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Recent Climate Shocks in the Sahel: A Systematic Review

Terence Epule Epule, Driss Dhiba and Abdelghani Chehbouni

Abstract

In Africa, the Sahel is increasingly susceptible to climate shocks such as droughts, sandstorms (winds), and floods. Through a systematic review this work tracks the frequency with which these shocks are reported in the literature during the period 1975–2020. This work examines trends to identify which shocks are most reported, documenting their spatial distribution and evaluating the impacts of climatic and non-climatic drivers. In general, 388 shocks were reported in 164 relevant peer review papers. Southern Niger recorded 15.97% of all the shocks while Ethiopia and Senegal recorded 11.85% and 10.85% respectively. Also, West African Sahel saw about 49.97% of all shocks followed by East African Sahel with 29.89% and Central African Sahel with 12.11%. Generally, droughts ($n = 219$), appear to be the most frequently reported shocks followed by floods ($n = 123$) and winds ($n = 46$). The 1975–1985 decade recorded the most shocks ($n = 207$), followed by the 1997–2007 decade which saw ($n = 80$) shocks while between 1986 and 1996 a total of 52 shocks were recorded. 52% of the shocks are driven by climatic factors while 47% are driven by non-climatic drivers.

Keywords: Climate change, Shocks, Droughts, Floods, Winds, Climatic, Non-climatic, Regional, Country-level, Sahel

1. Introduction

Global environmental changes cannot be excluded from the debates on development and environmental protection in Africa. The latter is true because ecosystems respond to climate change and climate change also determines the pace of global development in general and African development in particular [1, 2]. The influence of climate change in sub-Saharan Africa is even more evident as in the last three and a half decades the region has witnessed temperatures increasing in the range of 0.2–2.0° C amidst declining precipitation [3]. The projections of future temperatures right up to 2100 shows that it will cumulatively exceed the range of 0.2–2.0° C that was observed in the last three and a half decades. The fifth assessment report (AR5) of the IPCC further supports this assertion by observing that mean temperatures will potentially increase on a decade basis by 1.8° C in 2020, by 1.9° C in 2030, by 1.8° C in 2040, by 1.7° C by 2050 and by 1.2° C by 2100 [4]. The impacts of the above observations are enhanced vulnerability of cropping systems and amplified poverty, low adaptive capacity, and more frequent climate shocks [5, 6]. Despite the importance of climate factor in the region, non-climatic drivers such as agricultural expansion, deforestation, occasioned by rapid population growth have tilted the debate on which of climatic and non-climatic factors drives the shocks more [7].

Three main climate shocks (droughts, floods, and sandstorms (winds)) are dominant across Africa and the Sahel [8–15]. The Sahel is well known for its droughts and as a result, the region is one of the most susceptible to droughts globally [16–18]. The causes of these droughts are either human related (human induced climate change) or climatically driven (sea surface temperature, effects of vegetation, CO₂ emissions and land degradation, and dust feed backs) [11]. It has been reported that hydrological droughts are becoming frequent in the Sahel due to observations of enhanced discharge in rivers. Since the 1970s, river Niger for example has witnessed increase discharge of its tributaries. It is indeed surprising that while temperatures are observed to be rising in the Sahel and projections of the same are pessimistic, some rivers in the region are witnessing increase discharge in what has been termed the “Sahel paradox” [19–23]. Furthermore, the Sahel is increasingly impacted by airborne dust or sandstorms which are also impacting the climate of the region [3]. Satellite sensors have shown that Sahelian dust are not only regionally restricted but also globally distributed [14, 24]. In fact, reports hold that most of the dust outbreaks around the world are linked to the Sahel [25–27].

Climate change stakeholders in the Sahel have been active seeking ways and means of addressing these climate shocks. In this context, adaptations actions, policies and programs have been designed to help address the surge [28–30]. For example, the United Nations Reductions of Emissions from Deforestation and Forest Degradation (REDD+); has been designed to support reforestation project across the world [12, 31–37]. We also have the United Nations Framework Convention on Climate Change (UNFCCC) [38] which enhances research and adaptive capacity in developing countries. The African Development Bank (AfDB) has created the African Climate Fund which focuses on enhancing increase to climate finance in Africa [39]. Additionally, the Pan African Agency for the “Great Green Wall (GGW)” has been involved in planting trees across the Sahel [40].

Even though there is an increase in the proliferation of studies on climate shocks in the Sahel, there is still a shortage of studies that provide updated and holistic information on the dominant shocks, their distribution, across the Sahel and their drivers. In fact, it is still unclear which climate shocks are most reported in the scientific literature over time. This enhances the ability to monitor existing gaps in the scientific scholarship and to pave the way for the future. In addition, it provides a holistic picture of the regional and country level variations in the dominant shocks impacting the Sahel and further provides and opportunity to leverage our understanding in shaping adaptation actions.

2. Country and regional distribution of climate change shocks and affiliation of authors

A total of 388 climate shocks (droughts, floods, and winds) were documented in 164 peer reviewed papers. The results show further that in terms of countries, Southern Niger recorded the highest frequency and percentage of reports of climate change shocks (n = 62, 15.97%) between 1975 and 2020. Ethiopia which is second recorded 46 or 11.85% of the shocks, Senegal next with 41 or 10.56% of the shocks and Kenya with 33 or 8.5% of the climate shocks (**Figure 1**). Regionally, West African Sahel recorded the highest number of shocks (n = 193, 49.97%), then second was East African Sahel (n = 116, 29.89%) and Central African Sahel with (n = 47, 12.11%) (**Figure 2**).

A total of 164 peer review papers were recorded for this chapter. Of this number, 55 authors are affiliated in the USA, 19 in France, 17 in the United Kingdom and 10 in Germany. These countries are countries that have colonial ties in Africa and

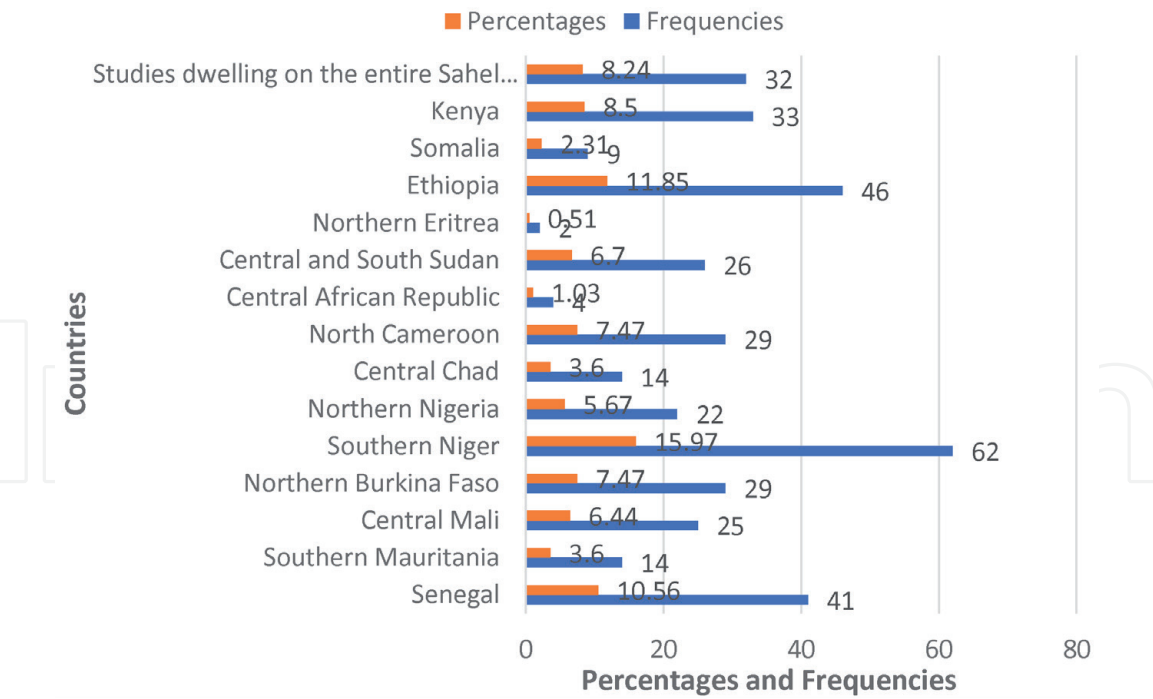


Figure 1.
Percentages and frequencies per country of reported/tracked climate shocks in the Sahel from 1975 to 2020.

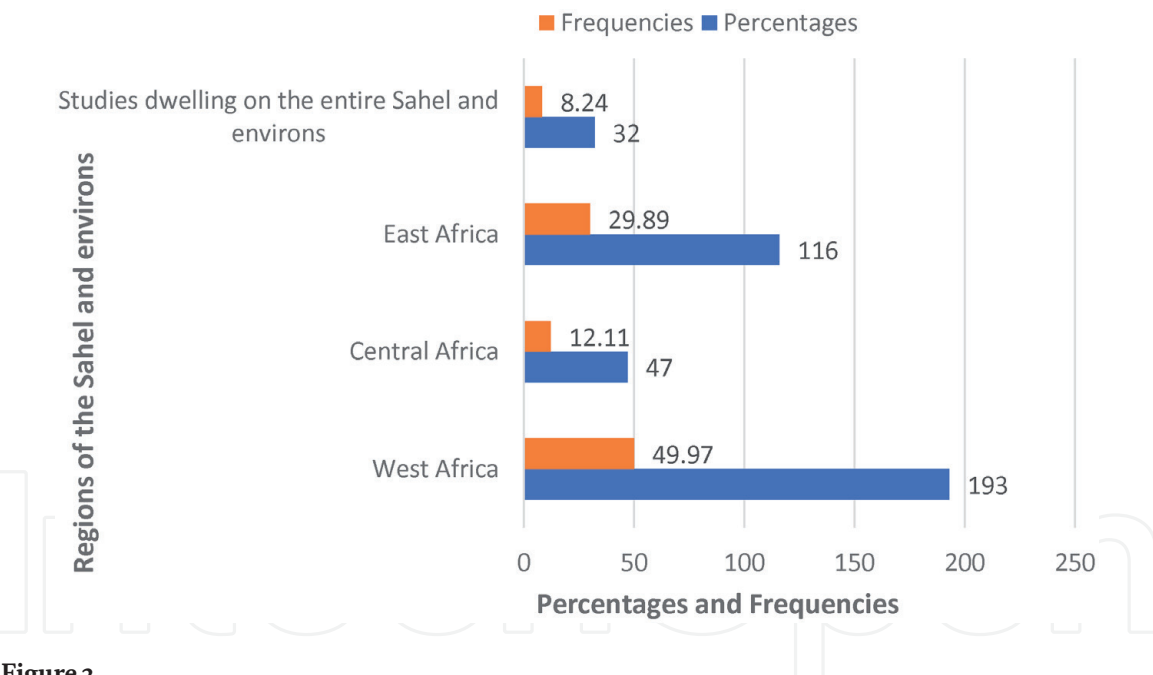


Figure 2.
Percentages and frequencies of reported/tracked climate shocks in various regions of the Sahel from 1975 to 2020.

are leveraging huge research grants on the Sahel troubled region. In the context of African authorship 9 authors are from Nigeria, 6 from Ethiopia and Niger and about 4 authors from Cameroon. In general, we observe that most of the authors involved in this genre of research are affiliated out of Africa.

3. Frequently reported climate change shocks in the Sahel

This study has found out that three key shocks are recorded in the Sahel of Africa. These shocks include droughts, floods, and winds/sandstorms. Droughts are reported as the most frequent among these shocks (n = 219) (Figures 3 and 4 and

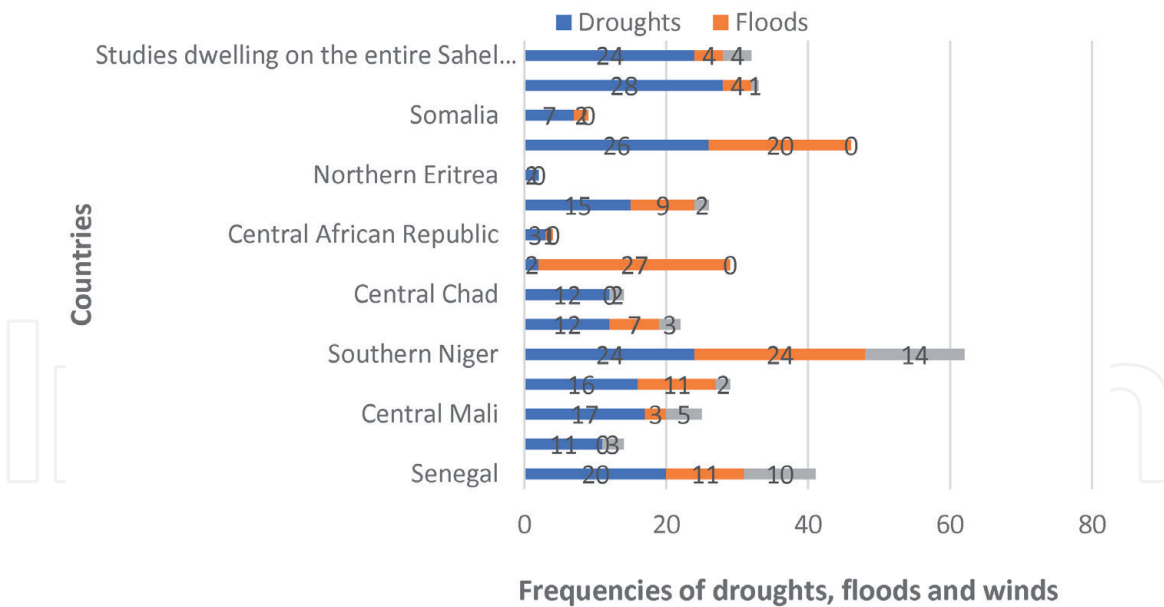


Figure 3. Composite frequencies per country of reported/tracked climate shocks in the Sahel from 1975 to 2020.

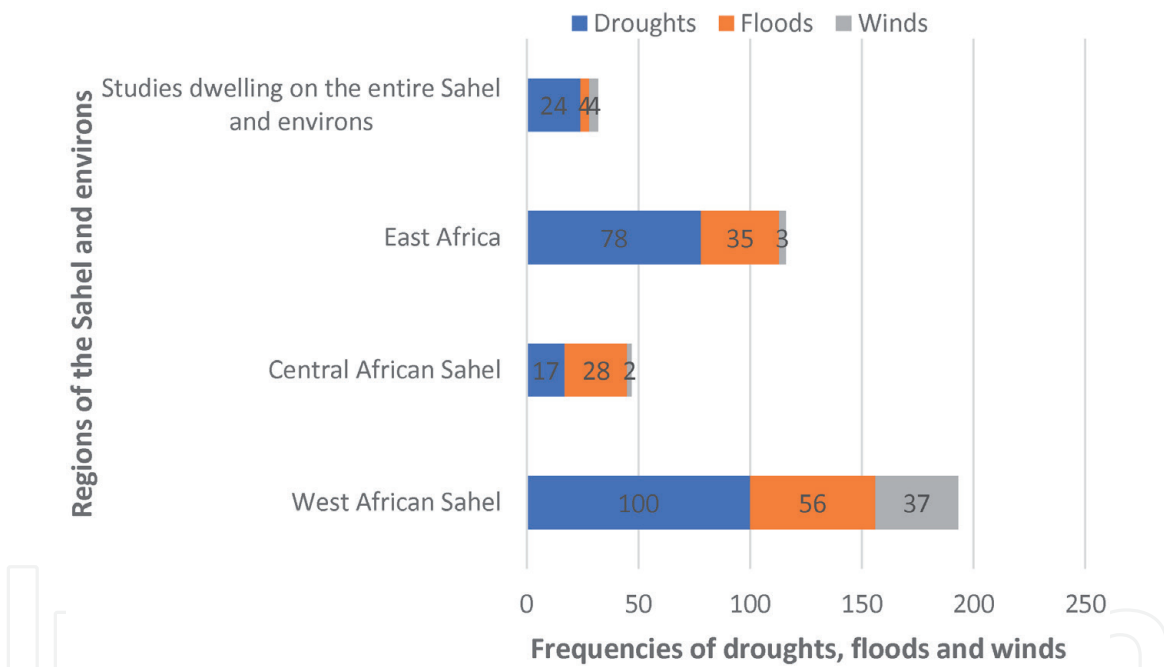


Figure 4. Composite frequencies per region of reported/tracked climate shocks in the Sahel from 1975 to 2020.

Table 1). The other shocks in order of importance are floods (n = 123) (**Figure 2**) and winds/sandstorms (n = 46) (**Figures 3 and 4**). It can be inferred that the Sahel is a zone of climatic extremes with droughts topping the chart during the dry periods and with floods taking over during periods of prolonged precipitation which confirms the fact that one of the consequences of climate change is the amplification of extreme events.

In terms of the distribution of these shocks in various countries, the following countries recorded the highest number of shocks in order of importance: in term of droughts, Kenya recorded 28, Ethiopia recorded 26 and Niger recorded 24. In the domain of floods, Cameroon was the highest with 27 shocks, Niger with 24 shocks, and Ethiopia with 20 shocks. In the case of winds/sandstorms Niger observed the most shocks with the highest of 14 shocks, Senegal recorded 10 shocks and Mali recorded 5 shocks (**Figure 3**).

Shocks	Examples of studies
Droughts: WAS	
Senegal	Faure and Gac [39]; Agnew and Warren [8]
Niger	Boyd et al. [40]; Reenberg [41]
Mali	Nicholson [42]; Hiernaux et al. [43]
Burkina Faso	Nicholson [44]; Prospero and Nees [16]
Mauritania	Le Houerou [45]; Nicholson [42]
Northern Nigeria	Adefolalu [46]
Droughts: EAS	
Somalia	Boyd et al. [40]; Hitchcock and Hussein [47]
Ethiopia	Deressa et al. [48]; Turton and Turton [49]
Kenya	Epule et al. [12]; Nicholson [44]
Eritrea	Huho et al. [50]; Keller [51]
Sudan	Agnew and Warren [8]; Epule et al. [30]
Droughts: CAS	
Central African Republique	Nicholson [42]; Epule et al. [30]
Northern Cameroon	Nicholson [42]; Nicholson [44]
Chad	Nicholson [42]; Ozer et al. [52]

WAS: West African Sahel; EAS: East African Sahel; CAS: Central African Sahel.

Table 1.
Examples of Sahel countries with drought studies.

Regionally, West African Sahel witnessed the highest number of droughts of about 100 cases while East African Sahel had 78 shocks. As concerns floods, West African Sahel recorded the highest of about 56 cases while East African Sahel recorded 35 shocks and Central African Sahel recorded 28 shocks. As concerns winds/sandstorms, West African Sahel witnessed 370 shocks, while East and Central African Sahel recorded East 3 and 2) shocks respectively (**Figure 4**).

4. Decade with the highest number of shocks and the drivers of climate change shocks in the Sahel

At the decade scale, the 1975–1985 decade witnessed the largest number of shocks which 207 shocks recorded. The decade 1997–2007 recorded 80 shocks while the decade 1986–1996 recorded 52 shocks and the decade 2008–2016 recorded 49 shocks (**Figure 5**). In addition, the decade 1975–1985 witnessed the greatest number of droughts with 182 shocks. The decade 1997–2007 recorded the largest number of floods and winds of about 50 & 23 respectively (**Figure 5**). There is a decrease in the number of reports on climate shocks in general over time. We observe for example that the number of droughts reported has steadily decline over time from 182 in the decade 1975–1985 to 9 in the decade 2008–2016. Floods on the other hand witnessed increased reports of cases from about 12 in the decade 1975–1985 to 39 in the decade 2008–2016. Winds/sandstorms are irregular in the scientific publications and no concrete established trends have been recorded (**Figure 5**).

The most important drivers of the observed climate shocks are climatic with about 341 or 52% of the shocks. The non-climatic shocks account for about 314 or 47% of the shocks. When combined, these shocks account for about 655 shocks

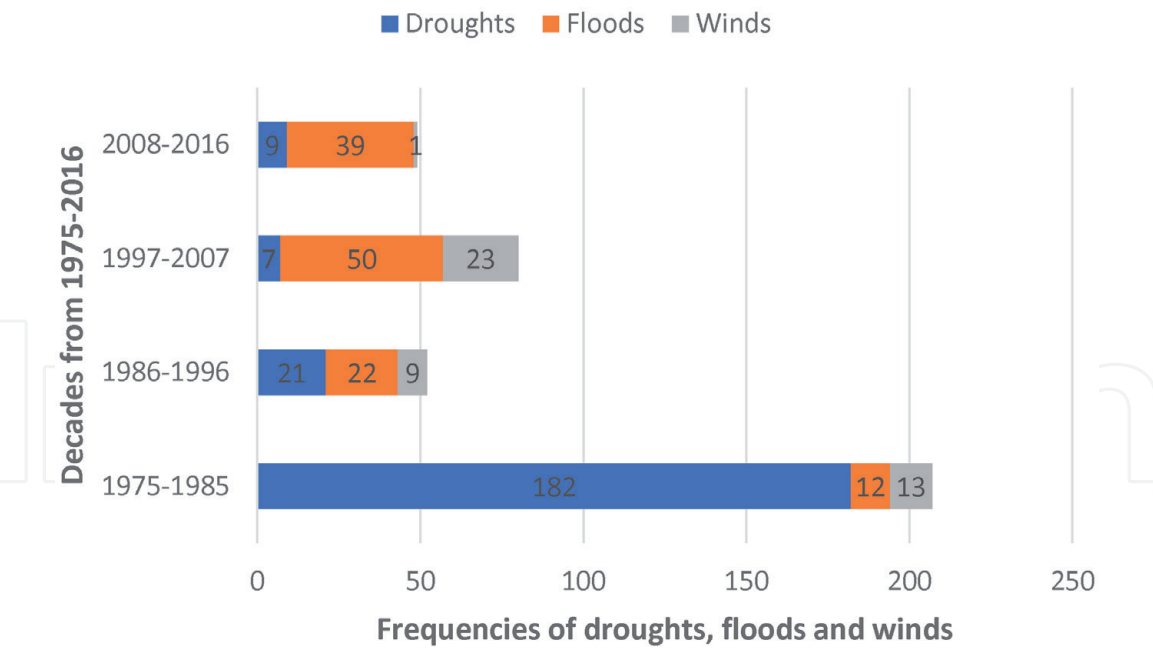


Figure 5.
Composite distribution of shocks per decade from 1975 in the Sahel.

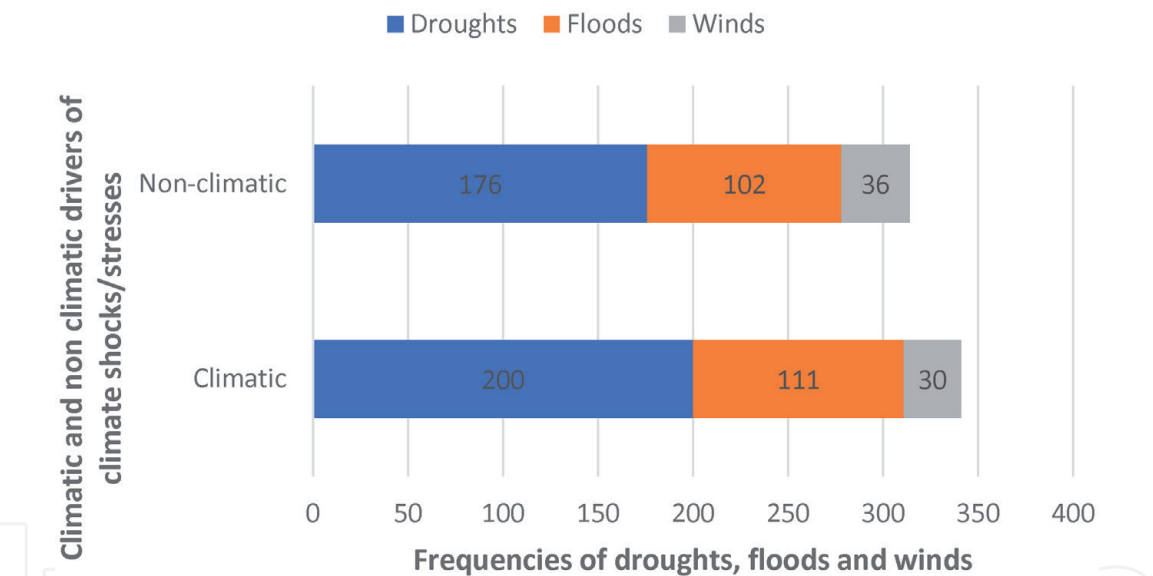


Figure 6.
Composite frequencies of reported/tracked climate shocks and their relationships with climatic and non-climatic variables.

which are more the 388 which are the total number of shocks reported as some studies reported both climatic and non-climatic drivers (**Figure 6**). Climatic drivers account for about 200 droughts, 111 floods and 30 winds/sandstorms. Non-climatic drivers accounted for 176 droughts, 102 floods and 36 winds/sandstorms. Climatic drivers account for most of the climate shocks but non-climatic drivers are increasingly becoming important. Some shocks such as droughts, floods, and winds (sandstorms) can result from a combination of climatic and non-climatic factors.

5. Discussion and implications

In this chapter, we examine the occurrence of climate shocks across the Sahel based on reports in the primary peer review literature. The work also examines the

role of climatic and non-climatic drivers of the climate shocks and their evolution over time. These results provide a basis for assessing where shocks are occurring and to design adaptation actions based on the latter.

An analysis of where climate change shocks are occurring, what climate change shocks researchers are focusing on and their evolution over time goes a long way in providing insights that can enhance the ability to cope with the shocks. Already, this work has shown that in the Sahel, current adaptation strategies must be tailored to cope against droughts which are the most frequently reported climate shock in the Sahel. Invariably, droughts should be followed by floods and winds in any policy strategies aimed at cubbing shock and enhancing climate resilience in the Sahel. Even though floods have gained importance in the scientific scholarship over time, droughts remain the dominant climate forcing in the Sahel around which most adaptation actions should be drawn. Basing adaptations on site specific drivers is consistent with the systematic approach described by [53] and [11] describing the drivers of forest degradation in Bolivia and Cameroon respectively and using these drivers to propose policy options. This approach provides room for sustainability and accuracy and is a departure from the approach that is based on generalizations the copy pasting of what has worked elsewhere. This chapter provides a snapshot of the frequency in which climate change shocks are reported in the scientific literature, the affiliations of the authors, when and where the shocks occurred and the relative contributions of climatic and non-climatic drivers of these shocks.

Furthermore, this chapter has found out that Southern Niger and West African Sahel recorded the highest number climate change shocks in the Sahel. Kenya however recorded the highest number of reported droughts, while Cameroon recorded the highest number of floods. On the other hand, Niger recorded the highest number of winds. Researchers, and other decision-making stakeholders must prioritize these dominant shocks. Most of the peer review studies reported here argue both climatic and non-climatic drivers are driving these climate shocks in the Sahel. For a long time, the scientific literature has noted that many of the environmental problems faced across Africa were caused by climate change. However, this current chapter notes that non-climatic drivers are gaining importance. There is scientific evidence across Africa and the Sahel that illustrates that most of the environmental issues facing the region are driven by non-climatic drivers such as deforestation, population growth, wars and unsustainable approaches of land tenure and use like shifting and slash and burn cultivation inter alia while climate change only playing a reinforcing role [1, 7, 44, 54–58].

The decade 1975–1985 recorded the highest number of shocks in the Sahel. This surge has been attributed to the ravaging droughts that impacted most sub-Saharan African countries in the 1970s and early 1980s [50, 59–64]. At the dawn of the mid 1980s, the droughts that ravaged the continent had reduced in intensity giving rise to a surge in other climate shocks such as floods. Recent normalized difference vegetation index (NDVI) studies across the Sahel show that from the mid-1980s onwards, the Sahel has witnessed increasing precipitation and greening of the landscape [7, 54, 60, 61, 65–71]. This work is unique in that it is the first to use the systematic approach to verify the temporal and spatial distribution of climate shocks in the Sahel as well as their drivers. This approach has previously been used in tracking adaptations around the world as reported in the following studies, [1, 41, 43, 63, 64, 67–72]. It is important to caution that, this work provides a proxy-based approach offering a baseline from which climate change can be evaluated and monitored in the Sahel.

As this work is a first attempt to track climate change adaptations in the Sahel, going forward, the following recommendations are made: 1. similar systematic reviews across larger scales across Africa such as African continent. 2. Inclusion of

both peer review and gray literature to better capture the shocks that might have been reported in non-standardized studies 3. Providing further insights into the leverage of research in the context of who is researching what and where are they affiliated. This option will help is encouraging a higher leverage of research funding for the region. Though this work is based on proxies, it has also been verified that through ground truthing that these results are generally valid as ground truthing has not resulted in any new information that can contradict these findings.

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Conflict of interest

“The authors declare no conflict of interest.”

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References

- [1] Giannini, A., Saravanan, R., Chang, P. Oceanic forcing of Sahel Rainfall on interannual to interdecadal timescales. *Science*, 2003, 302:1027-1030.
- [2] Reynolds, J.F., Stafford, S.D.M., Lambin, E.F., Turner, B.L., Mortimore, M., Batterbury, S.P., Downing, T.E., Dowlatabadi, H., Fernandez, R.J., Herrick, J/E., Huber-Sannwald, E/, Jiang, H., Leemans, R., Lynam, T., Maestre, F.T., Ayarza, M., Walker, B. Global desertification: building a science for dryland development. *Science*, 2007, 316: 847-851.
- [3] IPCC. Climate Change 2007: Impacts, Adaptations and Vulnerability. Contributions of the Working Group 2 to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, 2007, pp. 976.
- [4] IPCC. Climate change 2013: the physical science basis. Contributions of the Working Group 1 to the Fifth Assessment Report of the IPCC. Cambridge University Press, Cambridge, 2013, pp. 979.
- [5] Epule, T.E., Ford, J.D., Lwasa, S., Lepage, L. Vulnerability of maize yields to droughts in Uganda. *Water*, 2017a, 29, 181. <http://dx.doi.org/10.3390/w9030181>.
- [6] Epule, T.E., Ford, J.D., Lwasa, S. Projections of maize yield vulnerability to droughts and adaptation options in Uganda. *Land Use Policy*, 2017b, 65, 154-163.
- [7] Giannini, A., Biasutti, M., Held, I.M., Sobel, A.H. A global perspective on African climate. *Clim Chang*, 2008, 90:359-383. Doi: 10.1007/s10584-008-9396-y.
- [8] Agnew, C.T., Warren, A. A framework for tackling drought and land degradation. *Journal of Arid Environments*, 1996, 33, 309-320.
- [9] Agnew, C.T., Chappell, A. Drought in the Sahel. *Geojournal*, 1999, 48, 299-311.
- [10] Vanmaercke, M., Zenebe, A., Poesen, J., Nyssen, J., Verstaeten, G., Deckers, J. Sediments dynamics and the role of flash floods in sediment export from medium-sized catchments: a case study from the semi-arid tropical highlands in northern Ethiopia. *Journal of Soil Sediments*, 2010, 10, 611-627.
- [11] Epule, T.E., Peng, C., Lepage, L., Chen, Z. The causes, effects, and challenges of Sahelian droughts: a critical review. *Reg. Environ. Change*. 2014a, 14, 145-156.
- [12] Epule, T.E., Peng, C., Lepage, L., Chen, Z. Policy options towards deforestation reduction in Cameroon: an analysis based on a systematic approach. *Land Use Policy*, 2014b, 36, 405-415. Doi: 10.1016/j.landusepol.2013.09.004.
- [13] Mamadou, I., Gautier, E., Descroix, L., Noma, I., Moussa, I.B., Maiga, O.F., Genthon, P., Amogu, O., Abdou, M.M., Vandervaere, J.P. Exorheism growth as an explanation of increasing flooding in the Sahel. *Catena*, 2015, 131, 130-139.
- [14] Karam, D.B., Flamant, C., Knippertz, P., Reitebuch, O., Pelon, J., Chong, M. Dabas, A. 2008. Dust emissions over the Sahel associated with West African monsoon intertropical discontinuity region: a representative case study. *Q.J.R Meteorol. Soc.* 2008, 134, 621-634.
- [15] Hastenrath, S., Polzin, D., Mutai, C. Diagnosing the droughts and floods in Equatorial East Africa during Boreal Autumn 2005-08. American Meteorological Society, 2009, 813-818. Doi: 10.1175/2009jcli3094.1.
- [16] Prospero, J., Nees, R. Dust concentration in the atmosphere of the

equatorial north Atlantic: possible relationship to the Sahelian drought. *Science*, 1976, 196, 1196-1198.

[17] Sivakumar, M.V.K., and Wallace J.S. Soil water balance in the Sudano-Sahelian zone: need, relevance, and objectives of the workshop. In: Sivakumar M.V.K., Wallace J.S., Renard C. and Giroux C. Soil water balance in the Sudano-Sahelian zone. IAHS Publication 199, Wallingford, 1991, pp. 3-10.

[18] Tarhule, A. Damaging rainfall and flooding: the other Sahel hazards. *Climate Change*, 2005, 72, 355-377.

[19] Amogu, O., Descroix, L., Yero, K.S., Le Breton, E., Mamdou, I., Ali, A., Vischel, T., Bader, J.C., Moussa, I., Gautier, E., Boubkraui, S., Belleudy, P. Increasing river flows in the Sahel? *Water*, 2010, 2, 170-199. Doi: 10.3390/w2020170.

[20] Albergel, J. Sécheresse, désertification et ressources en eau de surface-Application aux petits bassins du Burkina Faso. The Influence of Climate Change and Climatic Variability on the Hydrologic Regime and Water Resources (Proceedings of the Vancouver Symposium, August 1987). IAHS Publ.1987, no. 168 Available online at: http://iahs.info/redbooks/A168/iahs_168_0355.pdf.

[21] Lu, J., Delworth, T.L. Oceanic forcing of the late 20th century Sahel drought. *Geophysical Research Letters*, 2005, 32: L22706. Doi: 10.1029/2005GL023316.

[22] Mertz, O., Mbow, C., Reenberg, A., Diouf, A. 2009. *Environmental Management*, 43, 804-816.

[23] Lopez-I-Gelats, F., Fraser, E.D.G., Morton, J.F., Rivera-Ferre, M.G. What drives the vulnerability of pastoralist to global environmental change? A qualitative meta-analysis. *Global*

Environmental Change, 2016, 39, 258-274.

[24] Anuforom, A. Spatial distribution and temporal variability of Harmattan dust haze in sub-Sahel West Africa. *Atmospheric Environment*, 2007, 41, 9079-9090.

[25] Jankowiak I, Tanre D. Satellite climatology of Saharan dust outbreaks: Method and preliminary results. *J. Climate*, 1992, 5: 646-656.

[26] Alpert, P., Ganor, E. A jet stream associated heavy dust storm in the western Mediterranean. *J. Geophys. Res.* 1993, 98, 7339-7349.

[27] Tengberg, A. Nebkha dunes as indicators of wind erosion and land degradation in the Sahel zone of Burkina Faso. *Journal of Arid Environments*, 1995, 30, 265-282.

[28] Tall, R., Mason, S.J., Van Aalst, M., Suarez, P., Ait-Chellouche, Y., Diallo, A.A., Braman, L. Using seasonal climate forecast to guide disaster management: the Red Cross experience during the 2008 West African floods. *International journal of Geophysics*, 2012, 986016, Doi: 10.1155/2012/986016.

[29] Lwasa, S. A systematic review of research on climate change adaptation policy and practice in Africa and South Asia deltas. *Regional Environmental Change*, 2015, 15, 815-825. Doi: 10.1007/s10113-014-0715-8.

[30] Epule, T.E., Peng, C., Lepage, L. Environmental refugees in sub-Saharan Africa: a review of perspectives on trends, causes, challenges and way forward. *Geojournal*, 80, 79-92.

[31] Dixon, R., Smith, J., Guill, S. Life on the edge: vulnerability and adaptation of African ecosystems to global climate change. *Mitigation and Adaptation Strategies for Global Change*, 2010, 8, 93-113.

- [32] Drees, L.R., Manu, A., Wilding, L.P. Characteristics of Aeolian dust in the Niger, West Africa. *Geoderma*, 1993, 59, 213-233.
- [33] Eklundh, L., Olsson, L. Vegetation index trends for the African Sahel 1982-1999. *Geophysical Research Letters*, 2003, 30, 8, 1430. Doi: 10.1029/2002GL016772.
- [34] Mulitza, S., Heslop, D., Pittauerova, D., Fischer, H., Meyer, I., Stuut, J.B., Zabel, M., Mollenhauer, G., Collins, J.A., Kuhnert, H., Schulz, M. Increase in African dust flux at the onset of commercial agriculture in the Sahel region. *Nature Letters*, 2010, 466, 226-228.
- [35] UNREDD+. Executive summary: 2015 annual report of the UN-REDD Program Fund. 2015, Available online at: <http://www.unredd.net/documents.html?view=browse&customtags=172&startdate=&enddate=&dmlang=>
- [36] United Nations (UN). Paris agreement. United Nations, New York. 2015, Available online at: http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf.
- [37] African Climate Change Fund. Supporting African countries to access international climate finance: enabling a transition towards climate resilient, low-carbon development. The African Development Bank. 2016, Available online at: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Africa_Climate_Change_Fund_Supporting_Africa_countries_to_access_international_climate_finance.pdf.
- [38] O'Connor, Ford, J.D. Increasing the effectiveness of the "Great Green Wall" as an adaptation to the effects of climate change and desertification in the Sahel. 2014, *Sustainability*, 6, 7142-7154. Doi: 10.3390/su6107142.
- [39] Faure, H., Gac, J.Y. Will the Sahel drought end in 1985? *Nature*, 1985, 291, 475-478.
- [40] Boyd, E., Cornforth, R.L., Lamb, P.J., Tarhule, A., Lele, M.A., Brouder, A. Building resilience to face recurring environmental crisis in African Sahel. *Nature Climate Change*, 2013, 3, 631-637.
- [41] Reenberg, A. Land-use dynamics in the Sahelian zone in eastern Niger-monitoring change in cultivation strategies in drought prone areas. *Journal of Arid Environments*, 1994, 27, 179-192.
- [42] Nicholson, S.E. The west African Sahel. A review of recent studies on the rainfall regime and its interannual variability. *ISRN Meteorology*, 2013, 453521, Doi.org/10.1155/2013/453521.
- [43] Hiernaux, P., Diarra, L., Trichon, V., Mougin, E., Soumaguel, N., Baup, F. Woody plant population dynamics in response to climate change from 1984 to 2006 in Sahel (Gourma, Mali). *Journal of Hydrology*, 2009, 375, 103-113.
- [44] Nicholson, S.E. Sub-Saharan rainfall 1981-84. *Journal of Climate and Applied Meteorology*, 1985, 24, 1388-1391.
- [45] Le Houerou, H.N. Climate change, drought, and desertification. *Journal of Arid Environments*, 1996, 34, 133-185.
- [46] Adefolalu, D.O. 1986. Further aspects of Sahelian drought as evident from rainfall regime of Nigeria. *Arch. Met. Geoph. Biocl*, 36, 277-295.
- [47] Hitchcock, R., Hussein, H. Agricultural and non-agricultural settlements for drought-affected pastoralists in Somalia. *Disasters*, 1987, 11, 1, 30-39.
- [48] Deressa, T., Hassan, R., Ringler, C., Alemu, T., Yesuf, M. Determinants of farmers' choice of adaptation methods

to climate change in the Nile Basin of Ethiopia. *Global Environmental Change*, 2009, 19, 248-255.

[49] Turton, D., Turton, P. Spontaneous resettlement after drought: an Ethiopian example. *Disasters*, 1984, 8, 3, 178-189.

[50] Huho, J.M., Ngaira, J.K.W., Ogindo, H. *Educational Research*, 2011, 2, 1, 779-789.

[51] Keller, E. Drought, war and the politics of famine in Ethiopia and Eritrea. *The Journal of Modern African Studies*, 1992, 30, 4, 609-624.

[52] Ozer, P., Erpicum, M., Demaree, G., Vandiepenbeeck, M. The Sahelian drought may have ended during the 1990s. *Hydrological Sciences Journal*, 2003, 48, 3, 489-492. Doi: 10.1623/hysj.48.3.489.45285.

[53] Anyamba, A., Tucker, C.J. Analysis of Sahelian Vegetation dynamics using NOAA-AVHRR NDVI data from 1981-2003. *Journal of Arid Environments*, 2005, 63: 595-614.

[54] Nicholson, S.E. Rainfall and atmospheric circulation during drought periods and wetter years in West Africa. *American Meteorological Society*, 1981, 109, 2191-2208.

[55] Maranz, S. Tree mortality in the African Sahel indicates an anthropogenic ecosystem displaced by climate change. *Journal of Biogeography*, 2009, 36, 1181-1193.

[56] Anyamba, A., Eastman, J. Inter-annual variability of NDVI over Africa and its relation to El Niño/Southern Oscillation. *International Journal of Remote Sensing*, 1996, 17, 2533-2548.

[57] Nielsen, J. Ø., Reenberg, A. Cultural barriers to climate change adaptation: A case study from Northern Burkina Faso. *Global Environmental Change*, 2010, 20(1), 142-152. Doi: 10.1016/j.gloenvcha.2009.10.002.

[58] Nielsen, J.Ø., D'Haen, S., Reenberg, A. Adaptation to climate change as a development project: A case study from Northern Burkina Faso. *Climate and Development*, 2012, 4(1), 16-25.

[59] Muller, R., Pistorius, T., Rohde, S., Gerold, G., Pacheco, P. Policy options to reduce deforestation based on a systematic approach of drivers and agents in lowland Bolivia. *Land Use Policy*, 2013, 30, 895-907.

[60] Birkett, C., Mutugudde, R., Allan, T. Indian Ocean climate event brings floods to East Africa's lakes and Sudd Marsh. *Geophysical Research Letters*, 1999, 26, 8, 1031-1034.

[61] Samimi, C., Fink, A.H., Paeth, H. The 2007 floods in the Sahel: causes, characteristics, and its presentation in the media and FEWS NET. *Natural Hazards and Earth System Sciences*, 2012, 12, 313-325.

[62] Billi, P., Alemu, Y.T., Ciampalini, R. Increased frequency of flash floods in Dire Dawa, Ethiopia: change in rainfall intensity or human impact? *Natural Hazards*, 2015, 76, 1373-1394.

[63] Nka, B.N., Oudin, L., Karambiri, H., Paturel, J.E., Ribstein, P. Trends in floods in West Africa: analysis based on 11 catchments in the region. *Hydrology and Earth System Sciences*, 2015, 19, 4707-4 719.

[64] Ologunorisa, T., Adeyemo, A. Public perception of floods hazard in the Niger Delta, Nigeria. *The Environmentalist*, 2005, 25, 39-45.

[65] Nicholson, S.E., Tucker, C.J., Ba, M.B. 1998. Desertification, drought, and surface vegetation: an example from the west African Sahel. *Bulletin of the American Meteorological Society*, 1998, 79, 5, 815-829.

[66] Nicholson, S.E. A detailed look at the recent drought situation in the

Greater Horn of Africa. *Journal of Arid Environments*, 2014, 103, 71-79.

[67] Moreno, T., Querol, X., Castillo, S., Alastuey, A., Cuevas, E., Hermann, L., Mounkaila, M., Elvira, J., Gibbons, W. 2006. Geochemical variations in Aeolian mineral particles from the Sahara-Sahel dust corridor. *Chemosphere*, 2006, 65, 261-270.

[68] McLeman, R. Settlement abandonment in the context of global environmental change. *Global Environmental Change*, 2011, 21, 108-120.

[69] Ochola, S., Eitel, B., Olago, D. Vulnerability of schools to floods in Nyando River catchment, Kenya. *Disaster*, 2010, 34, 3, 732-754.

[70] Noble, I., Huq, S. Adaptation Needs and Options (New York: Cambridge University Press) chapter, 2014, 14.

[71] Fernandez, A., Najafi, M., Durand, M., Mark, B.G., Moritz, M., Jung, H.C., Neal, J., Shastri, A., Laborde, S., Phang, S.C., Hamilton, I.M., Xiao, N. Testing the skill of numerical hydraulic modeling to simulate spatiotemporal flooding patterns in the Logone floodplain, Cameroon. *Journal of Hydrology*, 2016, 539, 265-280.

[72] Kaly, F., Marticorena, B., Rajot, J.L., Janicot, S., Niang, A., Yah, A., Thiria, S., Zakou, A., Coulibaly, B.S., Kone, I., Traore, S., Diallo, A., Ndiye, T. Variability of mineral dust concentrations over West Africa monitored by the Sahelian Dust Transect. *Atmospheric Research*, 2015, 164, 165, 226-241.