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UNEP/GEO Reports on Desertification Issue: Testing for Contemporaneity, Consistency and Accuracy

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Abstract

The GEO project, UNEP's flagship project that reviews the state of the world's environment has evolved over time, as can be clearly seen in the six reports issued from 1997 to 2019. The first three reports (1997, 2000, and 2002), because of limited size and unclear methodological foundation, were largely only sketchy description of the state of the environment at the global and regional levels. Stricter scientific standards were implemented in GEO-4 (2007) as a result of the "IPCC-ization" of the report's methodology. The recent trend to make GEO reports more "solution-oriented" has resulted in the multiplying of subjects and the more prolific use of grey literature, changes that have influenced the scientific quality of the reports in a variety of ways. The paper aims to assess the GEO reports' evolution by analysing how well desertification issue have been represented in them. We found that the increasing size and complexity of the most recent reports raise concerns regarding data quality and the consistency of the different chapters.

Keywords: Environmental assessment; Global environmental issues; Land degradation; Desertification; Drylands

Introduction

The GEO is the flagship environmental assessment report of the UN Environment Programme (UNEP), which is mandated as a global entity to "keep under review the world environmental situation" [1]. The GEO reports are considered relatively effective in providing an accurate assessment of global environmental issues [2].

There have now been six GEO reports, and while the report itself has evolved, the three major structural sections of each report have not changed. These three sections are based on: (1) an assessment of the state of the global environment by both environmental media (land, air, water etc.) and the UN macro-regions (Africa, Asia and Pacific, Europe, Latin America and the Caribbean, North America, West Asia); (2) an assessment of global and regional environmental policy aimed at addressing major environmental challenges; (3) an analysis of the outlook of the state of the environment and whether alternative policies could be applied at the global, regional and national levels.

There have been two important developmental transformations involving the GEOs over time. These are the strengthening of its scientific standards and its ever-increasing profile in the political sphere. The turning point for the scientific development of the reports came during the preparation of the GEO-4 report (2007) when new, stricter standards of writing were implemented under the direction of UNEP. The process was referred to by Bakkes et al. [3] as the "IPCC-ization" of GEO reports, a reference to the Intergovernmental Panel on Climate Change (IPCC). These new standards included a prerequisite to exclusively use peer-reviewed publications, the exclusion of grey literature sources, more citations (resulting in the current 5-6 citations per page) and improving the ratio of cited sources published within the last five years.

The IPCC's approach regarding the nomination of experts to write the reports was adopted and that made it the responsibility of national governments to ensure that this was the case [3,4]. Prior to GEO-4, the contributing authors were drawn from a network of so-called GEO Collaborating Centres (GEO CCs). By 2000, there were 22 CCs, only 8 of which were in Europe and North America. The difference between the various capacities of the CCs was to be addressed through "the learning-by-doing" approach. However, some experts saw the differences in the centres' institutional and analytic capacity as a challenge to ensuring the scientific credibility of the GEO reports [5]. Thus, what was originally seen as a key resource for the GEO reports was sacrificed to better correspond to standard modern procedures when making scientific assessments.

Furthermore, in the course of this "IPCC-zation", a comprehensive process of two-three circles reviewing each chapter of the GEO reports was established whereby authors had to respond to each comment and suggestion line by line. In the first few reports, the manuscripts were only reviewed internally by UNEP staff, editors and some leading authors.

Along with the improvements to their scientific inputs and outputs, there has been a process to gain higher political recognition of the GEO reports. The early reports' target audience was not clearly defined [5]. According to current understanding, the primary role of GEO reporting is "to translate the highly technical environmental data assessments into information usable by managers and planners, especially in developing countries" [1].

There were also important changes in the procedure of presenting GEO reports to the policymaking community. In the early reports, the summary of policy-relevant findings was prepared and finalised by contributing authors and the UNEP team [3]. Since GEO-4, the process has changed so that the reports were now approved by different parties that include national scientific reviewers, governments and international policymakers, where the latter group can veto specific sections. Since GEO-5, the Summary for Policy Makers (SPMs) of these assessments is now a negotiated text comprehensively discussed line-by-line by national delegations at a plenary [4].

Only recently, the GEO programme was internally perpended and two evaluations were sanctioned by UNEP itself. They were Rowe et al. [4], who specifically focused on GEO-5, and Kowarsch et al. [6] who presented a wider analysis of the methodological problems of the reports. Both evaluations recommended that the GEO reports turn towards "solution-oriented science engagement" [7], even if some proponents of this new paradigm admitted that "it is often unclear what exactly is meant by "solution orientation" [8]. Kowarsch et al. [9] estimated that 44% of the content presented in GEO-5 could be classed as "solution-relevant" material and that this was a positive development when compared with 22% in GEO-4 and 15-18% in the earlier GEOs.

This new course was accompanied with more tolerant attitude to use of non-reviewed sources in GEO reports. The exclusive use of peer-reviewed scientific publications was questioned by Rowe et al. [4], who argued that reports aimed to propose "policy options" and "priority solutions" and had to rely on a more multifaceted knowledge foundation such as grey literature and indigenous knowledge. The draft document prepared by Mercator Research Institute on Global Commons and Climate Change for the GEO-6 Intergovernmental and Multi-stakeholder Consultation held in 2014 in Berlin, stated that it wanted "to encourage" GEO authors to use grey literature in GEO-6. This phrasing was opposed by some experts from the audience (including the author of this paper).

The evaluation noted that the predominant participation of scientific institutes in GEO reports has to be also revised to be more representative of all GEO programme stockholders to better include governmental structures, international organizations, NGOs, indigenous peoples' networks, and the private sector [8]. Jabbour & Flachsland [10] claimed that the global environmental assessment "enterprise now finds itself at crossroads" and suggested strengthening the collaboration of different UNEP partners by employing "digital-based knowledge platforms (e.g., Environment Live)". Some authors have also argued that the ultimate goal of the GEO reports should be presenting an entire spectrum of experts' views and opportunities for policies rather than seeking to achieve scientific consensus [11].

Rowe et al. [4] determined the major limitation of the GEO-5 report to be a lack of "real policy experts" among the authors who were recruited primarily from the area of natural sciences. However, Minx et al. [12] saw it as overoptimistic to primarily rely on expert knowledge outside the area of natural sciences in producing such complex environmental assessment reports. They agreed that there was an under-representation of social scientists in reports as such those from the IPCC but regard it as problematic for social science to provide relevant policy advice given its value-laden character posing "a threat to both the scientific credibility and the political legitimacy of social science policy assessments".

This paper aims to trace the evolution of the state of the art of the GEO reports and does so through the lens of desertification issue. Over the years GEO reports have been progressively transformed into "consensus" documents and, as such, represent a version of contemporary scientific knowledge and public environmental concerns shaped by what was deemed as necessary compromises among co-chairs, scientific and policy advisory panels, UNEP and the reports' authors. As such, one can expect to find a rather complex evolutionary picture of the state of the art in the GEO reports as two rather divergent perspectives compete, with one presenting and promoting strict scientific standards while the other seeks to increase the political engagement and impact of the reports. Without determining which, or indeed, if either perspective should hold sway, the increased momentum of the political engagement perspective must not compromise the scientific quality of the reports.

Methods and Materials

In this review we use three criteria to assess the quality of treatments related to desertification in GEO reports: contemporaneity, consistency, and accuracy. Contemporaneity *("up-to-dateness")* refers to the extent to which a GEO report captures *current* (as opposed to dated) scientific findings on desertification. *Consistency* refers to the extent to which thematic and regional sub-sections of the GEO avoid drawing on conflicting data or claims. *Accuracy* is more complex: it measures the extent to which treatment reflects the facts and logic present in contemporary scientific discourse on desertification. The main developments of the dis-

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course regarding desertification can be summarised in the following [13]:

a) United Nations Conference on Desertification (UNCOD) in 1977 set a benchmark for the role of science in UN conferences [14]. Experts criticised the initial concept of desert encroachment and called for a complex understanding of the desertification issue, including both biophysical and socio-economic dimensions;

b) Several UN organisations launched their first global assessments, which include: the UNESCO Map of Global Desertification (1977), the second edition of the UNESCO map (1984), Global Assessment of Human-Induced Soil Degradation (GLASOD) (1992) and, finally, the first and second editions of the World Atlas of Desertification (WAD) (1992; 1997). The most influential GLASOD assessed land degradation in drylands and non-drylands by different types of degradation processes (water, wind erosion, salinisation etc.). These global assessments were all based on aridity indexes (AI) and experts' opinions (see Cherlet et al. [15]);

c) At Rio-de-Janeiro in 1992, the United Nations Conference on Environment and Development (UNCED) adopted a principal decision on the Convention to Combat Desertification (UNCCD) which was signed by 87 parties in 1994 and ratified by the required 50 parties on 26 December 1996. With the entering onto force of the UNCCD, desertification had become an "institutional fact", i.e., "one that an institution wanted to believe, one that served its purposes" [16,17];

d) In the 1990s, the Sahel became a testing ground for remote sensing (RS) methods. Pioneer RS studies had discovered that the region was "greening-up" due to increased precipitation while the effect of human activity was smaller in scale than anticipated and not always negative [18-21]. The increased precipitation was later explained by a link (teleconnection) with temperature anomalies in low-latitude oceanic waters [22];

e) In 2002, the FAO launched the Land Degradation Assessment in Drylands (LADA) project designed to develop and validate quantitative, reproducible methods (that is RS) for assessment of land degradation, especially in drylands. In 2008 the project yielded the Global Assessment of Land Degradation and Improvement (GLADA) which showed that most degraded land could be observed in humid climate areas (78% of degraded lands) but very little in arid (5%) and semi-arid (9%) climates. Approximately 16% of global terrestrial land area (mostly pasturelands) had been improved in terms of biomass productivity since 1981 [23];

f) Following global RS-based assessments generally confirmed "greening-up" as a global-scale climate phenomenon, although concrete regional figures for degraded and improved lands were dependent on the methods and databases used [24-27];

g) The language and interpretation of the UNCCD were promptly adjusted to align with these new scientific findings by using the term "land degradation" more broadly rather than just associating it with specific geographical conditions of drylands [28]. The UNCCD has now been ratified by about 200 parties, many of which are located in humid climate zones that could not be classed as affected by desertification under its prior usage (e.g., Central and Eastern Europe) [29];

h) Simultaneously, the UNCCD expanded its thematic area by assimilating new policy notions such as "ecosystem services" (2005), MDGs (2000) and SDGs (2015). In 2012, the Secretariat of the UNCCD, at the United Nations Conference on Sustainable Development, successfully promoted the adoption of SDG 15.3 seeking to achieve Land Degradation Neutrality (LDN) at both the global and regional levels by 2030.

Results

i. **GEO-1**, published in 1997, provided little information about land degradation and desertification problems, an oversight that may be excused by the limited space offered in a 262-page report. In the report's introduction, the term desertification is used only once while the term land degradation was commonly used, especially in the context of food security problems in Africa and Asia, while the SoE section did not define "desertification". Although the GLASOD and WAD estimates were met in the report here and there, deteriorating climatic conditions were evidently regarded as the major threat for the world's drylands. A graph entitled "Sahel precipitation 1897–1990" showed the extraordinary severity of the Sudan-Sahel drought which began in 1968 and persisted up to 1990. Another map prepared by UNEP-GRID portrayed the entire Sudan-Sahel belt as suffering from overgrazing. However, several still anonymous authors[1] claimed recurrent droughts were a more important factor than overgrazing in the worsening condition of the Sahel: "With each drought cycle desertification increases. Currently 36 countries are affected by droughts and *some degree* desertification". The new scientific approaches of the day, such as remote sensing, were not mentioned in the text while the list of references consisted exclusively of official reports by UNEP and other international organisations.

ii. **GEO-2** was published in 2000 and its limited size (399 pages) also explains the rather sketchy representation of several global environmental issues. The sources of information about the extent and severity of land degradation in drylands globally and regionally were exclusively the GLASOD and the second edition of WAD. According to these estimates, drylands occupied 40 per cent global land surface area which was home to 1 billion people. More than 1 billion ha of drylands were evaluated as degraded due to water (42%) and wind (45%) erosion, chemical (10%) and physical (3%) deterioration. In the regional SoE review of Africa, all the estimates of the degree of land degradation were taken from the second edition of WAD. However, the authors referred to

[1] *The first three GEO reports have no indication of authorship for chapters.*

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the WAD-2 to claim that overgrazing was not the primary cause of desertification in Northern Africa: "… it is now thought that rainfall variability and long-term droughts are more important determinants"[2]. One more important region in terms of desertification was South and Southeast Asia (SSE). The very high estimates for land degradation in SSE were taken from the Assessment of the Status of Human-Induced Soil Degradation in South and South-East Asia (ASSOD), a sequel to GLASOD, but presented a more advanced map due to a large dataset of soil degradation sites in geo-reference (grid) format[3]. At the same time, the GEO report noticed the high rate of growth of yields of major crops in SSE countries between 1957 and 1990.

iii. **GEO-3** subtitled "Past, Present and Future Perspectives" was used as the UNEP's input to the 2002 World Summit on Sustainable Development in Johannesburg. The report had 446 pages which, compared to GEO-1's 262 pages, provided much more space for discussion of new scientific findings and policy developments concerning global environmental issues. The first chapter was devoted to the evolution of global environmental policy since 1972 (the Stockholm Conference) where a question was raised about the lower status of the UNCCD when compared to the UNFCCC and the UNCBD. The UNCCD was nick-named "Rio's stepchild" as it did not get as much attention as the two other global conventions. Developed counties were criticised for their weak engagement in combating desertification as it was mostly the problem of poor countries. A sub-section entitled "Land" took a global perspective and primarily relied on the GLASOD estimates, according to which, 23% of the world's usable land had been affected by land degradation to a degree sufficient to reduce its productivity. Although the anonymous authors called GLASOD estimates "compelling statistics", they acknowledged that "some studies are beginning to question the data, arguing that degradation estimates are overstated". Moreover, they cited a pamphlet "Lessons from the Theatre: Should this be the Final Curtain Call for the Convention to Combat Desertification?" by C. Toulmin [31]. This pamphlet emphasised the high degree of uncertainty regarding the estimates concerning degraded areas which "ranged from one-third of the world's surface area to about 50 per cent, and people affected from 1 in 6 to 1 in 3". A regional review of Africa and other UN regions presented results of the GLASOD, WAD and similar assessments obtained, for example, by overlaying climatic, soil quality (using the FAO world soil map from 1977) and population density maps (see Reich et al. [32]). The resultant high estimates of degraded areas – 46 per cent of Africa, of which, 55 per cent of that area was at high or very high risk does not reflect the actual condition of the land area but is, at best, a precis of its theoretical vulnerability. New RS methods were not mentioned in the GEO-3, although they had been actively applied by environmental scientists from the mid-1990s. A regional review of Asia and the Pacific resulted in a more complex discussion on land degradation in a social and economic context (such as the influence of fiscal and market incentives offered under governmental programmes). The interlinkages between climate change and desertification issues were not dealt with except for a single line that noted the possible exacerbation of desertification on the African continent due to climate change.

iv. **GEO-4** was a 540-page volume with a focus on the 20th anniversary of the UN report entitled "Our Common Future" (1987). GEO-4's chapter 3, under the heading of "Land", opened with a very critical review of GLASOD with reference to a paper "How good is GLASOD?" by Sonneveld & Dent [33]. One of the authors of this paper (D.L. Dent) served as the corresponding lead author of the Land chapter. A new, quantitative global assessment of the Land Degradation Assessment in Dryland (LADA) project undertaken by GEF/UNEP/FAO was positively featured in this chapter. One advantage of LADA was seen in its trend analysis of biomass production (NPP) derived from satellite measurements of the Normalized Difference Vegetation Index (NDVI) and other greenness indexes used for the last 30 years. A negative trend in NDVI was seen to be a reliable basis for the identification of "black spots" in land degradation, however, these "black spots" do not necessarily indicate an adverse human impact on soil and vegetation as there could be several other factors in play, especially rainfall. The latter proposition is illustrated by the "Global land degradation using biomass production and rain-use efficiency trends between 1981–2003" map, a predecessor of GLADA [23]. Although the authors of the chapter 3 admitted these results were preliminary and required validation on the ground, they confirmed that the Sahel had experienced a "greening" between 1982–1999 caused by increased precipitation and as a result of improved land management. A theory of the aridisation of regional climate caused by the anthropogenic generation of dust [34] in semi-arid zones was attested to as being "speculative", a verdict supported by examples such as northern Chad and western China where natural processes are known to create about 90 per cent of the dust.

The authors of the chapter are also concerned about the general lack of systematic measurements of the extent and severity of soil erosion in non-drylands. The main problem, they said, is

[2]The explanatory note for the WAD thoroughly reviewed numerous different contemporary publications and gave no clear indication of the editors' position on relative importance of climatic and human causes of vegetation change in the Sahel or other semi-arid regions. Thus, it was rather a choice of anonymous authors of the SoE chapter to downplay human factor in the Sahel.

[3]ASSOD (at a scale 1:5 million) presents a qualitative classification of land in terms of the impact of degradation on agricultural production. Although this new map was considered an improved version of GLASOD, it had obvious limitations, for example, Zika [30] pointed out that the sum total of all degraded areas, stable terrain and wasteland would exceed the total area of a given grid cell.

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that "regional or even global estimates have, quite wrongly, scaled up measurements made on small plots, arriving at huge masses of eroded soil that would reshape whole landscapes within a few decades". Some examples of such overestimation were provided in the Land chapter. All the models of land erosion as a derived from topographic, soil, land cover and climatic variables it cited had a shared defect, namely that "potential erosion is not the same thing as actual one".

In the SoE regional chapter ("Regional Perspectives: 1987–2007") land degradation and desertification were not necessarily included in their list of priority issues at least some of the regions were facing (especially Europe and North America). However, none of the regional reviews referred to GLASOD or WAD while the African chapter contradicted the Land chapter review by claiming that the Sahel was the area on the continent most affected by desertification (with the reference to Reich et al. [32]). Although systematic data of land degradation in Asia and the Pacific region was lacking, "experts agree that land is being degraded in all sub-regions" but tempered this by noting that all the countries in the region applied sufficient countermeasures to achieve remarkable increases in food crop production in last 30 years. The sub-chapter concerning the Latin American and Caribbean regions provided very high figures for the extent of land degradation (15.7% of the total land area) and desertification (25%), which precisely coincide with the GLASOD and WAD estimates (but without the sub-chapter referring to these sources). West Asia was also characterised as having a very high incidence of land degradation, impacting 79% of the cultivated land area and with 98% of that having an anthropogenic source.

Nevertheless, a weak connection between the desertification and climate change parts is noticeable through the report. In the "Climate Change" chapter, the term "desertification" is not mentioned at all, this is despite there being many cross-references between climate change and biodiversity loss cited in various chapters in the report.

v. **GEO-5** was issued in the final stages of the preparations for the UN Conference on Sustainable Development (Rio+20) in June of 2012. The report focused on an assessment of the progress made towards meeting internationally agreed goals and the identification of the most promising response options in the various regions. This policy-oriented approach and wider (than in GEO-4) application of new concepts such as "ecosystem services" and Millennium Development Goals (MDGs) noticeably extended the list of issues reviewed in the now 528 page report.

The Land chapter was structured using four basic land categories, namely forests, drylands, wetlands and, finally, grasslands and savannas. The chapter also included two other categories labelled as urban areas and human infrastructure. Land degradation and desertification issues were discussed only in the drylands sub-section which recognized that the "spatial extent of drylands remains uncertain due to variations in ecosystem sub-types, data variability and the different classes and thresholds applied to remotely sensed data, making global comparisons challenging". Many natural variables (e.g., fluctuation in precipitation, poor soils and water stress), as well as anthropogenic factors (overgrazing, converting rangelands into croplands, poverty and isolation from political centres), were cited as the primary drivers of long-term degradation. The annual bio-productivity (NPP) loss, the key measure for land degradation, reached 4-10% in the drylands and 2% in global terrestrial NPP. The most degraded regions were the Sahel, China, Iran and, to a lesser extent, Australia and Southern Africa. These estimates were based on two maps – "Dryland areas" and "Extent of dryland degradation" – produced by Zika & Erb [35], both of which were based on an updated version of the GLASOD database[4]. Likewise, the "Atmosphere" chapter, which also had a global perspective, only included a single short paragraph noting the clear long-term trend towards drier conditions in drylands, especially in the Sahel and northern India. It was supported by the map "Trends in African and South and West Asian rainfall, May 1960-1998" produced by Hulme et al. [36]. A reference to the GLADA project [21] appeared only once in the regional chapter for Latin America and the Caribbean where a small box mentioned that around 22% of the region's surface area was degraded. This was, however, accompanied by an estimate that degraded croplands in the region reach 28% based on the map by Zika & Erb [35]. The principal difference in methodology and geographic distribution of degraded lands obtained in the two assessments were not meaningfully explained for readers.

Furthermore, the desertification issue mentioned in chapter 7, entitled "An Earth System Perspective", aimed to present global environmental changes in the context of "an integrated, interconnected whole that is the Earth System". This chapter had a sub-section (among many others): Drylands. The desertification issue was attested to in this sub-section as "one of the greatest environmental challenges facing human society". The Sahel had been the subject of many high-profile scientific studies which showed that rainfall variability and land-use changes had been the major and interacting factors of the vegetation dynamic in the last century. Rainfall variability was said to be driven by patterns in global sea surface temperature (SST) which, at the time, are leading to a greening trend in the Sahel. However, GEO-5 authors claimed that the details visible within the trend demonstrate its complexity since vegetation changes are not always directly related to precipitation changes. The main reference for this claim came from a study by Huber et al. [37]. However, when looking close-

[4]The authors of these maps admitted that the quality of the results was largely dependent on the quality of the input data and admitted "possible limitations, overestimations and subjectivity" stemming from the base GLASOD map [30].

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ly at the referred to study one can discern that there is a certain amount of inaccuracy regarding the GEO report's interpretation of the study's results in chapter 7. The primary conclusion of the study was centred on the complex interaction of oceanic regions and vegetation dynamics in different parts of the Sahel[5], whereas the impact of land-use changes on the Sahel's vegetation dynamic was not discussed.

In GEO-5 there is one more innovative section labelled as "Review of Data Needs" (chapter 8) which analysed data gaps and limitations in the methods related to different global issues. Assessments of the extent of drylands were characterised as unreliable due to the different classifications and methodologies applied to the delineation of dry zones. Nevertheless, GLASOD was cited as "an essential information base", even though new, and arguably better, methods using satellite data were being developed and increasingly used at the time. RS-based assessments were rather negatively evaluated because of their limited time coverage, changing sensor technology, insufficient ground-truthing and a lack of agreement on ecosystem delineations. These concerns related not only to the application of RS methods for drylands but extended to all other land use categories – forests, wetlands and urban areas – for which large different estimates of their extent and state had been derived from RS satellite images.

In summary of this section, concerns regarding GEO-5 are centred on the fact that it is generally characterised by an inconsistent reflection of the contemporary science of the time. On one hand, the report was sceptical and dismissive of the emerging modern RS methods (chapter 8) but, on the other hand, readily employed outdated estimates of global and regional land degradation using dated science. In "An Earth System Perspective" (chapter 7), which was specifically included in the report to show the interconnectivity of various global issues, the link between desertification and climate change was mentioned only in passing.

The most recent report in the series, the 708-page long **GEO-6** (2019), is principally designed to be policy-oriented and uses the overarching theme of "Healthy Planet, Healthy People". The Outlook section of the report presents possible pathways forward to reach the goals of the 1,300 Multilateral Environmental Agreements (MEAs) and 17 Sustainable Development Goals (SDGs). The report has an extensive policy chapter presenting an analysis of the efficiency of more than 25 policy case studies related to the five main global thematic areas: Air, Land, Oceans, Biodiversity and Freshwater. It differs from other GEOs by its inclusion of two new and separate chapters on the primary drivers of global environmental change and so-called "cross-cutting issues" while the regional SoE section is absent.

A brief (15 pages) chapter under the heading of "The Current State of our Data and Knowledge", which was inherited from GEO-5, presents a short evaluation of the state of knowledge concerning the global thematic areas and cross-cutting issues. "Land" is cited as "one of the most data-rich domains due to the effectiveness of earth observation in monitoring land surfaces". However, this claim is immediately somewhat undermined as the chapter then notes problems with assessments resulting from variations among the quality of the different satellite sensors used, the resulting inconsistency of measurements taken and difficulties in interpreting the NDVI. The report states that some processes, such as soil erosion, salinisation and desertification, are "all difficult to measure from satellite images, and there are questions as to the appropriate scale of observation". Along with these critical comments, the chapter proceeds to promote the more extensive use of "citizen" science, social media and open digital platforms or big data access to provide "broader understanding and access to policy-relevant knowledge".

The report's global perspective chapter 8 "Land and Soil" is richer in terms of the issues covered and more policy-oriented than the corresponding chapter in GEO-5. Land degradation and desertification issues are, nevertheless, only discussed in one sub-section entitled "Land quality dynamics". This sub-section highlights the different definitions of land degradation and methods used in determining it which result in conflicting estimates on its magnitude, spatial locations, impact and costs. The chapter routinely draws attention to the ongoing issues involving desertification as a whole because, for example, degradation estimates for Mongolia range from 9 per cent to 90 per cent [38]. Such issues are added to by the fact that previous generalisations about the exclusive character of land degradation in semiarid areas are not supported by satellite-based observations. While land degradation can occur in woodlands, shrublands, grasslands, and croplands, the Sahel was the region long regarded as the primary showcase for desertification but is currently greening due to a period of increased precipitation and decreasing pressure on land caused by emigration. A similar positive trend can also be observed in semi-arid areas of China [39].

In GEO-6, analysis of the traditional drivers of global environmental change – population, economic development and technological advance is complemented by the inclusion of urbanisation and climate change. "Cross-cutting issues" in the GEO-6 report include health, environmental disasters, gender, education, urbanisation, climate change, polar and mountain regions, chemicals and waste, resource use as well as energy and food systems. This broad-sweep of topics make the report difficult to read because of the inevitable duplications of information through the report, although this could stimulate the authors of the different chapters to look more closely at the links between these various global en-

[5]Huber et al. [37] investigated the teleconnection between Sahelian vegetation dynamics and climatic conditions of various oceanic regions (Indian, Pacific, North Atlantic) using two different satellite-based series of images that were gridded and showed monthly changes (NDVI and SST) in the period from 1982-2007.

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vironmental issues.

The global perspective SoE chapter on biodiversity has many cross-references to the Land chapter. Most of them provide estimates of anthropogenic pressure on different land categories that are "greatly decreasing the ability of these ecosystems to support biodiversity". For example, the report states that 49 per cent of grassland ecosystems experienced degradation over ten years (2000-2010), with nearly 5 per cent experiencing strong to extreme degradation (Gang et al.)[6] [40]. Chapter 5 (Air) discusses the global impact of wind-blown dust from deserts and agricultural areas in arid and semi-arid regions. Although RS observations show there has been little change in the frequency and severity of dust storms globally over the last 30 years, there were significant increases in such events in North America, Central Asia and Australia. Parties of the UNCCD have to address the underlying causes of sand and dust storms.

The climate section of GEO-6 presents little specific data on the role of climate change in current vegetation dynamics in drylands, only claiming that "dry areas are becoming drier, and wet areas are becoming wetter, but multiple exceptions exist"[7]. A reversing trend in precipitation was observed in tropical land areas from the 1970–1990 when it was negative to positive in proceeding period resulting in no significant overall positive trend from 1951 to 2008. Regarding drought, the report notes that the frequency and intensity have likely increased in the Mediterranean and West Africa and have likely decreased in central North America and north-west Australia[8].

Discussion

In general, the GEO reports have reflected the evolution of the UNCCD from being an environmental agreement in the narrow context of desertification in arid and semi-arid marginal regions to a position of global stewardship of land resources [45]. The term "land degradation" has gained dominance over "desertification" as the former is not associated with specific geographical conditions [28]. This shift in terminology was clearly articulated in the UNCCD's Ten Year Strategy [46].

In the early GEO reports, land degradation was used in a geographically limited way and terminologically as a synonym for "desertification". GEO-4's (2007) Land chapter included "forest" as a separate sub-section, thus expanding the list of biomes accepted as subject to desertification/land degradation. The corresponding chapter in GEO-5 (2012) was further expanded to include four land area categories: drylands, forests, wetlands, and urban areas. Desertification and land degradation issues were regarded only within the drylands sub-section while other sub-sections focused on other issues such as deforestation rates, the disappearance of wetlands, global food production and security as well as increasing urban sprawl. In GEO-6, which applied the MA definition of land degradation as the "ability of the land to provide ecosystem services which are vital for human existence", land is regarded as a provider of food, fodder, fibre, forest products and other ecosystem services such as carbon sequestration, water purification and pollination while also possessing cultural and aesthetic values. This focus is related to SDG 2 (aimed at ending hunger and achieving food security) and SDG10 (promoting gender equality and reducing other forms of inequality). GEO-6 also has numerous references to SDG 15.3, which aims to achieve Land Degradation Neutrality (LDN) by 2030.

The evolution of the scientific quality of the GEO reports looks more problematical. The early GEO reports generally adhered to the UNCCD's original concept of desertification as land degradation in drylands with primarily anthropogenic causes. The significant improvement of the scientific quality of reports is obvious from GEO-4 (2007) onwards when the "IPCC-zation" process was palpably embraced by UNEP. GEO-4 repeatedly levelled direct criticism at the UNCCD's concept of desertification, although in some regional chapters outdated estimates of the scale of land degradation were cited. The analysis presented here found that some chapters in GEO-5 and GEO-6 employed outdated and inconsistent estimates of land degradation (for example, by referencing Hulme's et al. [36] map from 1998) and basing conclusions on defective methodology (such as the GLASOD database). In GEO-6, no discussion on climate change (as a "cross-cutting issue") or the current and future state of drylands could be found. In short, there is an underwhelming improvement in the scientific quality in these two reports when compared to GEO-4, which can arguably be seen as the best in the series thus far in terms of scientific content.

The most evident and pressing shortcoming of the early GEO reports was their size, which necessarily resulted in the limited allocation of space to discuss key thematic issues. The required

[6]The study is based on RS methods and uses NPP loss to measure the extent of land degradation. While GEO-6 only cites estimates for the degradation of grasslands (primarily caused by climate), the original paper also shows that the land area experiencing a positive trend (restoration) is slightly larger than degraded areas. Human activities contributed 39.4 per cent to this restoration whereas climate change and combined effects contributed 30.6 and 30.0 per cent respectively.

[7]However, there controversy remains between two propositions: "warmer is more arid" vs "warmer is less arid" as defined by Roderick et al. [41] in their "global aridity paradox". This conflict has arisen because global RS studies seem to confirm a greening trend in drylands while studies relying on the traditional AI approach have projected increased aridity in drylands as a result of global warming [42-44]. The GEO report should have more clearly presented and explained this controversy.

[8]This is referred to in AR5 IPCC (2014). The report assesses the increasing precipitation trend across the mid-latitude land areas of the Northern Hemisphere with medium confidence. However, for other latitudinal zones, area-averaged long-term positive or negative trends have low confidence due to variable data quality, lack of data completeness and disagreement among available estimates.

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brevity of the thematic sections necessitated only sketching out a brief review of global environmental issues and the authors had to reduce or eliminate many of the nuances of their findings and discussions. While the increased page count of recent GEO reports may initially seem to offer hope that this issue has been dealt with, the proliferation of included subjects (from gender issues to circular economies) has maintained the pressure on available space to discuss each topic. Adding to this is the sanctioned use of grey literature, which introduces problems of data quality and may have contributed to the inconsistencies that crept into the reports. GEO-5 and GEO-6 have responded to this challenge with the inclusion of special sections reviewing data and method quality, although this appears to still be insufficiently implemented as the thematic chapters still often contain unexplained contradictory or outdated estimates while overlooking important scientific sources. When investigating such problems, Rowe et al. [4] detailed why the Data and Indicators Working Group failed to guarantee strong scientific consistency and credibility through the GEO-5 report. In essence, the group was set up too late given that preparations for the zero draft were already in full swing and the authors of thematic chapters, understandably, resisted any last-minute interference in the process. Additionally, the GEO Data Portal hosted by the Global Resource Information Database (GRID) in Geneva was not maintained or updated as expected and was barely used by the various chapter authors, most of whom preferred to access the original sources of information.

It is likely that this problem regarding data quality is not the result of a technical failure as primary responsibility for data quality falls to individual authors. However, exercising this responsibility is complicated for such authors by the GEO programme's shifting priorities away from physical (land use dynamic, land erosion, soil organic content etc.) to humanitarian aspects of environmental issues (food security and trade, land tenure rights, gender equality etc.), a factor which could account for the quality of the scientific content of the report. A possible solution to this is to separate future GEO reports into two halves along the lines of the last IPCC report (AR5), which consists of two distinctly separate volumes of scientific analysis dealing with matters of physical changes and its impact as well as a third "solution-oriented" volume. This would help to resolve the problem of apparent under-representation of social scientists in GEO reports while the major effort of further development of the GEO project is to make it solution-oriented.

Conclusion

The changes in the structure of the various GEO reports may have been well-intentioned efforts to improve clarity and usefulness of the assessments to users and particularly decision-makers. This seems to have been a goal pursued by separating assessing status and trends from identifying policy needs and options, thus enhancing the human dimensions of the GEOs and their other goals. However, the changes made the treatment of global environmental issues such as desertification not just difficult to follow systematically but also created the risk of them being obscured or even lost in the now diverse range of emerging issues. In this paper we demonstrate that progressively multiplying political and social aspects of environmental changes the scientific quality of the reports is compromised, for example, by using outdated estimates of global and regional land degradation. The recommendation is to divide the GEO into two distinctly separate volumes of scientific analysis dealing with matters of physical processes and its social and other impacts.

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