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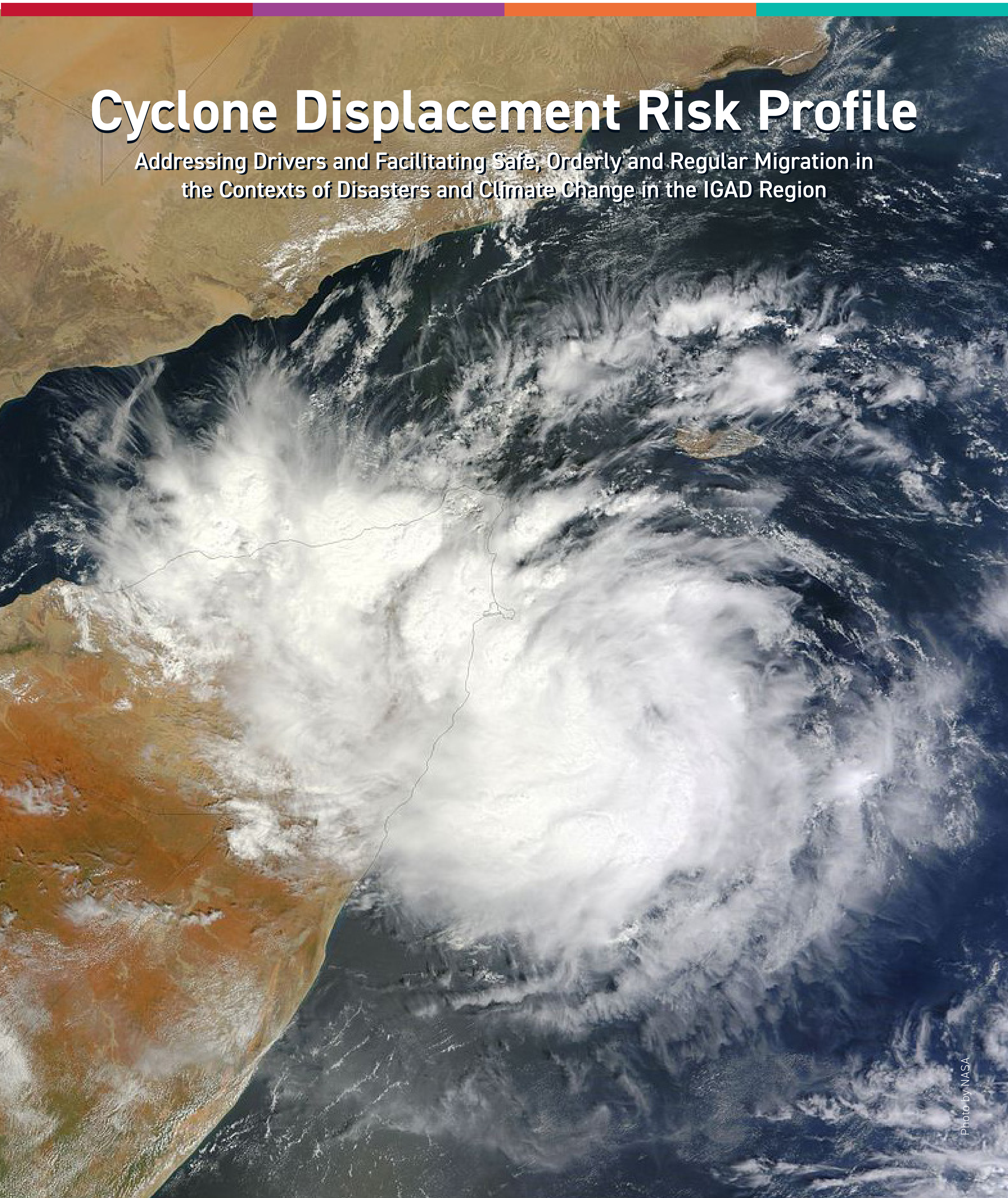
Cyclone Displacement Risk Profile

Addressing Drivers and Facilitating Safe, Orderly and Regular Migration in the Contexts of Disasters and Climate Change in the IGAD Region



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Background

The member states of the Intergovernmental Authority on Development (IGAD) are some of the most vulnerable to disasters globally. it is not unusual that the Region experiences sequences of drought periods contrasted by wet periods that cause widespread flooding, landslides and storm damage, resulting in destruction of property and loss of services and livelihoods. In 2019, more than 1.5 million people were newly displaced, both within their countries, and across international borders. Many of those forced to move had previously been affected by widespread rain shortages in a region classified as 60 -70 per cent arid and semi-arid; in Somalia alone, 1.15 million people were displaced in the context of drought and land degradation during 2017 and 2018.

Severe drought and flooding contributed to extensive displacement in 1993, 1999, 2005, 2011 and 2015; with earthquakes, landslides, tsunamis, wildfires and high winds having similarly contributed to displacement across IGAD over the last fifty years. These examples reflect a persistent pattern of large scale displacement in the context of natural hazards induced disasters across the region. Sea level rise, changes in temperature, erratic rainfall and the increasing intensity of extreme weather events related to climate change are projected to further adversely affect people's livelihoods, exacerbating displacement, and making adaptive migration more difficult.

Disaster displaced persons can be particularly vulnerable to rights violations, including through lack of access to essential documentation, security, community life, education, and other basic amenities. Vulnerable groups, including socially marginalised populations, children, older persons and those with disabilities are especially at risk. For governments, both short-term and protracted displacement pose serious socio-economic challenges 'in terms of basic service provision, social cohesion and individual and collective wellbeing.' High levels of displacement moreover prejudice sustainable development 'and have the potential to undermine broader development gains, particularly if the needs of those affected are not adequately addressed.'
IGAD member states have consequently recognised the need to develop a coordinated and protection-centred response to disasters that allows people to move in order to mitigate the worst effects of natural hazards, including through the recent endorsement of a Free Movement of persons Protocol, which permits movement across regional borders 'in anticipation of, during or in the aftermath of disaster'. In addition to these developments in migration policy, IGAD members have identified the need to protect against future displacement through effective disaster risk reduction (DRR), climate change adaptation (CCA), and development policies and strategies. Where displacement does occur, these policies also help ensure that the rights of those displaced are safeguarded, and that displaced people are able to build back better when the effects of a disaster abate.

In order to achieve this goal, numerous regional and international agreements, including the Nansen Initiative Protection Agenda on the rights of those displaced in the context of disasters, the Global Compact on Refugees, and the Global Compact for Safe, Orderly and Regular Migration have made clear that DRR, CCA and Development policies should incorporate human mobility concerns. The Sendai Framework for Disaster Risk Reduction (SFDRR) specifically recognises the particular protection needs of the disaster displaced. There remains, however, a lack of comprehensive information on the extent to which human mobility is incorporated in DRR, CCA and development policies and strategies in the IGAD region, which limits progress in advancing the protection of those displaced by disasters and climate change.

To this end, a number of UN agencies and partners established a Joint Programme[1] funded under the Migration Multi-Partner Trust Fund (MPTF)[2] to improve regional and national migration governance in the context of the adverse impacts of climate change and environmental

degradation. To enhance this governance, evidence is key. The Joint Programme has therefore supported this study developing as an innovative solution to addressing risk modelling.
Among the sudden onset hazard that are relevant in determining such important displacement figures cyclones play an important role at least for some of IGAD member states, namely Somalia, Djibouti and Eritrea.
Therefore, the compilation of a displacement risk profile forced by strong wind damages from cyclonic system seems an important piece of information to reconstruct the puzzle of displacement risk in the region.

1 - Joint Programme: Addressing Drivers and Facilitating Safe, Orderly and Regular Migration in the Context of Disasters and Climate Change in the IGAD Region bit.ly/Joint-Programme-IGAD Partners include IOM, the International Labour Organization (ILO), the Platform on Disaster Displacement (PDD), UNHCR, and the IGAD Secretariat including the IGAD Climate Prediction and Application Centre

2 - The MPTF is the first and only UN inter-agency pooled funding instrument focusing on migration. It was called for by Member States through the adoption of the GCM (A/RES/73/195) in 2019. More information at www.migrationnetwork.un.org and https://mptf.undp.org/factsheet/fund/MIG00

Overall methodology

Several methodologies exist for the development of a Risk assessment and often there is not a better or worse methodology. They are intimately linked with the application they are intended for. However, some methodologies have a higher information content and allow for more flexibility in their practical use. One of these is the probabilistic risk assessment approach, which is the methodology we are proposing in this study, in continuity with the work done by UNDRR and other actors (e.g. GFDRR) in the African continent from profiles at national and subnational level.
The added value of a Probabilistic Risk Assessment (PRA) is often misunderstood, as audiences tend to view it as a highly technical method that is difficult to apply or understand. These difficulties represent a challenge for communicating risk results. Within the present risk profile strong emphasis is placed on the knowledge transfer that is a key ingredient of the methodology. The process of risk definition was in fact developed together among all the partners.
A probabilistic disaster risk profile should be seen as a risk diagnosis instrument, as it provides indications on possible hazardous events and their impacts. Both past and probable future events have been taken into consideration in a comprehensive risk assessment exercise.
Probabilistic disaster risk profiles consider all possible risk scenarios in a certain geographical area. This means that both low frequency, high loss impact events, as well as high frequency, lower loss impact events are calculated. Included is their probability of occurrence, and all elements of the risk equation, their variability and uncertainty ranges.

$$Risk = \frac{Hazard \times Exposure \times Vulnerability}{Capacity}$$

Events which have never been historically recorded but might occur in the near future are also considered in the risk analysis. By assigning a probability of occurrence to each event magnitude, a probabilistic risk profile usually quantifies the expected direct impacts of disasters through economic metrics and affected population. When dealing with displacement probabilistic risk assessment, direct impacts are translated in terms of potential displacements.
As this risk information is framed within return periods as a conventional probability measure, a displacement PRA approach provides a clear vision of the risk trends.

This disaster displacement risk information - expressed in an annual average displacement (AAD) and a probable maximum displacement curve (PMD) – is calculated both at a national scale, as well as at subnational scale, allowing for a geographic and quantitative comparison of displacements within a country.

These analyses and comparison exercises are an important step of the disaster displacement risk awareness processes, key in pushing for displacement risk reduction, adaptation and management mechanisms to be put in place.

CYCLONE RISK ASSESSMENT INVOLVES FOUR MAIN STEPS:

1. Historical Cyclone Data collection (both hazard and impact)
2. Cyclone hazard assessment
3. Identification and characterization of exposed elements (e.g., People, Housing stock)
4. Vulnerability assessment of the identified exposed elements based on the historical data

From the combination of these four steps we are able to determine direct impacts on the selected exposure categories, fundamental for determining disaster displacement risk.

Data review and organisation to support cyclone risk assessment

Data collection

A targeted data collection was performed to support the implementation of a cyclone disaster risk profile focused on displacement for countries in the IGAD region based on agreed risk metrics. A selection of countries (i.e. Djibouti, Kenya and Somalia) for the data collection was made on the basis of historical data analysis and in consultation with stakeholders and regional experts.

THE DATA COLLECTION WAS MAINLY BASED ON THE FOLLOWING DATA SOURCES:

The International Best Track Archive for Climate Stewardship (IBTrACS)*

The IBTrACS project is the most complete global collection of tropical cyclones available. It merges recent and historical tropical cyclone data from multiple agencies to create a unified, publicly available, best-track dataset that improves inter-agency comparisons. IBTrACS was developed collaboratively with all the World Meteorological Organization (WMO) Regional Specialized Meteorological Centres, as well as other organizations and individuals from around the world.

EM-DAT International Disaster Database

EM-DAT is an international database that collects disaster data in a systematic way providing invaluable information to governments and agencies in charge of relief and recovery activities. EM-DAT provides an objective basis for vulnerability assessment and rational decision-making in disaster situations. For example, it helps policymakers identify the disaster types that are most common in a given country and that have had significant historical impacts on human populations. In addition to providing information on the human impact of disasters - such as the number of people killed, injured or affected - EM-DAT provides disaster-related economic damage estimates and disaster-specific international aid contributions.

Desinventar

DesInventar is a conceptual and methodological tool for the generation of National Disaster Inventories and the construction of databases of damage, losses and in general the effects of disasters. The Disaster Information Management System is a tool that helps to analyze the disaster trends and their impacts in a systematic manner. With increased understanding of the disaster trends and their impacts, better prevention, mitigation and preparedness measures can be planned to reduce the impact of disasters on the communities.

Global Internal Displacement Database (GIDD)

The database aims to provide comprehensive information on internal displacement worldwide. It covers all countries and territories for which IDMC (internal Displacement Monitoring Centre) has obtained data on situations of internal displacement, and provides data on situations of:

- Internal displacement associated with conflict and generalized violence (2003-2020);
- Displacement associated with sudden-onset natural hazard-related disasters (2008-2020);
- Modelled disaster-related displacement risk metrics for more than 200 countries and territories.

Reports on the Web or available in IGAD and MS institutions

The data collection also includes event reports that could be collected openly on the web or by direct contact with IGAD programs and institutions as well as IGAD Member States. The research included also international organizations active in the disaster domain in the Region.

* *https://www.ncei.noaa.gov/products/international-best-track-archive*

Data Attributes Used

The dataset constructed develops along the following products:

- Cyclone events list, from '80s until now, report events, their intensity (i.e., wind intensity) and their recorded impacts (direct and indirect)
- Impact footprint of the cyclone (GIS layer and textual description of the districts and cities hit by the event).
- where possible, distinction between cyclones damages and floods damages.
- Information about direct impacts of the cyclone articulated as follows depending on information availability:
    - Number of affected people (always present in the DB)
    - Number of displaced people (always present in the DB)
    - Number of houses damaged destroyed by cyclones
    - Number of critical facilities (schools, hospitals, health structures) damaged or destroyed by cyclones
    - Number of shops, industries, services damaged or destroyed by cyclones
    - Hectares of crops damaged or destroyed by cyclones.
    - Loss of livestock due to cyclones
- Information about indirect impacts of the cyclone articulated as follows depending on information availability:
    - Food supply chain
    - Water access
    - Energy distribution
    - Communication

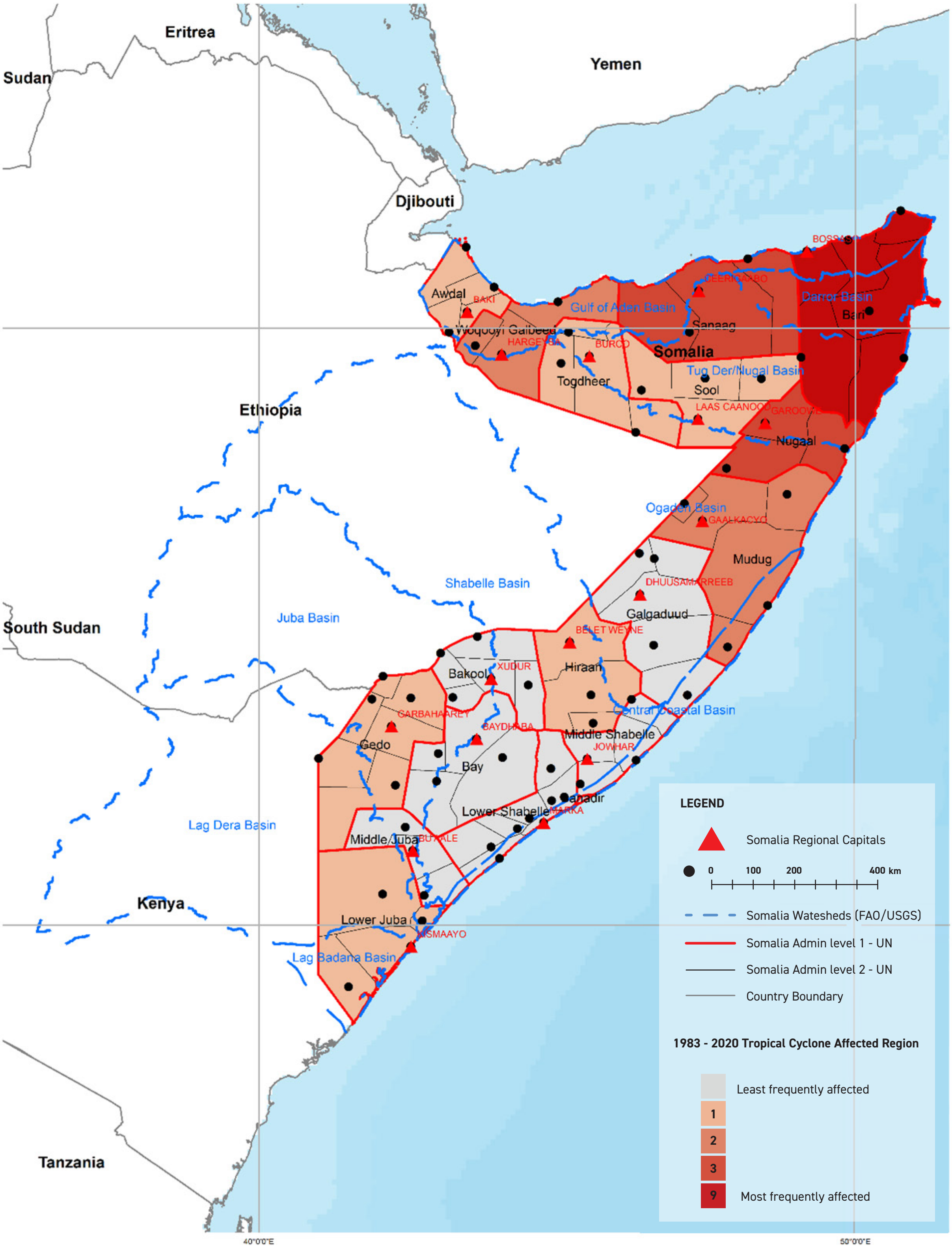

Photo by Mohamed Abdiwahab/AFP/Getty Images

Year	Event Name	Date of event (start)	IBTrACS_ ID	Glide Serial Number	Wikipedia Summary Description
1984	Tropical Cyclone 1A	12/7/1984	1984145 N11056		May 28, 1984 - After becoming the first documented tropical cyclone to move through the Gulf of Aden, a tropical storm struck about 65 km (40 mi) west of Berbera, Somalia and quickly dissipated.
1984	Tropical Cyclone 4B	12/8/1984	1984332 N08086		December 7, 1984 - A weak tropical cyclone struck eastern Somalia in Mudug province, and quickly dissipated
1992	Tropical Cyclone 12A	12/24/1992	1992354 N03075		December 24, 1992 - A tropical storm in the southern Bari region, bringing beneficial rainfall to normally arid areas
1994	Tropical Cyclone 05A	11/19/1994	1994317 N07070		November 20, 1994 - A cyclonic storm moved ashore eastern Somalia near Eyl, producing winds of 104 km/h (65 mph) in Bosaso. The storm's high winds and rainfall killed 30 people and injured hundreds others.Several boats and homes were washed away.
1997	Tropical Cyclone 03A	11/9/1997	1997308 N08069		November 9, 1997 - A weak tropical storm struck Puntland in northeastern Somalia, and quickly dissipated.
2004	Tropical Cyclone Agni	12/4/2004	2004332 N02072		December 4, 2004 - The remnants of Cyclone Agni moved southwestward along the Somalia coastline, dissipating just east of the capital Mogadishu.
2010	Tropical Cyclone BANDU		2010136 N09057		
2012	Tropical Cyclone Murjan	2012-01-01 T00:00:00Z	2012297 N11067		October 25, 2012 - Cyclonic Storm Murjan struck the Bayla District of eastern Somalia, bringing heavy rainfall of over 40 mm (1.6 in) and gusty winds to the country and neighboring Ethiopia. Flash flooding washed away livestock and bridges in the Bari region, causing some fatalities.
2013	Tropical Cyclone 3A	2013-11-10 T00:00:00Z	2013310 N06066	2013-000140	November 11, 2013 - A deep depression struck near the border of the Nugal and Bari regions and caused severe flash flooding. It was the deadliest tropical cyclone on record in Somalia, killing more than 162 people. The depression also destroyed over 1,000 houses, displaced tends of thousands of nomads, and killed millions of livestock.
2015	Tropical Cyclone Chapala	2015-11-02 T00:00:00Z	2015301 N11065	2015-000149	November 2, 2015 - Cyclone Chapala entered the Gulf of Aden as the strongest tropical cyclone on record.[14] The storm dropped heavy rainfall in Puntland and Somaliland, killing over 25,000 animals and leaving thousands of people homeless, leaving some local nomadic tribes without any food
2015	Tropical Cyclone Megh	2015-11-09 T00:00:00Z	2015301 N11066	2015-000152	November 9, 2015 - Just days after Chapala, Cyclone Megh passed 57 km (36 mi) north of Cape Guardafui, Somalia,[18] where it dropped heavy rainfall 300% of the annual average. Eyl reported 160 mm (6.3 in) of rainfall over 24 hours. Megh damaged roads, crops, and schools.
2018	Tropical Cyclone Sagar	2018-05-19 T00:00:00Z	2018137 N13051	2018-000059	May 19, 2018 - After traversing much of the Gulf of Aden, Cyclone Sagar made the westernmost landfall in the northern Indian Ocean when it struck Lughaya in northwestern Somaliland with winds of 75 km/h (45 mph). The storm dropped a years' worth of rainfall in Somalia and neighboring Djibouti, reaching around 200 mm (7.9 in) near where it moved ashore. The storm caused flash flooding that carried away houses, bridges, and entire fields, leaving 5,640 people homeless. Sagar killed 3 in Puntland, 50 in Somaliland, and 2 in Djibouti. A landslide related to the storm killed 23 people in the Somali Region of eastern Ethiopia.
2019	Tropical Cyclone Pawan	12/7/2019		2019-000165	December 7, 2019 - Cyclonic Storm Pawan made landfall in Somalia just south of Eyl with winds of around 65 mph (40 mph). The storm dropped heavy rainfall along the northeast Somali coast. Flash flooding killed six people. Pawan continued westward into Ethiopia and weakened.
2020	Tropical Cyclone Gati	2020-11-21 T00:00:00Z		2020-000232	November 22-23, 2020 - Very Severe Cyclonic Storm Gati made landfall in northern Somalia, becoming the first hurricane-equivalent storm to hit the Horn of Africa.

TABLE 1 - Summary of Tropical Cyclones that made landfall on the IGAD Countries (1984 - 2020)

List of Horn of Africa tropical cyclones

From the gathered data empirical maps have been derived to support the modelling framework. in particular statistics about the observed frequencies of impact were reconstructed form data as depicted in the figure below.



Map showing the Tropical Cyclone (TC) affected districts in Somalia (1984 - 2020).
The most frequently affected regions are to the North of Somalia while some of the least are in central Somalia.
Bari Region is the most frequently affected with it being hit by TCs up to 9 times.

Modeling Framework

The cyclone risk model for Somalia was developed combining historical wind speed information derived from reanalysis data (ERA5 - https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5) for the events identified in the impact data collection with population distribution information living in houses classified in different building typologies. The model was calibrated using historical information on affected population at country level as well as district level for some main cyclone events occurred in recent years (see section 1). This section provides a short description of the modelling framework adopted.

Cyclone Hazard Assessment

The ERA5 reanalysis dataset combines vast amounts of historical observations into global estimates using advanced modelling and data assimilation systems. It provides hourly estimates of many atmospheric, land and oceanic climate variables. The data cover the Earth on a approximately 30km grid and resolve the atmosphere using 137 levels from the surface up to a height of 80km. For the Somalia cyclone model, hourly maximum wind speed at district level was derived from the ERA5 datasets as a main indicator of hazard related to cyclones for the historical events listed in the following Figure 1.

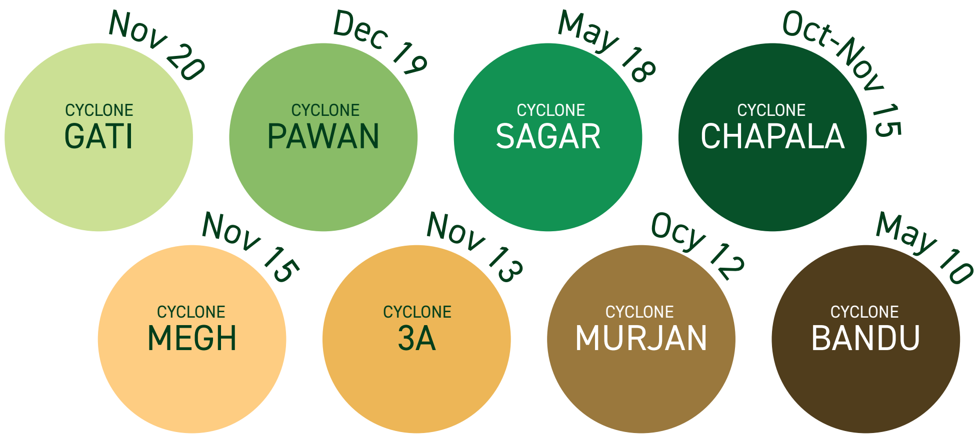
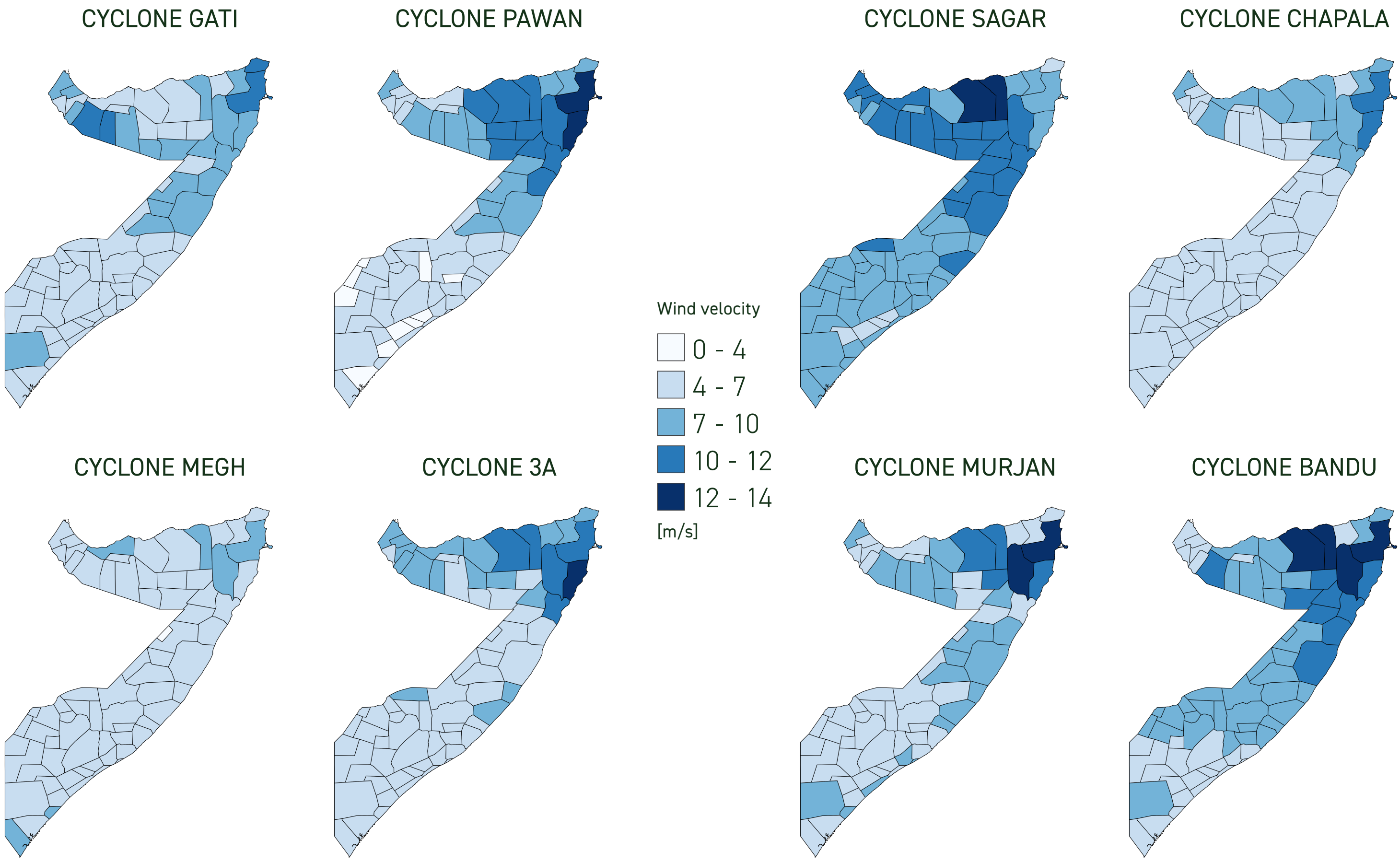


FIGURE 1 - List of historical cyclone events considered for the model development

The vulnerability of buildings to windstorms is usually expressed by vulnerability functions. Windstorm vulnerability functions represent the relationship between a hazard metric and a damage indicator, usually represented by an a-dimensional mean damage ratio. The hazard metric most frequently utilised is the wind speed at 10 m, adjusted considering terrain roughness and averaged over a period of time, which is usually 3-s gust 1 or 10 minutes sustained.

The value of wind velocity derived from ERA5 refers to a maximum value on a 30 kilometres spatial resolution grid cell in an hourly time window. To use standard wind vulnerability curves, that refer to single location gust wind speed, a conversion factor needs to be used to convert the ERA5 data in wind speeds consistent with the one used in the standard vulnerability functions. The conversion factor was obtained taking into consideration maximum local wind speed from observed wind data in specific locations for the historical cyclone events listed below.

MAXIMUM WIND SPEED AT DISTRICT LEVEL DERIVED FROM ERA5 REANALYSIS FOR SOME HISTORICAL CYCLONES



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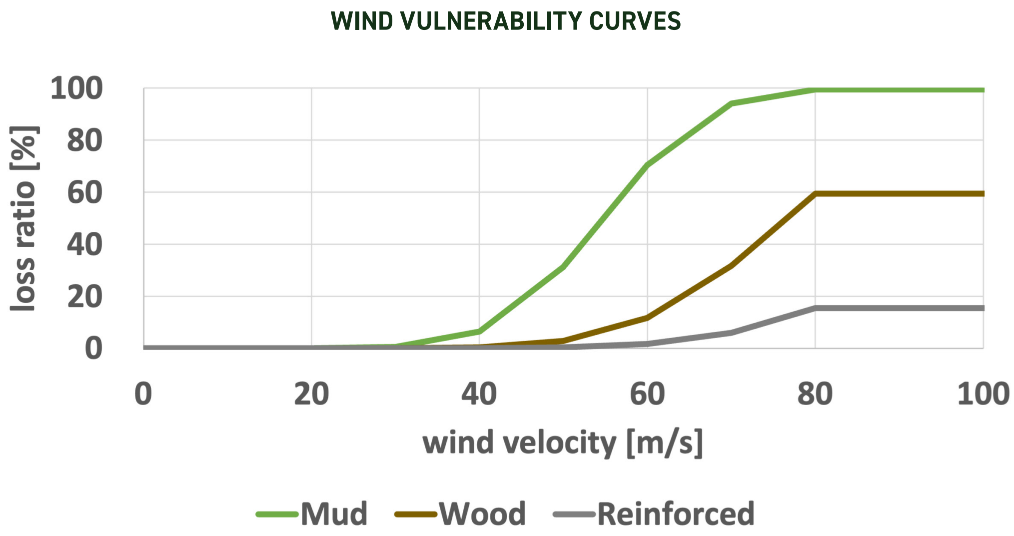
Vulnerability and exposure characterization

In the following figure, the selected wind vulnerability curves for different building typologies (i.e., traditional, wood, concrete) are shown: those curves were derived by CIMA Research Foundation for previous analysis and successfully applied for loss assessment due to wind events in similar contexts.



To apply those curves, it was necessary to characterize the building stock in Somalia at district level in statistical terms. This characterization was done using the exposure information contained in the Global Assessment Report 2015 . For each district the percentage of different building typologies (e.g., concrete, wood, masonry etc.) and rescaled with the total building stock distribution. The population could be then redistributed according to this specific information among the different building typologies. Damages suffered by the buildings as a function of wind speed could be computed. When a certain level of damage is reached, we assume that the population living in that house typology is likely to be affected by the event specifically when a building reaches at least a damage of 10%. However, the curves used are empirically derived at asset level. Therefore, a correction factor that considers that we are aggregating figures at district level is necessary. The more intense the hazard the larger the area potentially affected, therefore an inverse linear relation of the proposed correction factor with the maximum wind speed at district level. This relation was calibrated on the different estimates obtained in terms of affected people for each cyclone event listed in Figure 1. In Table 2 a comparison between the modelled number of people affected and the number of people affected as reported in the consolidated data collection is shown, this after the application of the correction factor: due to the intrinsic uncertainty of this type of estimations as well as the one associated to the reported figures, the modelled estimates of people affected are nicely matching with the reported ones at country scale.

	HISTORICAL DATA	MODELLED DATA	HISTORICAL VS. MODELLED
Cyclone Gati	120.000	123.000	98%
Cyclone Pawan	213.000	250.000	85%
Cyclone Sagar	669.000	680.000	98%

TABLE 2 - Comparison between people affected during recent cyclone events as reported in the event reports and modelled ones

A similar approach but with a higher threshold on the vulnerability curves (i.e., 50%) was used to assess the number of people potentially displaced due to cyclone events.
The calibration of this threshold and the validation of these estimates were challenging because the estimates of people displaced reported in different post damage reports are sometimes

inconsistent: in some cases, the proportion of people displaced out of the total number of people affected ranges from 2% to 30%. The reasons for these differences can be multiple and difficult to investigate without any additional analysis, therefore only selected cyclones with more reliable data (e.g., cyclone Sagar) were considered reliable and used for the calibration of the displacement component.

The hypothesis and conversions factors calibrated and validated with historical data were used to simulate possible cyclone events: this step is fundamental to assess cyclone risk with a fully probabilistic approach.

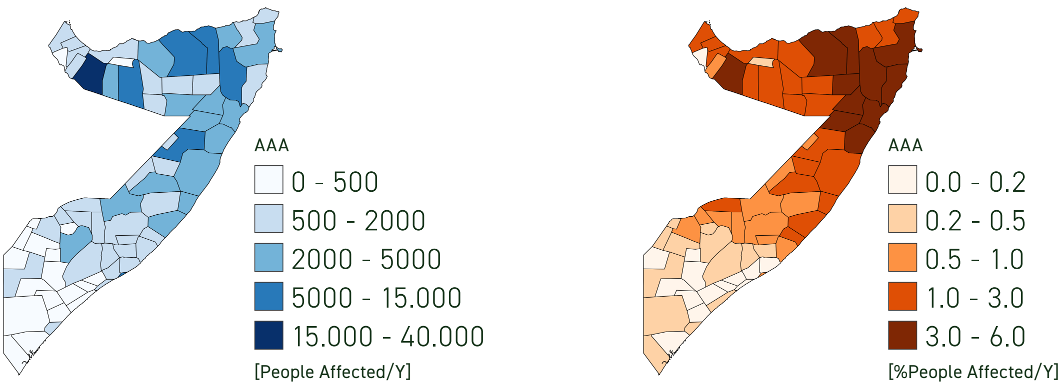
The ERA5 wind velocity at admin1 level, converted to capture peak wind speeds, were used as input data in a multivariate gaussian copula: the big advantage of such approach is the fact that any multivariate joint distribution can be written in terms of univariate marginal distribution functions and a copula, which describes the dependence structure between the variables. The possibility of separating the marginal distributions from the correlation structure is a useful and powerful property of the copula approach, fundamental when dealing with complex system with several marginals as in this case.

A multivariate random generator based on the copula correlation matrix and the marginal distributions' parameters was used to simulate approximately 1500 years of possible cyclone events that could affect Somalia. Those events, defined at district level in terms of wind velocity, were used in combination with the exposure information described before and the vulnerability curves to assess the number of people potentially affected and displaced.

Results

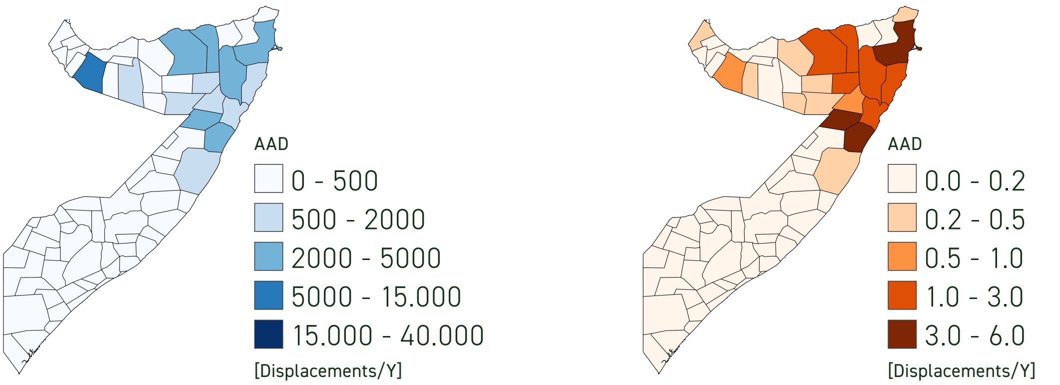
The output of the multivariate random generation is an event catalogue at district level with the number of people potentially affected. By assigning a probability of occurrence to each event, it was possible to compute and summarize the risk through specific quantitative risk metrics of interest, namely Annual Average Affected/Displacement (AAA/AAD) and Probable Maximum Affected/Displacement (PMA/PMD), at national and district level.
In general terms, the Average Annual Displacement (AAD) is the expected displacement per year, averaged over many years. The Probable Maximum Displacement (PMD) curve describes the displacement figure which can be expected corresponding to a given likelihood. It is expressed in terms of annual probability of exceedance or its reciprocal, the return period. Typically, PMD is relevant to define the size of disaster and therefore of resources which, insurance companies or a government should have available to manage displacement.
In the next figure it is possible to observe the annual average number of people affected due to cyclone events at district level in absolute figure as well as in percent of the total population at district level.

ANNUAL AVERAGE NUMBER OF PEOPLE AFFECTED BY CYCLONE EVENTS AT DISTRICT LEVEL (ON THE LEFT) AND THE CORRESPONDING PERCENTAGE IN RESPECT TO THE TOTAL POPULATION AT DISTRICT LEVEL (ON THE RIGHT)



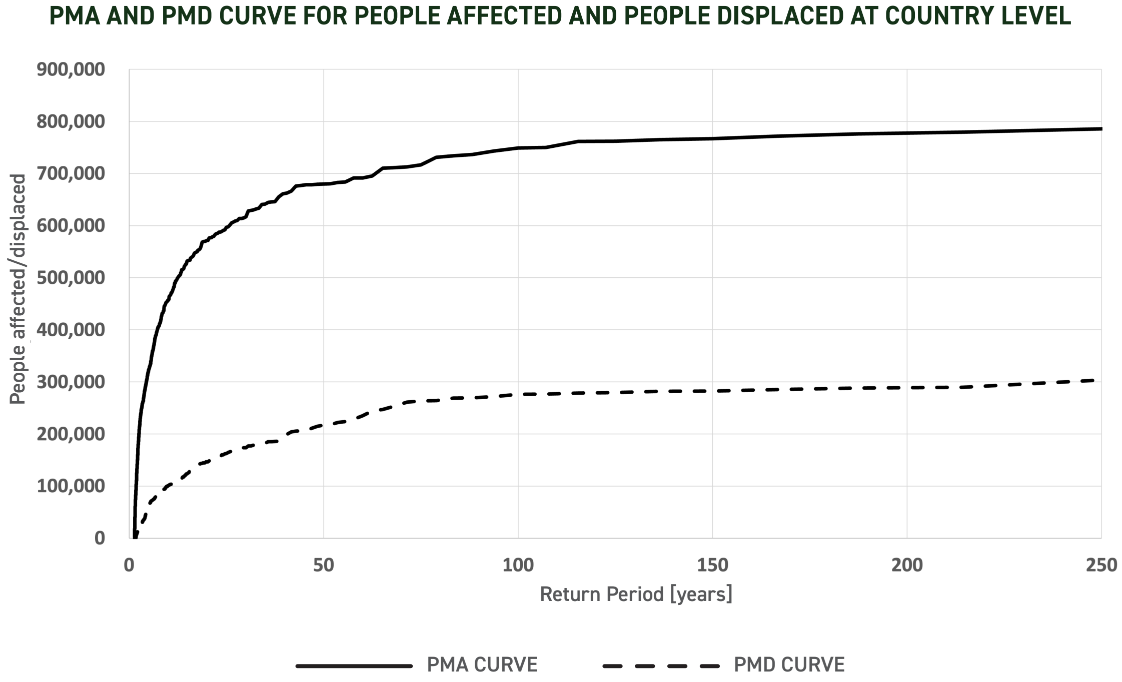
The total number of people potentially affected by cyclone events in Somalia is around 180,000, corresponding to 1% of the total country population: in some districts in the northeastern part of the country this value exceeds 5%.

ANNUAL AVERAGE NUMBER OF PEOPLE POTENTIALLY DISPLACED BY CYCLONE EVENTS AT DISTRICT LEVEL (ON THE LEFT) AND THE CORRESPONDING PERCENTAGE IN RESPECT TO THE TOTAL POPULATION AT DISTRICT LEVEL (ON THE RIGHT)



The maps above shows the annual average number of people potentially displaced due to cyclone events at district level: the total amount at country scale is around 30000, approximately 1/6 of the affected population. The northeastern part of the country is the one suffering the most.

In the following figure the PMA and PMD curves for population at country level are shown.



The shape of both curves presents a fast rising first segment that indicates a high vulnerability level of Somalia: high numbers of affected and displaced people can be observed already for very frequent events. The PMD curve can be used to assign a return period to the last cyclones that affected Somalia, this allows to understand how often on average such impacts can be expected. Figure 3 defines the return period of the three last cyclones that hit the area.

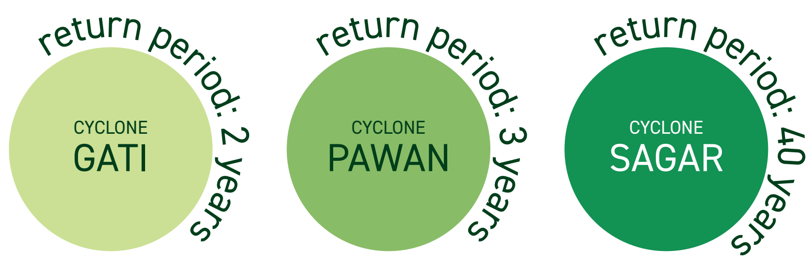


FIGURE 3 - Return period assigned to the number of people affected by the last cyclones in Somalia

Recommendations

The present study represents a strong advancement in the current panorama addressing the quantification of risk of displacement for cyclones solidly based on historical evidence. However, several improvements could be imagined to increase the level of reliability of the results.

As a main area of improvement, a more holistic representation of vulnerability, including socio-economic elements, would help identify effective strategies to reduce vulnerability and, by extension, to reduce the number of people at risk of being forcibly displaced. For example, people who depend on the primary sector of the economy (farming, herding, fishing, etc) – especially for subsistence – are at higher risk of displacement in case of sudden-onset disasters, because of the relatively greater impact on their livelihoods. This diversity in vulnerability is now only indirectly represented in the predictive model used (e.g., through the building typology which is often strongly correlated with the income level). To capture this dimension explicitly an effort is needed on one hand in conceptually clarifying how 'vulnerability' can be captured and on the other hand in collecting more and better disaggregated and local data. in this direction the possibility of using other modelling framework such as Agent Based Models in connection with the physical models classically used in PRA seems a promising research avenue.

The main advantage of PRA is its forward looking nature. This study delivers estimates that include events that have never been experienced, but refers to the current climate without considering the influence of climate change in modifying the frequency and intensity of cyclones in the area. Therefore, an effort should be made in modelling the effects of climate change for different scenarios in the future.

The current study is based on local data on wind and on historical data on impacts caused by cyclones. A strong effort has been made to collect that best data possible. A continuous effort in improving these datasets would strongly improve the reliability of future updates of the profile results. Therefore, a continuous investment in that direction should be considered.

https://geoportal.icpac.net/