragmentation or even contradictions between the objectives of multilateral environmental agreements. This is particularly true regarding the three Rio Conventions or the biodiversity-related conventions with mechanisms aiming at enhancing coherence and cooperation in implementation and favour synergies and coordination[80]. Nevertheless, the fragmentation of environmental law remains an issue. The gap of collaboration between scientists and policy-makers has been highlighted in 2017 by a report of the United Nations Environment Programme[81]. 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 the legal norm must be conceived in all the genericity of the

[79] Brundtland report, 1987, p. 330.
[80] With the creation respectively of the Joint Liaison Group and of the Biodiversity Liaison Group.
[81] United Nations Environment Programme, *Strengthening the Science-policy Interface: A Gap Analysis*, (UNEP, 2017).

question to be regulated, each case of applications corresponding to an instance[82] of the norm to the empirical situation considered. The particularity of environmental law lies in the fact that the empirical situation - an ecological system, the state of some environment or resources - evolves according to endogenous dynamic processes for the most part subject to natural laws. This simple remark - this truism - nevertheless has two major consequences: a) the environmental legal norm can be designed generically only on the basis of a precise knowledge of environmental state and dynamics; (b) the instantiation of the generic norm - e.g. 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.

Another key concern resides in the choice of the scientific knowledge to be integrated into environmental law. Thus, law should be adaptive[83] to take into account the environmental dynamic. It means that with the development of SMART environmental targets we should elaborate 'smart' procedures able to put into action innovative methods (machine assisted, or machine-based), translating environmental or socio-ecological systems changes into related updates into 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 tools, relying on opportunities given by Big Data and Artificial Intelligence:

- smart targets
- smart indicators
- smart legal procedures.

---

[82] In modelling language, an instance is 'a concrete manifestation of an abstraction' in J. Booch, J. Rumbaugh and I. Jacobson *The unified modelling language user guide*, 2d Ed., (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.) to the abstraction (e.g. the generally defined target; the corresponding general type of data; etc.).

[83] S. Morand & C. Lajaunie 'The Role of Law, Justice and Scientific Knowledge in Health and Biodiversity' in *Biodiversity and health. Linking life, ecosystems and societies*, (Elsevier ISTE press 2017).

As any legal instrument, these tools should be conceived in order to ensure their relevance (respond in an appropriate manner to a specific issue), feasibility (production and implementation), transparency (understandable and traceable), robustness (ensure legal security). Nevertheless, the notion of smartness is justified in order to address specific challenges: 1) ensure intersectoral consistency; 2) integrate in a harmonious way the objectives of environmental protection and conservation with those of sustainable development; 3) adapt to evolution of environmental and social systems in a responsive, clear, traceable and predictable way; 4) ensure a continuum of environmental governance and environmental goals through ecosystem and social scales as well as legal and political levels (allocation of responsibilities, gradations of obligations and penalties; compilation of decisions; efficiency and effectiveness of norms)[84].

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 reach not one but a set of prescribed targets (e.g. linking environmental and sustainable development targets). The conditions for achieving these trajectories are documented, as well as the direct and indirect changes and trends. By allowing the advantages and disadvantages of several scenarios to be compared and evaluated, this approach provides a base of evidences for discussing the desirability or acceptability of a particular policy or regulatory option. Indicators can also be diversified at the request of stakeholders and depending on 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

[84] See L.M. Campbell et al., n. 36 above.

to 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.[85]'

These basic elements constitute 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 issue of choice of the appropriate scientific knowledge, as illustrated by the role of the IPCC, comes from the multiple interactions in an open system, the temporal and spatial scales but also from the fact that recommendations from science on global environmental issues cannot be separated from the fundamental issues of fairness, equity and social justice[86].

The use of Big Data and AI-based software raises various intertwined ethical issues[87] to be considered carefully in the elaboration of a specific epistemology for environmental law. The use of AI and Big Data constitutes an opportunity but also a risk: it necessitates an evaluation of the way the information and knowledge are produced and operated, and for which purpose. The same statement concerns the way environmental knowledge is gathered and produced and in turn the way legal knowledge (and specifically environmental goals and targets) is designed and monitored[88]. Moreover, in addition to the need for transparency of knowledge (and data) acquired and their accessibility, their uses' options are at the heart of debates on sustainable development, since these uses have serious and differentiated societal impacts. The analysis of the ethical implications of these elements is in itself an essential research avenue that is of

---

[85] A. C. Newton 'Implications of Goodhart's Law for monitoring global biodiversity loss' (2011) 4 *Conservation Letters* at p. 264–268.

[86] UNEP 2017, above.

[87] See e.g. J. van den Hoven, 'Moral methodology and information technology' in K. E. Himma and H. T. Tavani (eds) *The handbook of information and computer ethics* (Hoboken: Wiley 2008, 49–67). M. Anderson & S. Leigh Anderson (eds) *Machine Ethics* (Cambridge Univ. Press, New York, 2011); European Commission, High-Level Expert Group on Artificial Intelligence 'Draft Ethics Guidelines for Trustworthy AI' (European Commission, Directorate-General for Communication, 2018).

[88] For environmental knowledge as well as legal knowledge see the analysis of general knowledge versus particular knowledge and the way to apply a rule 'local and situated knowledge' in settings that are mutable, in determinant (some facts are unknown), and particular see J.C. Scott *Seeing like a State: how certain schemes to improve the hum an condition have failed* (Yale University Press, New Haven and London, 1998).

increasing interest not only to ethicists but also to researchers working on various environmental issues[89].

6. Conclusion

This world requires a rethinking of the very notion of normativity, contrasting legal and technological normativity and also 'a novel approach to law making which addresses the challenges of technology, legitimacy, and political-legal theory'.[90] This shift to technological normativity has not only practical dangers, but the potential to radically alter our understanding of legal legitimacy.[91] On the other hand, it is aligned with the move towards 'proactive law" which from its origin in Scandinavian legal thought[92] increasingly also influences the technology regulation regime in the EU,[93] and here also in particular environmental regulation.[94]

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. Even though there is now a direct connection between formal law and their software implementation, law will never uniquely determine the engineering solutions, leaving a range of design choices to the engineer. All of these 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

---

[89] N. Tuana, 'Leading with ethics, aiming for policy: new opportunities for philosophy of science' (2010) 177 (3) *Synthese* 471–492. https://doi.org/10.1007/s11229-010-9793-4. For a study on the ethical side of interdisciplinary research on the environment cf. C. Lajaunie and P. Mazzega (Invited editors), 'The ethics of biodiversity conservation' vol 10 (4) Asian Bioethics Review, Special Issue, (Springer Nature Singapore, 2018).

[90] Ibid at 428. See also R. Leenes, 'Framing techno-regulation: An exploration of state and non-state regulation by technology' (2011) *5*(2) *Legisprudence*, 143-169.

[91] B.J. Koops, 'Law, technology, and shifting power relations' (2010) 25, *Berkeley Technology Law Journal* 973; M. Hildebrandt 'Legal protection by design: objections and refutations' (2011) 5 no. 2 *Legisprudence* 223-248.

[92] See in particular P. Wahlgren (ed.) 'A Proactive Approach' (2006) Volume 49 *Scandinavian Studies in Law*, Stockholm; in H. Haapio (ed.) 'A Proactive Approach to Contracting and law' (Turku 2008).

[93] 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 (Accessed 27 Jan 2019)

[94] G. Berger-Walliser & P. Shrivastava, 'Beyond compliance: sustainable development, business, and proactive law' (2014) 46 *Georgetown Journal of International Law* at p. 417.

reduced to formally executable code. The result is a range of implementation options which are all consistent with the law, but mutually inconsistent with each other.

This ultimately treats legal regulation itself 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 actors themselves. The interact with other legal objects in complex and not always intentionally planned ways, 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, 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[95] and also with knowledge about socio-environments.

Despite all this, our account is still within a traditional jurisprudential framework in one crucial sense: The legislator, and only the legislator, generates laws, and courts, and only courts, generate the relevant feedback data from a particular case that interpret the law.

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

[95] For examples see e.g. R. Winkels & A. Boer 'Finding and Visualizing Dutch Legislative Context Networks' (2014):3 *Diritto, Scienza, Tecnologia* 157-182; 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* 23-47.

Box 1. What does environmental Big Data look like?

Three characteristics are generally considered to classify a set of data among 'Big Data': volume (or size), speed (frequency of the generation of new data) and variety[96]. There is no consensus on quantitative criteria for applying this categorization. The following examples, however, provide an idea of what Big Data looks like for environmental issues. Thus, the only imagers and radars aboard the six Sentinel satellites of the Copernicus European program for observing the atmosphere, the oceans and the earth, should generate several Terabytes of structured data per day[97]. With regard to biodiversity changes, the scenario analyses shifted from single model-based analyses[98] to multi-model and data source analyses[99]. A search for data sets on the Global Biodiversity Information Facility website returns 40,464 data sets and more than 1 billion species occurrence records[100].

It is estimated that 95% of Big Data is composed of unstructured data[101] especially texts, audio files (e.g. in ecology, soundscape records) or pictures (flora and fauna, habitats, etc.) and videos - and requires specific methods of automatic analysis. The query of the EUR-Lex legislative database[102] with the keyword 'ecosystem' returns a list of 5237 references to EU law and related documents. The texts of the multilateral environmental agreements, the documents resulting from the Conferences of the Parties associated with the main international conventions and the reports of the numerous working groups, represent tens of thousands of pages that only natural language processing tools can explore as a whole. This holistic approach is required to avoid the damage (cognitive and environmental) associated with the fragmentation of legal regimes[103] and to design opportunities for mutual supportiveness between measures[104].

---

[96] O. Kwon, N. Lee & B. Shin,'Data quality management, data usage experience and acquisition intention of big data analytics' (2014) 34(3): *International Journal of Information Management*, 387–394.

[97] See http://newsletter.copernicus.eu/article/data-volume

[98] See e.g. UNEP, *Global Environment Outlook 4* (United Nations Environment Programme, 2007); Secretariat of the Convention on Biological Diversity, *Global Biodiversity Outlook 2* (UNO-SCBD Montreal, 2006) vii + 81 pp.

[99] P. Leadley, H. M. Pereira, R. Alkemade, J. F. Fernandez-Manjarres, V. Proenca, J. P. W. Scharlemann & M. J. Walpole, *Biodiversity scenarios: projections of 21st century change in biodiversity and associated ecosystem services*, Tech. Ser. no. 50, (Secretariat of the Convention on Biological Diversity, Montreal 2010), 132 pp.

[100] As of 6 July, 2018, see https://www.gbif.org/

[101] A. Gandomi & M. Haider, *Beyond the hype: Big data concepts, methods, and analytics* (2015) 35 International Journal of Information Management, 137–144. http://dx.doi.org/10.1016/j.ijinfomgt.2014.10.007

[102] Accessed on 2 August 2018, see https://eur-lex.europa.eu/homepage.html

[103] H. Van Asselt, *The fragmentation of global climate governance. Consequences and management of regime interactions.* (Edward Elgar Publishing, Cheltenham, 2014).

[104] J. O. Velázquez Gomar, L. C. Stringer and J. Paavola, 'Regime complexes and national policy coherence: experiences in the biodiversity cluster' (2014) 20(1) *Global Governance: A Review of Multilateralism and International Organizations*, 119-145