Earth observation as a tool to assess climate migration and policy-making: legal aspects

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Abstract. The impact of climate change on the biosphere and atmosphere is well documented but its impact on the anthroposphere needs to be better understood. Indeed, divergent views remain both at the regional level -as shown by (i) the EU case-by-case approach (ii) the African *Kampala Convention* (2009) and (iii) the Latin-American *Lineamientos regionales* (2018)- and finally the international one. As the Paris Agreement (2015) urges States to use best available scientific knowledge to counter the negative effects of climate change, we argue that Earth Observation (EO) could be potentially exploited by policy-makers as an efficient platform for modeling, forecasting, characterizing and understanding the severity of migration flows, contributing to evidence-based Anticipatory Action (A-A) for the effective management of climate migration, and setting the direction for future policies in this field that would be equitable on both regional and international scales. Hence, in implementing the Paris Agreement, States should increase the funding and use of EO and Causality as policy-supporting tools, to reduce the need for reactive and costly responses to displacement, and promote the safety, dignity, and well-being of people affected by climate change. However, based on said input, a well-adapted framework for the legal protection of climate migrants should be adopted.

1 Environmental migration policies

In 1990, the Intergouvernemental Panel on Climate Change (IPCC) noted that climate change might be a substantial cause of migration flows [1]. Indeed, extreme weather events (e.g., typhoons, floods, droughts, avalanches, mudflows) may provoke serious damage and put at risk human settlements, property [2], and critical infrastructure [3].

Until now, although there is a consensus that any rules addressing climate migration should be based on effective collaboration, policies remain divided over the issue. The regional frameworks focus on particular aspects of the problem, and the international community has mainly based its response on practical measures. Thus, existing efforts are restricted to adopting policies of a limited scope; they are also focused on supporting proposals for *ad hoc* legislative solutions, as well as on implementing and sharing best practices at the regional level.

The principal criticism is that international refugee law has "not yet adjusted to the realities of climate migration" [4]. However, the body of scientific data, measurements and analysis tools that could be used for decision-making in this field has grown considerably in recent years; this is possibly a result of the obligation - set out in Article 7.7 c of the Paris Agreement (2015)- for States to strengthen "scientific knowledge on climate, including (…) systematic observation of the climate system (…) in a manner that (…) supports decision-making".

In this context, it is suggested that Earth Observation (EO) and Causal modeling of climate-induced migration from EO data could allow implementing Anticipatory Action (A-A) early warning systems, to forecast climate events and their impact. It could additionally provide support for adaptation measures such as climate-resilient infrastructure and livelihoods, and offer assistance to people who are forced to relocate due to climate-related events. The aim would be, in such case, to create a solid scientific basis in order to address climate migration *ex ante*, while using reliable input; the ultimate goal being to implement well-adapted policies for the protection of people affected by climate change

This article proposes to present first the principal lines of key policies for climate migration, and their shortcomings; then to examine in which manner EO and Causality would allow producing reliable tools and input that could be used to adopt better policies. We contend

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that in implementing their international law obligations, States should encourage the development and use of EO and Causality as policy-supporting tools; nevertheless, although relevant scientific knowledge should be strongly promoted, relied upon and developed further, a well-adapted and binding framework for the legal protection of climate migrants should furthermore be adopted.

1.1 Regional approaches

1.1.1 The EU framework

The EU underlined -in the late 90s- that climate change and environmental degradation will affect the poorest and most vulnerable populations worldwide, while increasing the incidence of "environmental refugees" [5]. As other studies examined whether it would also cause threats to EU security [6], [7], it became apparent that climate change would increase migration pressures and that effective action would soon be necessary.

On this basis, the EU Commission stated that climate change effects transcend the national boundaries and that solidarity and inter-State collaboration is required [8]. Additional steps were taken to clarify the links between climate change and migration; the prevailing approach was that -given the broad variety of migration patterns- responses must be tailored to local needs and conditions. The emphasis was put on coping mechanisms and helping communities to find solutions for displaced people, *in situ* [9]. In particular, preference was given to long-term, development-led policies to tackle the problem at its roots (rather than only promoting emergency responses), involving all actors concerned and adapting to each geographic region [10].

As a result, the EU reshaped, in 2017, its external policy framework, to take into account environmental or migratory challenges, and to foster its resilience at all levels [11]. Hence, it would continue to implement its *2013-2020 Resilience action plan* [12] guided by the *2013 Council Conclusions on an EU approach to resilience* [13]; it would also place a greater emphasis on addressing protracted crises, including environmental degradation, climate change, migration and forced displacement [11]. In 2019, the *European Green Deal* was adopted [14], to tackle climate-related issues; there, climate change was regarded as a threat multiplier and a source of instability, pushing the EU to work will all partners to increase resilience and "prevent these challenges from becoming sources of conflict (…) and forced migration".

The *European Climate Law* (2021), contrary to all expectations, did not address climate-induced migration (apart from a very general reference to the fact that EU's and member States' climate action "aims to protect people") [15]; the rationale being that the EU aims at tackling climate change issues at their roots. Therefore, the EU policy in this field mainly promotes case-by-case interventions, giving priority to cooperation with regions in need and support for economic and social recovery *in situ*; such as investments, assistance and the transfer of technology and expertise e.g., in the regions of Sahel, MENA and the Asia Pacific [16].

However, it is also voiced that additional efforts must be made to reinforce these initiatives and obtain more convincing results. In other words, that the EU "human-rights based approach to international affairs" should extend to the protection of climate migrants [16]. Otherwise, namely pending the establishment of appropriate measures for the protection of climate migrants, the protection already afforded at the EU level for particular categories of migrants like refugees (i.e., based on Directive 2011/95/EU; Directive 2001/55/EC and, to certain extent, Directive 2008/115/ EC) should be extended to climate migrants as well [17].

Either way, the fact is that the EU framework is limited in scope, addressing climate migration on an *ad hoc* basis and in a particular area or context (i.e., *in situ*). In response, other regional frameworks were adopted. To provide a complete picture of the issues and solutions proposed, this article will dwell on the general features of *first*, the *Kampala Convention* (2009) and *then*, of the *Lineamientos Regionales* (2019) adopted by the SACM (South American Conference on Migrations).

1.1.2 The Kampala Convention (2009)

The *Kampala Convention* signed within the context of the African Union in 2009 comes from a long tradition of addressing displacement challenges. The *OAU Convention Governing the Specific Aspect of Refugee Problem in Africa* (1969) was the first regional binding instrument regulating this topic (intended to complement the 1951 *Refugee Convention*) [18]; it defined broadly refugees as "those who are displaced as a result of events including those 'seriously disturbing public order' ", which was regarded as able to include climate migrants, [18])". Likewise, the *African Charter on human and peoples' rights* (1981) laid down that all peoples are entitled to "a general satisfactory environment favourable to their development" (Art. 24), [18].

The *Kampala Convention* (*AU Convention on the Protection of and Assistance to Internally Displaced Persons*) was a milestone for African States. It was imposing binding and clear obligation on States to protect and assist Internally Displaced Persons (IDPs), and first to explicitly include persons displaced by natural or man-made disasters [see, 9]. Unlike the EU framework, the *Kampala Convention* focused on the effects of climate change on migration, and addressed the issue of internal displacements also as a result of environmentally related disasters. It precisely mentioned "displacement caused by natural disasters, which (…) have a devastating impact on human life, peace, stability, security, and development" (Preamble; Art. 4.4.f cites "forced evacuations in case of natural disasters"); hence, it was the "suffering and specific vulnerability of IDPs" which was here taken into account (Preamble).

Its objective is to promote and strengthen regional and national measures to prevent, mitigate and eliminate root causes of internal displacement (Art. 2.a), and to establish a legal framework for protecting and assisting

IDPs in Africa (Art. 2.b). The core obligations of States are spelled out in detail (Art. 3 et seq.); they include the adoption of laws, and creation of the necessary bodies for that purpose (Art. 3.2). States are additionally responsible for providing protection and humanitarian assistance to IDPs without any discrimination of any kind (Art. 5.1), while cooperating upon the request of any State concerned (Art. 5.2).

States are also expected to "devise early warning systems (…) in areas of potential displacement, establish and implement disaster risk reduction strategies, emergency and disaster preparedness and management measures" (Art. 4.2). Furthermore, they must "share information with the African Commission on Human and Peoples' Rights on the situation of displacement" (Art. 8.3.e). However, no further mention is made of any obligation to develop a scientific basis implementing these obligations, or for policy- making in this field.

Overall, the *Kampala Convention* puts a strong focus on acknowledging and effectively protecting IDPs, with little scope for scientific input and/or science-based decision-making. Observation of the occurrence of the phenomena is a sufficient criterion to be entitled for legal protection; to this end, the emphasis was put on *ex-post* action while establishing State responsibility (i.e., via "an elaborate accountability and monitoring system", [18]). Its main shortcomings are that it addresses only internal displacement -any relevance to cross-border displacement is indirect [18]- and leaves the developed States outside its scope of application.

1.1.3 The Lineamientos Regionales (2019)

The *Lineamientos regionales en materia de protección y asistencia a personas desplazadas a través de fronteras y migrantes en países afectados por desastres de origen natural* [19] is a set of guidelines built on previous initiatives aimed at developing disaster risk reduction strategies.

It is in line with the *Cancun Adaptation Framework* (2010) which lays down that States must strengthen and establish regional centres and networks to tackle the issue, as well as to "facilitate and enhance national and regional adaptation actions, in a manner that is country-driven, encouraging cooperation and coordination between regional stakeholders". As a result, climate induced displacement was discussed at regional level fairly early (e.g., in the 10th South American Conference on Migration /SACM (2010); the 14th SACM Meeting (2014) and subsequent high-level meetings).

The non-binding *Lineamientos Regionales* consider climate-induced displaced persons as being in a state of increased vulnerability, experiencing difficulty in exercising their rights [19]. Hence, they established a framework of minimum protection standards and created a specific mechanism: in case of sudden-onset natural hazards and/or slow-onset events, States may refer to general criteria and receive *inter alia* guidance for decision-making at the governmental level. By using it, they can ensure that "future responses to cross-border displacement in the context of disasters are more efficient, and consistent with their domestic regulations". In addition to that, the *Lineamientos Regionales* manage relevant information and enhance cooperation between the affected country/ies and the host one(s) [19]. The guidelines do "not create legal obligations or require the adoption of new laws, but remain based on the existing experiences, practices and regulations of the SACM member countries" [19].

Unlike the *Kampala Convention*, the *Lineamientos Regionales* leave States free to apply the guidelines "at border points or in border areas, as deemed relevant". States are encouraged to develop and strengthen long-term solutions for climate-induced displaced persons, without being prevented from adopting provisions or legislations that would be more favourable to protecting them [*idem*]. The proposed measures cover a wide array of situations. Nevertheless, they establish no monitoring and accountability system, which is explained by the fact that the guidelines apply to transboundary migration (i.e., States are not willing to accept any intervention in their migration policies). Thus, the scope of the *Lineamientos Regionales* is wider, but its effective implementation is essentially based on concerted efforts at regional and bilateral levels.

Regional frameworks show that they are tailored to mainly address regional needs and priorities. However, climate-induced migration is a fundamentally global issue, affecting several sectors and countries. Hence, it is both necessary and opportune to examine measures taken at the global level.

1.2 Initiatives in international law

One could argue that the international concern for climate migration dates back to the 1972 Stockholm Declaration (Principle 1 mentioned the "fundamental right to (...) adequate conditions of life, in an environment of a quality that permits a life of dignity and wellbeing", [20]). However, such wording is too general and may not be used to impose any obligation on States to protect climate migrants. Literally, the same applies to later instruments: the *UN Framework Convention on Climate Change* - UNFCCC (1992) only cites in Art. 1 that "Adverse effects of climate change' means changes having "significant deleterious effects (…) on the operation of socio-economic systems or human health and welfare", [21]); and the 2015 *Paris Agreement* only makes a general reference to the rights of migrants (i.e., "Parties should, when taking action to address climate change, respect, promote and consider their respective obligations on (…) the rights of (…) migrants", [22]). At the same time, the 1951 *UN Refugee Convention* as amended by its *1967 Protocol* is not well suited to resolve the issue, as climate migrants cannot be considered to be displaced "owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion (Art. 1.A.2)".

Thus, the key feature of international law is the lack of binding rules -let alone any comprehensive binding framework- to address climate migration. This resulted

first in different approaches on the question of legally defining people "displaced (in full or in part)" by climate change, and in a long and growing list of the suggested labels [23]. Despite that, due to the constantly increasing importance of the matter, soft-law instruments were adopted. In each case, the aim was to propose practical solutions; said soft-law instruments include *inter alia* the non-binding *UN Guiding Principles on Internal Displacement - IDPs* (1998) [24] (which also served as a reference for the Kampala Convention), or the *Cancun Adaptation Framework* (2010) inviting parties to adopt measures "to enhance the understanding, coordination and cooperation on climate change induced displacement, migration and planned relocation" [25].

Soft-law initiatives failed to achieve the expected results. Hence, the efforts of the international community to address climate-induced migration were continued and stepped up, as reflected in the subsequent works of the International Organization for Migration (IOM), [23, 26]. Additionally, a *Taskforce for Displacement* (TFD) was agreed upon at the COP21 (2013), under the *Warsaw Mechanism on Loss and Damage* which is part of the UNFCCC [27]: it works alongside other initiatives within the UNFCCC, like the *Nansen Initiative* of 2015 [28] -aimed at building consensus in this field- or the *Sendai Framework for Disaster Risk and Reduction* (2015) [28]. Finally, the *Global Compact for Safe, Orderly and Regular Migration* of 2019 [29] aims to "cover all dimensions of international migration in a holistic and comprehensive manner": it is grounded in international human rights law and reaffirms States' commitment to respecting, protecting, and fulfilling all human rights for all migrants (i.e., it paves the way for a cooperative framework complementing -from a human rights perspective- the protection granted to refugees).

Hence, *on the one hand*, regional frameworks failed to establish efficient and uniform protection of climate migrants (namely, protection remains uncertain and dependent on regional contingencies); *on the other hand*, the international community failed to adopt binding international law rules, providing a high-level protection to climate migrants on the basis of uniformity and inter-State effective collaboration.

Such case-by-case approaches could be explained by the fact that climate migrants are often regarded "as being in need of protection primarily *after* a desperate environmental situation spirals into violent chaos, given that such conditions are most conducive to fostering and sustaining the kind of clear-cut 'persecution' identified in the Refugee Convention". In other words, "no adequate legal instruments [*were adopted*] to address the situation preemptively" [23].

Nevertheless, as the *Paris Agreement* (2015) urges States to develop and use scientific tools allowing to address climate change issues, EO and Causality could be exploited to assist policy-makers in the development of efficient laws and frameworks based on *proactive action*. It addition to that, said tools could also help them acquire scientific data that would convince States about the necessity to adopt a binding regime providing full rights and protection for climate migrants (i.e., *after* the materialization of the climate risks).

2 Earth Observation & Causality

According to Article 7.7.c of the Paris Agreement, States should enhance their scientific understanding of climate change to address its adverse impacts. However, these states are free to determine the method of fulfilling this obligation. In this context, Earth Observation (EO) stands as a widely accepted technological tool that the scientific community consistently exploits to investigate Earth's historical and current physical condition. Satellites equipped with multi-modal sensors encircle the planet, yielding an unparalleled volume of data in a systematic, seamless, and standardized manner. This facilitates the accumulation of time-series, global-scale data on vital biochemical and physical properties of Earth System Variables (ESV), including soil moisture, land surface temperature, vegetation health and dynamics, atmospheric composition, and more.

In addition, EO is particularly fit to study and manage natural hazards for preparedness, early warning, emergency response and disaster impact assessment. The EU Commission, *via* its flagship *EO programme Copernicus*, has developed a set of qualified core products as part of its *Emergency Management Services*, which is now considered a commodity and is used by EU civil protection authorities in an operational context.

With the onset of Artificial Intelligence (AI), the rich EO archive can be further exploited to seamlessly monitor environmental variables and disaster impacts towards forecasting natural disasters, for example droughts [30], wildfires [31] and volcanic unrest [32]. Linking anticipated disasters with migration flows is a non-trivial task. Although there is ample empirical evidence supporting that climate change and migration are interrelated [33] and there is clear evidence that the numbers of climate-induced migrants will increase [34], at present, there is no theoretical approach which adequately represents the causal mechanisms through which climate change induces human displacement.

Indeed, recent research has demonstrated how alterations in climate patterns and the rise in the frequency and intensity of climate-related disasters are leading to the emergence of new and evolving patterns in human mobility [35]. This shift is making it more challenging to predict migration dynamics. The intricate relationship between climate change and human migration is difficult to quantify and disentangle due to the complex interplay of multiple causes [36] In fact, forced displacement occurs when a certain level of severity is reached within the affected region. This severity depends not only on the intensity of the shock but also on a variety of socio-economic, demographic, environmental, and political factors, among others [37].

Establishing causal relations between random variables from observational data is considered a major scientific challenge [38], and EO is no exception [39] Tarraga et al. [40] were the first to use Gaussian Processes as a data-driven modelling approach to learn which variables can explain the impact of floods and storms in the context of forced displacements, and to develop models that reproduce migration flows. However, to establish causal relations between climate

change impacts and migration flows, under the light of all possible (environment, socio-economic, conflict and violence-based) causal drivers, advanced Causal Inference methods are needed.

2.1. Need for curated datasets

Existing frameworks for studying of climate-induced migration patterns mainly define five categories of drivers affecting migration flows [41]: economic, political and legal, demographic, social and environmental. Individual migration decisions and flows are affected by these drivers which operate in combination, and the effect of the environment is therefore highly dependent on economic, political, social and demographic context [42]. Moreover, it is necessary to differentiate between migration caused by slow-onset events, such as droughts and land degradation as in Fig. 1 [43], and those caused by fast-onset events, such as floods, storms or fires. While the former is usually voluntary and often economically motivated, the latter is involuntary and tend to be short-term.

Causal inference algorithms extract links from time series of multiple variables using lagged statistical correlation tests. These methods can discover relations among heterogeneous variables, provided that adequate temporal samplings are available, and summarize the causal relations in a directed graph with information on the time lag of the causal associations.

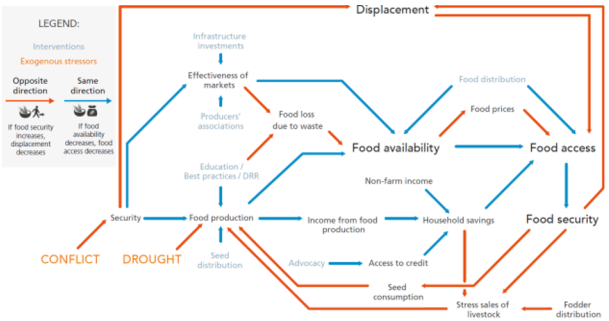

Fig. 1. The multicausal nature of pastoralists' displacement, considering drought and conflict dynamics (© iDMC) [43].

To model climate-driven migration, a curated, cohesive database is crucial. This database should include historical climate data (like temperature, moisture, precipitation), socio-economic indicators, climate extremes (such as famines, droughts, floods), as well as migration and displacement trends. Copernicus ERA5 offers meteorological data spanning 8 decades [44]. Migration details are accessible via the Internal Displacement Monitoring Centre (iDMC), the International Organization for Migration, and dedicated platforms like MigrationPortal, the WorldBank and the JRC MigrationApp. These sources provide migration flow descriptors, and even intricate concepts like vulnerability, integration, well-being, forced migration, and development. To comprehend the socio-economic factors influencing migration, essential indicators can be extracted from the World Bank's World Development Indicators dataset.

2.2 Science-based adaptation and mitigation

The European Union's Joint Research Centre (EU-JRC) in 2017 highlighted the importance of prioritizing risk-informed investments as a more cost-effective approach to disaster management and *emphasized the need to shift from a reactive to a proactive stance in addressing risks*. This approach recognizes the value of investing resources in risk reduction and prevention, ultimately leading to greater resilience and sustainability in the face of future disasters.

The utilization of Earth Observation and the establishment of causal relationships have surfaced as potentially important instruments for the purpose of modelling, predicting, delineating, and comprehending the magnitude of migration flows. This, in turn, holds the potential to support Anticipatory Actions (A-A) firmly grounded in evidence with the aim of proficiently managing climate-induced migration through the deployment of early warning systems. Already, A-A has been recently advocated and promoted by international humanitarian organizations, such as the iDMC, the World Food Programme (WFP) and the International Federation of Red Cross and Red Crescent Societies.

A-A encompasses various initiatives such as Forecast-based Early Action, Forecast-based Financing, and Early Warning Early Action. These initiatives rely on forecasts to trigger funding for preplanned actions before a shock escalating into a full-blown disaster. A-A reduces the costs of humanitarian responses by up to 50% in areas affected by climate hazards such as Bangladesh and Nepal. The WFP highlights the significance of A-A stating that "*activities such as commercial animal destocking, early procurement of food or other aid or animal health interventions can be carried out ahead of peak humanitarian needs*" [45]. Even when accounting for the potential occurrence of a false alarm, it is estimated that each US$1 invested in A-A could yield savings of US$3 in mitigating losses for the beneficiaries.

A-A for climate-induced migration involves implementing proactive measures at an early stage to mitigate the risks and impacts of climate change on vulnerable communities that are likely to face displacement. However, untangling and quantifying the intricate relationship between migration and climate change is an exceedingly challenging task. In this context the DeepCube project, funded by the European Commission, has developed a research prototype focusing on causal modelling of EO variables. This prototype facilitates the creation of graphical models and storylines that establish connections between projected climate extremes, environmental conditions, socioeconomic vulnerabilities, disease outbreaks, and migration flows. These models also account for time lags between variables. The graphical models and causal representations can be potentially used to perform interventional studies and address What If? questions and derive causal-guided predictive models, in which case the description of the causal mechanism-driven migration, along with regression models for inference, can be employed to gain insights and make predictions.

This causal examination, centered on population displacements in sub-Saharan Africa, has fortunately illuminated the intricate nature of the task, detailed in the Drought Displacement Modelling Report. This complexity becomes notably pronounced for gradual-onset hazards like droughts, where disentangling indirect confounding factors presents a formidable challenge. Longer time-lags and memory effects amplify this intricacy. This challenge isn't restricted to drought-related displacement but extends to other climate-induced displacements from events like storms and floods. For instance, a climatic variable may not be the ultimate driver, despite being crucial to the post-effect, as seen in droughts triggering displacement. Moreover, while extreme events like droughts or floods might incite displacement, migrants' socio-economic status is pivotal due to associated costs.

2.3 Challenges for modelling climate-induced migration

Causal inference (e.g., Granger causality and Structural Causal Models) from EO data allows systematic hypothesis testing, and discovering latent causes and new relationships. In contrast, causal analysis and modelling can be a useful scientific tool for uncovering spurious associations and supporting public administrations and non-governmental organizations in developing *truly causal policies and guiding adaptation strategies, early warning systems, and anticipation actions for climate-induced migration.*

However, achieving the ambitious objective of modeling the interplay between climate and migrations through observational causal inference is subject to certain limitations. Firstly, it is essential to address the issue of *data quality and uncertainties* across all data sources by employing methods for the rigorous quantification and propagation of uncertainties. Secondly, causal analysis is preconditioned on the *causal sufficiency assumption*, which necessitates the inclusion of all pertinent background explanatory variables in the analysis. The dataset should encompass diverse dimensions such as climate, environment, socio-economic, and cultural factors influencing human mobility. Additionally, it should encompass the spatial dimension of the areas of interest with an appropriate level of resolution. Furthermore, the dataset must exhibit a *meaningful time resolution* to uncover displacement phenomena and their effects. This aspect is crucial for tracking environmental and societal changes that impact displacement. Ideally, the extended time series should account for long-term effects, spanning at least 3-5 years to encompass memory effects and time lags, as well as short-term effects that capture temporary displacement and thresholds triggering the displacement flow.

Lastly, a significant theoretical challenge pertains to the plausibility of the causal relationships that can be inferred from empirical data. Although various causal discovery models exist in the literature, there remains a lack of clear consensus regarding the significance of the extracted causal knowledge obtained from real-world, highly heterogeneous structured and unstructured data [46]. Consequently, the development of pipelines for monitoring causal dynamics *should be accompanied by implementing explainable AI (XAI) techniques*. These techniques aim to rank the potential causes of migration, including environmental, climatic, socio-economic, cultural, and political factors. By employing XAI, it becomes possible not only to comprehend the models beyond mere fitting and identify tipping points but also assess the impact of specific anomaly events [47]. This ability is of utmost importance in forecasting and early warning systems, as it *enables a deeper understanding of the underlying causal mechanisms and facilitates proactive actions to mitigate the consequences*.

3 Conclusions

Chances are growing that we will pass the 1.5°C global warming in the next few years [48]. Therefore, it is more than ever necessary to strengthen collaboration and coordination among States (in line with the *Paris Agreement* purpose and the scientific direction suggested therein). Developments in the field of EO and Causality show that using them permits reduction of the margin of errors, bias and misinterpretation in the assessment of how climate change tends to impacts migration flows.

Hence, the use of EO and Causality (for steering and helping in decision-making) will allow States to avoid the pitfall of addressing the issue *via* a series of *ad hoc* measures; as is -for the time being- the case for regional frameworks. The reason for adopting such a science-based approach would be that *ad hoc* responses are, in the long run, more expensive while having a limited scope and efficiency. To this end, deployment of EO early warning systems can contribute to the implementation of evidence-based anticipatory actions towards more resilient societies to the impacts of climate change, including migration.

Literally, scientific approaches (allowing to tackle climate change effects) are favored at the international level; however, science-based international law measures adopted up to now to protect climate migrants, have the key disadvantage of not being as binding as one might have wished since they are usually guided by low political will to efficiently protect climate migrants. Global issues -e.g., climate change and climate-induced migration- require the adoption of both comprehensive and binding science-based solutions [49, 50]. Hence, the global fight against climate change effects should aim at enacting better adapted, binding rules [51] making the most of scientific knowledge (a treaty without wide ratification and implementation cannot address such a global issue [51]); in this context, scholars argue that the EU should “foster the protection of environmental migrants under international human rights obligations” and could play a leading role in this direction [16,17].

Following this reasoning, we contend that the time has come for the international community to draw up policies increasingly based on reliable innovative and scientific tools. It is imperative that the importance of climate-induced migration should be recognized by

agreeing upon a binding protective legal status for climate migrants, at least equivalent to the one established for refugees in the 1951 *Refugee Convention.*

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