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Guinea Worm Eradication - quantifying conflict zones and access - challenges of certification

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Original Research

Title: Guinea Worm Eradication - quantifying conflict zones and access - challenges of certification

Authors: Louise A. Kelly-Hope[1] and David H. Molyneux[1]

Corresponding author: Dr Louise Kelly-Hope
Department of Tropical Disease Biology
Liverpool School of Tropical Medicine,
Liverpool, L3 5QA, UK
Email: Louise.Kelly-Hope@lstmed.ac.uk
Ph: +44 (0) 151 705 3336
Fax: +44(0)151 705 3370

Institutional affiliation
1. Department of Tropical Disease Biology, Liverpool School of Tropical Medicine, Liverpool, L3 5QA, UK

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Abstract

Objectives: To quantify conflict events and access across countries that remain to be certified free of transmission of *Dracunculus medinensis* (Guinea worm disease) or require post-certification surveillance as part of the Guinea Worm Eradication Program (GWEP).

Setting and participants: Populations living in Guinea worm affected areas across seven pre-certification countries and 13 post-certification Sub-Saharan African countries.

Outcome measures: The number of conflict events and rates per 100,000 population, the main types of conflict and actors reported to be responsible for events were summarised and mapped across all countries. Chad and Mali were presented as case studies. Guinea worm information was based on GWEP reports. Conflict data were obtained from the Armed Conflict Location and Event Data Project. Maps were created using ArcGIS 10.7 and access was measured as regional distance and time to cities.

Results: More than 98,0000 conflict events were reported between 2000-2010, with a significant increase since 2018. The highest number and rates were reported in pre-certification Mali (n=2556; 13.0 per 100,000), South Sudan (n=2143; 19.4), DRC (n=7016; 8.1), and post-certification Nigeria (n=6903; 3.4), Central Africa Republic (n=1251; 26.4), Burkina Faso (n=2004; 9.7). Violence against civilians, protests and battles were most frequently reported with several different actors involved including Unidentified Armed Groups and Boko Haram. Chad and Mali had contracting epidemiological and conflict situations with affected regions up to 700km from the capital or 10 hours to the nearest city.

Conclusions: Understanding the spatial-temporal patterns of conflict events, identifying hotspots, the actors responsible, and their sphere of influence is critical for the GWEP and other public health programmes to develop practical risk assessments, deliver essential health interventions, implement innovative surveillance, determine certification, and meet the goals of eradication.

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Strengths and limitations of this study

- Conflict and insecurity is a major problem in many of the African countries that remain to be certified free of transmission of *Dracunculus medinensis* (Guinea worm disease) or require post-certification surveillance; we characterise the rate of increase in violent events and the main actors in these countries over the last two decades using various publicly available databases
- We present case studies for Mali and Chad to highlight the multifaceted epidemiological and conflict situations, the challenging access and safety issues, which will require bespoke risk assessments and innovative strategies to reach certification
- The extensive georeferenced conflict data used in the study is a valuable resource to use as a first step in assessing a situation, however, given the limitations of secondary data, it will be important to supplement this information with details from local, reliable sources and trusted partners on the ground
- We recommend that the methodology and databases are used by countries and the World Health Organization in preparation for certification missions for the Guinea Worm Eradication Programme, and used more widely as a management and risk assessment tool for other research and health programmes working in areas and countries of complex emergencies and insecurity

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Introduction

Guinea Worm or Dracunculiasis is one of two infections that have been designated formally by the World Health Assembly as diseases targeted for eradication, the other being poliomyelitis.[1–3] Yaws eradication has also been included as a target in the recently approved World Health Organization(WHO) Neglected Tropical Disease (NTD) Road Map 2021-2030.[4] Eradication requires Certification of each member state of the United Nations as being free of transmission of the infectious agent *Dracunculus medinensis*. The Guinea Worm Eradication Program (GWEP) has more recently adopted specific definitions approved by the International Commission for the Certification of Dracunculiasis Eradication (ICCDE), which reflect the criteria required to confirm the elimination from a country and following that the need for all countries to be free of transmission prior to Global Certification of Eradication by the World Health Assembly.[2]

> *Elimination of dracunculiasis is the confirmed absence of the emergence of adult female worms (the interruption of transmission of D. medinensis) in humans and animals for three consecutive years or longer from a country with such a low risk of reintroduction of the parasite that preventive measures could be reduced to a strict minimum. Worldwide eradication of dracunculiasis is the confirmed absence of the emergence of adult female worms (defined as compatible with the interruption of transmission of D. medinensis) in humans and animals for three years or longer at the global level.*[2]

Recently, the challenges of certifying elimination in countries and then eradication globally have been highlighted.[5,6] Whilst the numbers of human cases have declined by over 99% since the programme began in the late 1980s[7] from an estimated 3 million cases per year to some 27 cases reported to date in 2020,[3,8,9] the problems of animal infections, in particular in dogs, has arisen and in Chad new modes of transmission have been uncovered involving paratenic hosts in fish, predominantly small “fingerlings”.[10–13] Whilst Chad is the most serious challenge to global eradication given the high numbers of dogs reported infected annually (over 1900 in 2019 and 1500 in 2020),[14,15] dogs have been found infected consistently, albeit in small numbers in Mali, Ethiopia and Angola.[2,3]

Whilst the challenge of animal infections is a recent phenomenon, all countries previously certified have failed to report any animal infections despite surveillance in formerly endemic areas.[15] However, a significant further challenge is the problem of access to insecure areas due to conflict and violence.[5,6,15,16] Five endemic countries require to be certified together with the Democratic Republic of Congo (DRC) and Sudan (pre-certification countries), whilst not currently endemic,

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having not reported a human case since 1958 and 2002 respectively, require to be verified as free of transmission based on a visit from an International Certification Team (ICT). If access due to insecurity and conflict is curtailed or limited given the onus on any ICT is to "prove a negative" as far as is possible would be impaired and would limit the validity of any report which recommended that the country was free of transmission.

At present there is no standardised approach to evaluate the level of conflict risk in Guinea worm endemic countries which cover vast area of Africa. This is critical as conflict significantly disrupts the implementation of health service delivery, impact assessments, research and surveillance.[17–20] We present in this paper an approach to quantifying the risks in countries yet to be certified, as well as those already certified and require continuing surveillance until global eradication has been declared. Since elimination of transmission was confirmed by the ICCDE in some 13 countries in Africa, the security situation has changed as civil unrest will have impacted on the ability of countries to maintain a level of surveillance compatible with adequate post-certification scrutiny. This applies, in particular to Sahelian countries, where jihadist movements control large swathes of some countries and where national authorities have limited access or control -Niger, Burkina Faso, Nigeria, Senegal, Mauritania and Cameroon whereas inter religious conflict in Central African Republic (CAR) prevents access to the area bordering Chad.[21,22] In the DRC there is significant conflict in eastern regions of the country and the border of South Sudan and Sudan has a high level of insecurity.

To address this challenge, we examined the number of conflict events from 2000 to 2020 to highlight long-term temporal trends in countries previously certified as free of transmission, pre-certification countries those currently endemic and those countries that require certification but which have not recorded a case of the infection since the inception of the GWEP in the late 1980's. We quantified the number of conflict events and rates per 100,000 population for the most recent years, highlight the main types of conflict and the main actors responsible, as well as present specific data from Chad and Mali as case studies. This approach can also be applied to the polio eradication programme and has implications for other health interventions.

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Methods

Study area

The cross-sectional study included sub-Saharan African countries that were categorised as those in the pre-certification stage and those in the post-certification stage.

Pre-certification countries included those currently endemic for dracunculiasis, namely Angola, Chad, Ethiopia, Mali and South Sudan (from 2011 Independence onwards), and countries with historical evidence of Guinea worm but are yet to been certified as free from dracunculiasis, including the DRC and Sudan.

Post-certification countries included Benin, Burkina Faso, Cameroon, CAR, Cote d'Ivoire, Ghana, Kenya, Mauritania, Niger, Nigeria, Senegal, Togo and Uganda. The dates when these countries were certified free of transmission are provided in Molyneux et al..[5] See Figure 1 for the map of pre-certification and post-certification countries which cover vast geographical regions of sub-Saharan Africa covering more than 15 million square kilometres (km^2)[23] with poor accessibility to urban centres or cities.[24] The land area of each country is shown in Table 1 with Angola, Chad, DRC, Mali, Niger and Sudan more than 1.2 million km^2 in size.

Figure 1. Map of pre-certification and post-certification countries in sub-Saharan Africa

Data sources

To examine Guinea worm status in relation to spatial and temporal distribution of conflict events and regional access within each country, several data sources were obtained;

- Guinea worm information was based on World Health Organisation (WHO) annual reports and Dracunculiasis Eradication Portal,[2,15,25] and GWEP reports by The Carter Centre and the Centres for Disease Control and Prevention.[3,8]
- Conflict data were downloaded from the Armed Conflict Location and Event Data Project (ACLED),[26,27] including geo-referenced location data on conflict event types categorised as battles, riots, protests, strategic developments, explosions/remote violence and violence against civilians and actors i.e. groups of people or organisations reported to be responsible for the events (definitions available on ACLED website)[27] for the period from January 2000 to October 2020.
- Population were obtained from the World Bank databank and based on 2019 estimates.[23]

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- Administrative boundaries were obtained from the United Nations Office for the Coordination of Humanitarian Affairs (OCHA).[28]
- Accessibility information was based on regional distance (kilometres (kms)) to the capital city and from modelled maps of 'Accessibility to cities', quantified as travel time in minutes (converted to hours) to the nearest high-density urban centre or city at a resolution of 1 x 1 km for 2015.[24]

These data sources represent the best available in the public domain, and it is acknowledged that there may be some missing cases and conflict event data, and differences in population estimates, country size and accessibility compared with other sources.

Conflict and population data were downloaded and collated in Microsoft Excel (Microsoft Corporation, Redmond, WA) and the administrative boundary and accessibility to cities data were downloaded and imported into geographical information software ArcGIS 10.7 (ESRI, Redlands, Ca) for mapping and analysis.

Patient and public involvement

No patient was included in this study.

Data analysis and mapping

First, the number of conflict events for the pre-certification and post-certification countries were summarised for years from 2000 to 2020 to highlight long-term temporal trends and high-conflict Guinea worm countries.

Second, the overall number of conflict events and rates per 100,000 population for the most recent years, 2018 to 2020, were quantified for each country. The different types of conflict events were tabulated and mapped, and the countries with the most events and highest rates per population were identified as high-conflict countries. The main actors reported to be responsible for the highest number of events in the high-conflict countries were summarised.

Finally, the situation in Chad and Mali since 2018 was presented as contrasting case studies, and included a summary and maps of the number of Guinea worm human and/or animal cases and regions affected; the number of conflict events types and main actors in each region; and accessibility of each region measured as the distance (kms) between the centre of each region and each capital city, and the average time (hours) of each region to high-density urban centre or city.

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Results

Overall summary 2010-2020

The total number conflict events reported for pre-certification and post-certification countries between 2000-2020 is shown in Figure 2A and 2B (data available in Supplementary file 1). Overall, the temporal trends in conflict events across all countries were similar with a marked increase from 2010 onwards.

In the five endemic countries, a total of 18,895 conflict events were reported between 2000-2020 with the highest numbers in South Sudan (n=6986 from 2011 onwards) representing 37.0% of the total. In the first decade between 2000-2010, a total of 2437 events were reported, which increased 6.8-fold to 16,458 events between 2011-2020, with 41.5% reported in the last three years since 2018. In the two countries yet to be certified, a total of 30,805 events were reported with the highest numbers in DRC (n=17,385; 56.4%). Between 2000-2010, a total of 6387 events were reported, which increased 3.8-fold to 24,418 events between 2011-2020, with 41.5% reported in the last three years.

In the post-certification countries, a total of 48,615 events were reported with the highest numbers in Nigeria (n= 17,763) representing 36.5% of the total. In the first decade between 2000-2010, the 10,244 events were reported, which increased 3.7-fold to 38,371 events between 2011-2020, with around one third (37.3%) reported in the last three years.

Figure 2. Number of conflict events reported in pre-certification and post-certification countries between 2000 – 2020

Summary of conflict events in recent years 2018 – 2020

Pre-certification countries

In the five endemic countries, an overall total of 6,832 conflict events were reported between 2018-2020 (Table 1A; Figure 3). The highest numbers and rates per 100,000 population were reported in Mali (n=2556; 13.0 per 100,000) and South Sudan (n=2143; 19.4 per 100,000). Overall, the most frequently reported events included violence against civilians (n=2373), protests (n=993), and battles (n=2055) with South Sudan reporting the highest number violence incidents against civilians (39.1% of total) and battles (46.4%) and Ethiopia reporting the highest number of protests (49.8%). South

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Sudan also reported the highest rates of violence against civilians (8.4 per 100,000), and battles (8.6 per 100,000), and Mali the highest rates of protests (1.3 per 100,000). A summary of the actors reported to be responsible for the highest number and type of conflict events in the high-risk countries is shown in Table 2A. For Mali, the actors reported for the most events included JNIM: Group for Support of Islam and Muslims (n=661); Unidentified Armed Group (Mali) (n=434) and Protesters (n=261). For South Sudan, the actors included the Military Forces of South Sudan (2011-) (n=543), Unidentified Armed Group (South Sudan) (n=399) and the Sudan People's Liberation Movement-In Opposition (n=157).

In DRC and Sudan, a total of 10,139 events were reported between 2018-2020 (Table 1B; Figure 3). The highest number and rate per 100,000 population were reported in DRC (n=7016; 8.1 per 100,000). The most frequently reported events included violence against civilians (n=3242) protests (n=2656), and battles (n=2628) with DRC reporting the highest number of these events representing 76.6%, 38.6% and 86.2% of the total respectively. The DRC also reported the highest rates of violence against civilians (2.9 per 100,000) and battles (2.6 per 100,000), and Sudan the highest rates of protests (3.8 per 100,000). A summary of the actors reported to be responsible is shown in Table 2A. The actors associated with the two most reported events in both countries included an Unidentified Armed Group (DRC=1236; Sudan =233), and Protesters (DRC=975; Sudan=1590).

Figure 3. Location of conflict event types reported in endemic /pre-certified and certified countries between 2018 – 2020

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Table 1. Summary of conflict events reported in pre-certification and post-certification countries between 2018 – 2020

A. Pre-certification countries

Country	Land area (sq.km)	Population (millions)	Battles	Explosions Remote violence	Protests	Riots	Strategic develop-ments	Violence against civilians	Total number of events	Events per 100,000 population
Angola	1,246,700	31.8	8	4	108	37	12	53	222	0.7
Chad	1,259,200	15.9	125	36	63	41	57	99	421	2.6
Ethiopia	1,000,000	112.1	242	18	495	206	120	409	1490	1.3
Mali	1,220,190	19.7	727	319	259	123	245	883	2556	13.0
South Sudan	644,329	11.1	953	28	68	43	122	929	2143	19.4
Total	**5,370,419**	**191**	**2055**	**405**	**993**	**450**	**556**	**2373**	**6832**	**3.6**
DRC	2,267,050	86.8	2266	23	1025	574	645	2483	7016	8.1
Sudan	1,861,484	42.8	362	43	1631	197	131	759	3123	7.3
Total	**4,128,534**	**130**	**2628**	**66**	**2,656**	**771**	**776**	**3,242**	**10,139**	**7.8**
Overall total	**9,498,953**	**320**	**4683**	**471**	**3649**	**1221**	**1332**	**5615**	**16971**	**5.3**

B. Post-certification countries

Country	Land area (sq.km)	Population (millions)	Battles	Explosions Remote violence	Protests	Riots	Strategic develop-ments	Violence against civilians	Total number of events	Events per 100,000 population
Benin	112,760	11.8	20		32	50	9	35	146	1.2
Burkina Faso	273,600	20.3	498	139	289	73	273	732	2004	9.9
Cameroon	472,710	25.9	779	65	162	73	332	1106	2517	9.7
CAR	622,980	4.7	352	9	85	61	282	462	1251	26.4
Cote d'Ivoire	318,000	25.7	51	1	235	252	23	45	607	2.4
Ghana	227,540	30.4	64		211	161	21	101	558	1.8
Kenya	569,140	52.6	177	39	368	319	50	302	1255	2.4
Mauritania	1,030,700	4.5	4	1	388	24	9	8	434	9.6
Niger	1,266,700	23.3	165	63	63	42	144	431	908	3.9
Nigeria	910,770	201	1654	360	1746	611	312	2220	6903	3.4
Senegal	192,530	16.3	12	3	119	55	11	12	212	1.3
Togo	54,390	8.1	12		55	43	10	22	142	1.8
Uganda	200,520	44.3	103	3	270	453	53	327	1209	2.7
Total	**6,252,340**	**468.9**	**3891**	**683**	**4023**	**2217**	**1529**	**5803**	**18146**	**3.9**

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Table 2. Summary of main actors reported to be responsible for the most conflict event type most in selected pre-certification and post-certification countries between 2018-2020

A. Pre-certification countries

Country Main Actor	**Battles**	**Explosions Remote violence**	**Protests**	**Riots**	**Strategic develop-ments**	**Violence against civilians**	**Total number**
Mali							
JNIM: Group for Support of Islam and Muslims	253	216			45	147	661
Unidentified Armed Group (Mali)	88	17		1	83	245	434
Protesters (Mali)			259		2		261
Fulani Ethnic Militia (Mali)	75	1			10	136	222
Military Forces of Mali (2013-2020)	48	8		1	30	78	165
Islamic State (Greater Sahara)	62	12			5	58	137
South Sudan							
Military Forces of South Sudan (2011-)	362	10		1	19	151	543
Unidentified Armed Group (South Sudan)	69	16			7	307	399
Sudan People's Liberation Movement-In Opposition	67	2			17	71	157
NAS: National Salvation Front	67				4	41	112
Murle Ethnic Militia (South Sudan)	33				1	60	94
Unidentified Communal Militia (South Sudan)	18				2	49	69
DRC							
Unidentified Armed Group (DRC)	248	9			85	894	1236
Protesters (DRC)			972		3		975
Military Forces of the DRC (2019-)	528	4		1	70	116	719
ADF: Allied Democratic Forces	201	5			8	332	546
Rioters (DRC)				534			534
Military Forces of the DRC (2001-2019)	302	2		2	43	58	407
Sudan							
Protesters (Sudan)			1590		7		1597
Unidentified Armed Group (Sudan)	24	13	2		8	186	233
Rioters (Sudan)			1	182			183
Military Forces of Sudan (1989-2019)	77	22	3	1	12	43	158
Military Forces of Sudan (1989-2019) Rapid Support Forces	28	4	4	3	17	90	146
Darfur Communal Militia (Sudan)	20				3	119	142
Unidentified Communal Militia (Sudan)	9			1	3	102	115

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B. Post-certification countries

Country Main Actor	Battles	Explosions Remote violence	Protests	Riots	Strategic developments	Violence against civilians	Total number
Nigeria							
Protesters (Nigeria)			1735				1735
Unidentified Armed Group (Nigeria)	181	9		1	53	789	1033
Military Forces of Nigeria (2015-)	552	261	2	1	105	44	965
Fulani Ethnic Militia (Nigeria)	90				22	590	702
Rioters (Nigeria)				605			605
Islamic State (West Africa) and/or Boko Haram - Jamatu Ahli is-Sunnah lid-Dawatai wal-Jihad	236	57			26	204	523
Cameroon							
Islamic State (West Africa) and/or Boko Haram - Jamatu Ahli is-Sunnah lid-Dawatai wal-Jihad	192	34			144	447	817
Military Forces of Cameroon (1982-)	272	2		1	59	308	642
Ambazonian Separatists (Cameroon)	224	9			55	175	463
Unidentified Armed Group (Cameroon)	30	18			26	121	195
Protesters (Cameroon)			161				161
Rioters (Cameroon)				72			72
CAR							
Unidentified Armed Group (CAR)	71	5			66	129	271
UPC: Union for Peace in the CAR	64				37	54	155
FPRC: Popular Front for the Renaissance of Central Africa	25				19	51	95
Anti-Balaka	46				10	35	91
Protesters (CAR)			84		1		85
LRA: Lords Resistance Army	7				23	52	82
Burkina Faso							
JNIM: Group for Support of Islam and Muslims and/or Islamic State (Greater Sahara)	122	24			115	194	455
JNIM: Group for Support of Islam and Muslims	131	47			50	112	340
Protesters (Burkina Faso)			287		8		295
Military Forces of Burkina Faso (2015-)	40	26			25	89	180
Islamic State (Greater Sahara)	53	10			19	86	168
Unidentified Armed Group (Burkina Faso)	46	1		1	16	91	155

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Post-certification countries

In the post-certification countries, a total of 18,146 events (3.9 per 100,000) were reported between 2018-2020 (Table 1B; Figure 3). The highest numbers reported were in Nigeria (n=6903), Cameroon (n=2517), Burkina Faso (n=2004), and the highest rates in CAR (26.4 per 100,000), Burkina Faso (9.9 per 100,000) and Cameroon (9.7 per 100,000). The most frequently reported events included violence against civilians (n=5803) protests (n=4023), and battles (n=3891) with Nigeria reporting the highest number of these events representing 38.3%, 43.4% and 42.5% of the total respectively. The CAR reported the highest rates of battles (7.4 per 100,000), and violence against civilians (9.7 per 100,000), and Mauritania the highest number of protests (8.5 per 100,000).

A summary of the actors reported to be responsible for the highest number and type of conflict events in the high-risk countries is shown in Table 2B. For Nigeria, the actors associated with the two most reported events included Protesters (Nigeria) (n=1735) and an Unidentified Armed Group (n=1033). For Cameroon, the actors included the Islamic State (West Africa) and/or Boko Haram - Jamatu Ahli is-Sunnah lid-Dawatai wal-Jihad (n= 817) and Military Forces of Cameroon (1982-) (n=642). For CAR, the actors included an Unidentified Armed Group (CAR) (n=271) and the UPC: Union for Peace in the Central African Republic (n=155). For Burkina Faso, the actors included JNIM: Group for Support of Islam and Muslims and/or Islamic State (Greater Sahara) (n=455) and JNIM: Group for Support of Islam and Muslims (n= 340).

Chad case study

The capital N'Djamena and six regions reporting Guinea worm human cases and/or animal infections between 2018 and 2020 are shown in Figure 4A and 4 B, together with the conflict event types reported in Chad, and the neighbouring pre-certification country of Sudan and post-certification countries of Cameroon, CAR and Niger.

Guinea worm situation. Human disease cases were reported in 2018 (n=17), 2019 (n=48) and 2020 (n=13). The areas affected included the Chari Baguirmi region, in Bailli (2018; 2019), Bousso (2018; 2019; 2020), Dourbali (2019), Kouno (2019) and Mandelia (2018; 2020) districts; the Moyen Chai region, in Danamadji (2019), Korbal (2018; 2019) Kyabe and Sahr (2018; 2019; 2020) districts; the Salamat region, in Aboudeia (2018; 2019; 2020), Amtiman (2018; 2019) and Haraze (2019); the Tanjile region in Bere district (2018) and the Wadi-Fira region in Matadjana district (2020).

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Animal infections, predominately domesticated dog infections were high and reported in 2018 (n=1040), 2019 (n=1935) and 2020 (n=1464). The areas affected included the capital N'Djamena (2018) and the Chari Baguirmi (2018; 2019), Mandoul (2018), Moyen Chai (2018; 2019), Mayo-Kebbi Est (2018; 2019) and Salamat (2018; 2019) regions (Figure 4B).

Conflict events. The highest number of conflict events was reported in N'Djamena (n=104) (Table 3A), were predominately protests (44 events) with protestors reported as the main actors. In the other Guinea worm affected regions, the number of conflict events was lower and ranged from 0 - 13 events in 2018-2020. The main conflict event type in the Chari-Baguirmi region was of violence against civilians (3 events) with Military Forces, Police Forces and Moile Communal Militia the main actors; in Moyen-Chari was battles (2 events; Unidentified Communal Militia Chad); in Salamat was battles (2 events; Nomad and National Guard and Unidentified Communal Militia); in Tanjili was battles (10 events; Fulani Militia, Koutoune Communal Militia; Tandjile Communal militia and Unidentified Armed Group); and in Mayo-Kebbi Est was violence against civilians (4 events; Nomad and National Guard, Military Forces, Unidentified Armed Group (Cameroon and Chad)).

Regional access. The level of access in terms of distance (kms) to the capital N'Djamena and accessibility to a city in hours within Chad and in relation to Guinea worm status and conflict events is shown in Table 3A. Of the Guinea worm affected regions, Salamat (600-700kms) was the furthest from the capital and had the longest estimated time of 10 hours to the nearest city. Of the northerly non-endemic regions, the Lac (n=88), Quadd (n=57) and Tibesti (n=55) had the highest number of conflict events, with Tibesti (900-1000km) the furthest distance and had the longest estimated time of 42.1 hours to the nearest city.

Mali case study

The capital Bamako and two regions reporting Guinea worm animal infections in 2018-2020 are shown in Figure 4C and 4D, together with the conflict event types reported in Mali, and the neighbouring pre-certification countries of Burkina Faso, Niger and Mauritania.

Guinea worm situation. One human case was reported in early 2020 – the first human case reported since 2015. Animal infection, predominately domesticated dog infections were reported in 2018 (n=18), 2019 (n=8) and 2020 (n=9). The areas affected included the Mopti region, in Djenne (2018;

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2019; 2020) district, and the Segou region in Markal (2018), Tominian, Macina (2018; 2019; 2020) and Baroueli (2020) districts (Figure 4D).

Conflict events. The highest number of conflict events was reported in Mopti region (n=1206) (Table 3B), predominately violence against civilians (561 events) and battles (347 events) with Fulani Ethnic Militia, Groups for Support of Islam and Muslims, Unidentified Armed Group and/ or Military Forces reported as the main actors associated with these events. The main conflict events in the Segou region were battles (55 events) and violence against civilians (44 events) with Group for Support of Islam and Muslims reported as the main actors associated with battles and Military Forces of Mali and Dozo Communal Militia main actors for violence against civilians.

Regional access. The level of access in terms of distance to the capital Bamako and accessibility to a city in hours within Mali and in relation to case status and conflict events is shown in Table 3B. Of the Guinea worm affected regions, Mopti was the furthest from the capital Bamako, approximately 500-600 km, and had the longest accessibility time of 4.1 hours to the nearest city. Of the unaffected regions, Gao (n=503), and Tombouctou (n=264) had the highest number of conflict events, with Gao (1000-1100kms) the furthest away from the capital, and Tombouctou the longest estimated time of 62.9 hours to the nearest city.

Figure 3. Location of conflict event types reported in endemic /pre-certified and certified countries between 2018 – 2020

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Table 3. Summary of Guinea worm status, conflict events and regional access for case study countries

A. Chad case study

Region	Guinea worm status	Number of conflict events	Distance from N'Djamena (kms)	Accessibility to city (hrs)
N'Djamena	Dog	104	-	-
Chari-Baguirmi	Human/Animal	3	100-200	3.4
Moyen-Chari	Human/Animal	4	500-600	3.5
Salamat	Human/Animal	4	600-700	10.4
Tandjii	Human	13	300-400	3.7
Mayo-Kebbi Est	Dog	7	200-300	2.8
Mandoul	Dog	0	400-500	1.8
Barh-El-Gazel	No reports	1	300-400	11.2
Batha	No reports	3	400-500	8.6
Borkou	No reports	7	600-700	23.3
Ennedi Est	No reports	6	1000-1100	35.2
Ennedi Ouest	No reports	3	900-1000	30.8
Guera	No reports	1	400-500	4.9
Hadjer-Lamis	No reports	8	100-200	3.8
Kanem	No reports	3	300-400	14.1
Lac	No reports	88	100-200	4.9
Logone Occidental	No reports	8	300-400	1.9
Logone Oriental	No reports	6	400-500	1.9
Mayo-Kebbi Ouest	No reports	21	300-400	2.9
Ouadd	No reports	57	600-700	4.1
Sila	No reports	12	700-800	7.2
Tibesti	No reports	55	900-1000	42.1
Wadi Fira	Human	7	800-900	7.6

B. Mali case study

Region	Guinea worm status	Number of conflict events	Distance from Bamako (kms)	Accessibility to city (hrs)
Bamako	No reports	148	-	-
Mopti	Dog	1206	500-600	4.1
Segou	Dog	145	200-300	2.2
Gao	No reports	503	1000-1100	7.1
Kayes	No reports	62	200-300	3.8
Kidal	No reports	92	1200-1300	16.6
Koulikoro	No reports	63	100-200	3.7
Menaka	No reports	15	1200-1300	14.0
Sikasso	No reports	58	200-300	1.9
Tombouctou	No reports	264	900-1000	62.9

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Discussion

The GWEP has made remarkable progress since activities began in the late 1980's with the WHO reporting only tens of human cases in recent years. [15,25] This success has been driven by country commitment, the support from the WHO[2] and The Carter Center[3] and articulating the fundamental public health interventions to eliminate the transmission - case containment, control of copepods, access to safe drinking water (including filtration), regular reporting and surveillance, and instituting a reward system and the follow up of rumours.[5,7]

This paper, however, documents that over the past two decades, the numbers of incidents of conflict and violence have increased dramatically, especially in the last 3 years since 2018. This is not only of concern for endemic countries, but for the two countries yet to be certified, and the 13 countries that were previously endemic for the infection requiring ongoing surveillance.[2] The Guinea worm community have increasingly recognised that certification will face the challenges of acquiring comprehensive and reliable information in conflict zones and in accessing areas where national governments have limited control.[5,8,15] In addition, the porosity of international borders, extensive migration generated by insecurity, inter-country range of many of the actors responsible for violence, and the need for these geographically vast countries to ensure that any Guinea worm case is recognised and reported, highlights the immense challenges programmes face to satisfy the criteria for certifying the absence of transmission and the effectiveness of surveillance.[6]

The characteristics of the situation in areas of West and Central Africa are that there are many groups who are responsible for violence at both national and local levels and their motivations are different, even within the same region.[26,27] Understanding how these challenges for the GWEP can be overcome is essential if the country elimination objective and global eradication certification is to be achieved. Providing detailed data, as described in this paper, is necessary so risk assessments can be made to safely operationalise field work, especially in remote locations where access is limited.[18,29] This underscores the value of understanding the spatial and temporal patterns of conflict, identifying hotspots, the actors responsible and their sphere of influence. This information will allow the potential impact of violence on GWEP activities to be assessed consonant with the need to satisfy the robust criteria established by WHO a country to be certified by the ICCDE based on the information in the detailed national report submitted to WHO, and on which the ICT to base their assessments on the likelihood of the country being free of *D. medinensis* transmission.

We have summarised in detail the magnitude, geographical extent and increasing incidence of conflict and violence in those countries where Guinea worm remains a problem for those responsible for ensuring a successful endgame for eradication, which now has a target of 2030 for

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global certification.[4] The scale of the challenge can probably best be illustrated by the fact the that the total area of pre-certification countries is similar to continental USA.[23] This WHO NTD Roadmap target implies that all countries that remain to be certified must have zero cases in humans and animals by 2026/7 as a minimum of three years is required of zero global cases must be reported over the period 2027- 2030. This will require intense integrated human and animal surveillance, in countries at present suffering conflict events, with a trend that is regrettably accelerating rather than diminishing. The Chad and Mali case studies highlight the multifaceted epidemiological and conflict situations, the challenging access and safety issues, which will require bespoke risk assessments and innovative strategies to reach certification. A One Health approach including human, animal and environmental components should be considered given the evolving modes transmission,[30,31] taking the cost-effectiveness[32] and conflict context into account.

The case and conflict event data used in this study are valuable resources to use as a first step in assessing a situation. However, as there are some limitations with using secondary data, it will be important to supplement this information with details from local, reliable sources and trusted partners on the ground. The methodology and tools we have used in this paper provide a better understanding of the challenges the GWEP faces and is based on the recent studies undertaken to understand and address the risks for NTD programmes,[33] and should be more widely promoted not only for Guinea worm, but as a management and risk assessment tool for other research and health programmes working in areas and countries of complex emergencies and insecurity.

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Contributors

LAKH and DHM conceptualised the paper. LAKH accessed data sources, applied analytical methods and produce maps. Both contributed to the data interpretation, writing the first and final version of the manuscript.

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Competing interests

LAKH declares no competing interests. DHM is a member of the International Commission for the Certification of Dracunculiasis Eradication

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Data availability statement

All data are available in the paper, supplementary file and accessible from the public data sources.

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Figure legends

Figure 1. Map of pre-certification and certified countries in sub-Saharan Africa

Figure 2. Number of conflict events recorded in pre-certification and post-certification countries between 2000 – 2020

Figure 3. Location of conflict event types between 2018 – 2020 pre-certification and post-certification countries

Figure 4. Distribution of Guinea worm affected areas in relation to conflict event type between 2018 – 2020 in Chad and Mali

A. Chad affected regions

B. Chad - close up of affected regions

C. Mali affected regions

D. Mali - close up of affected regions

Supplementary files

S1. Data on the number of conflict events recorded in pre-certification and post-certification countries between 2000 – 2020

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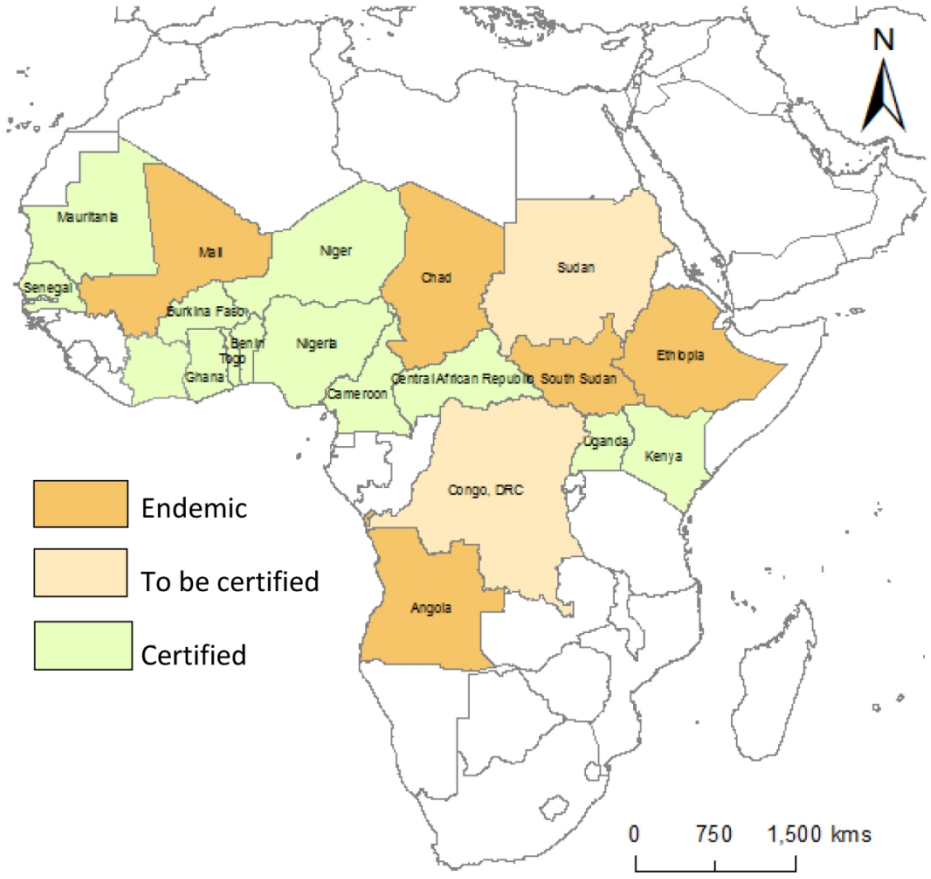

Figure 1

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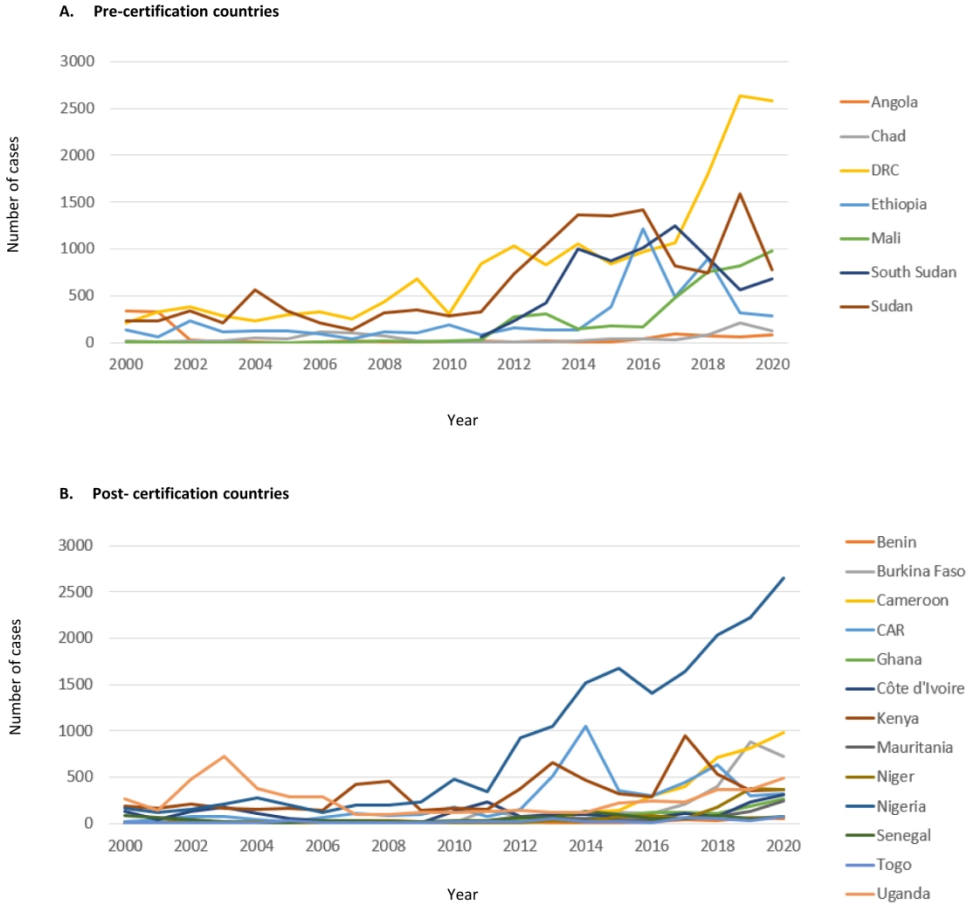

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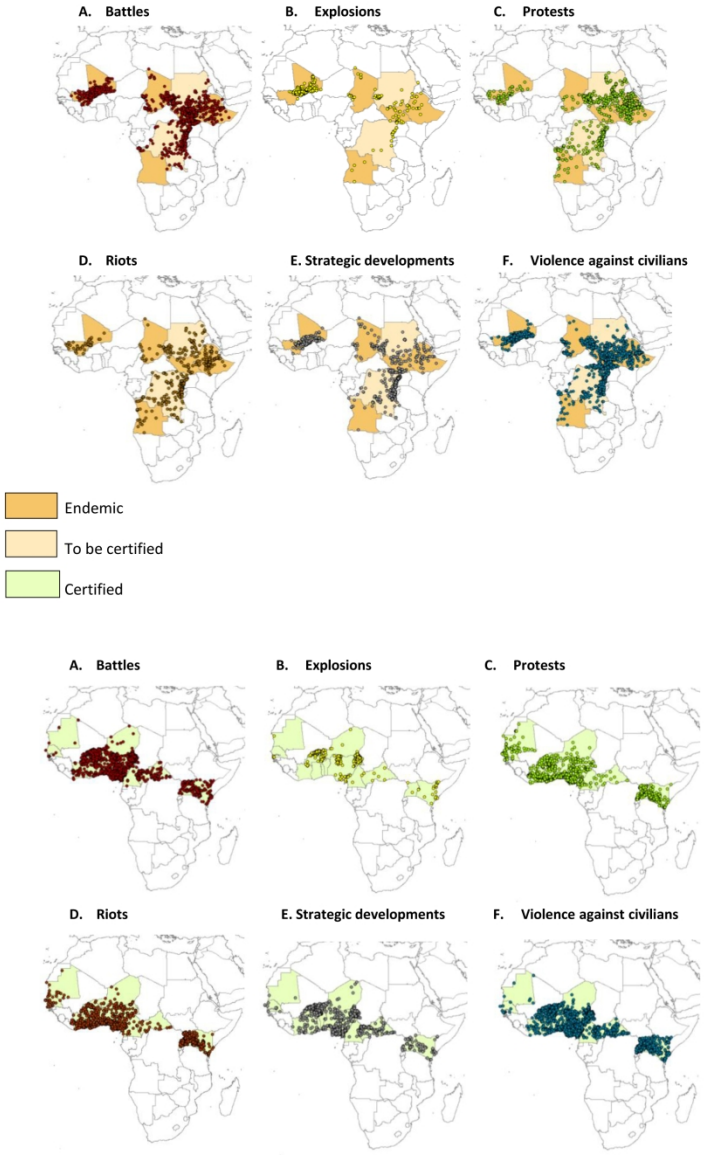

Figure 3

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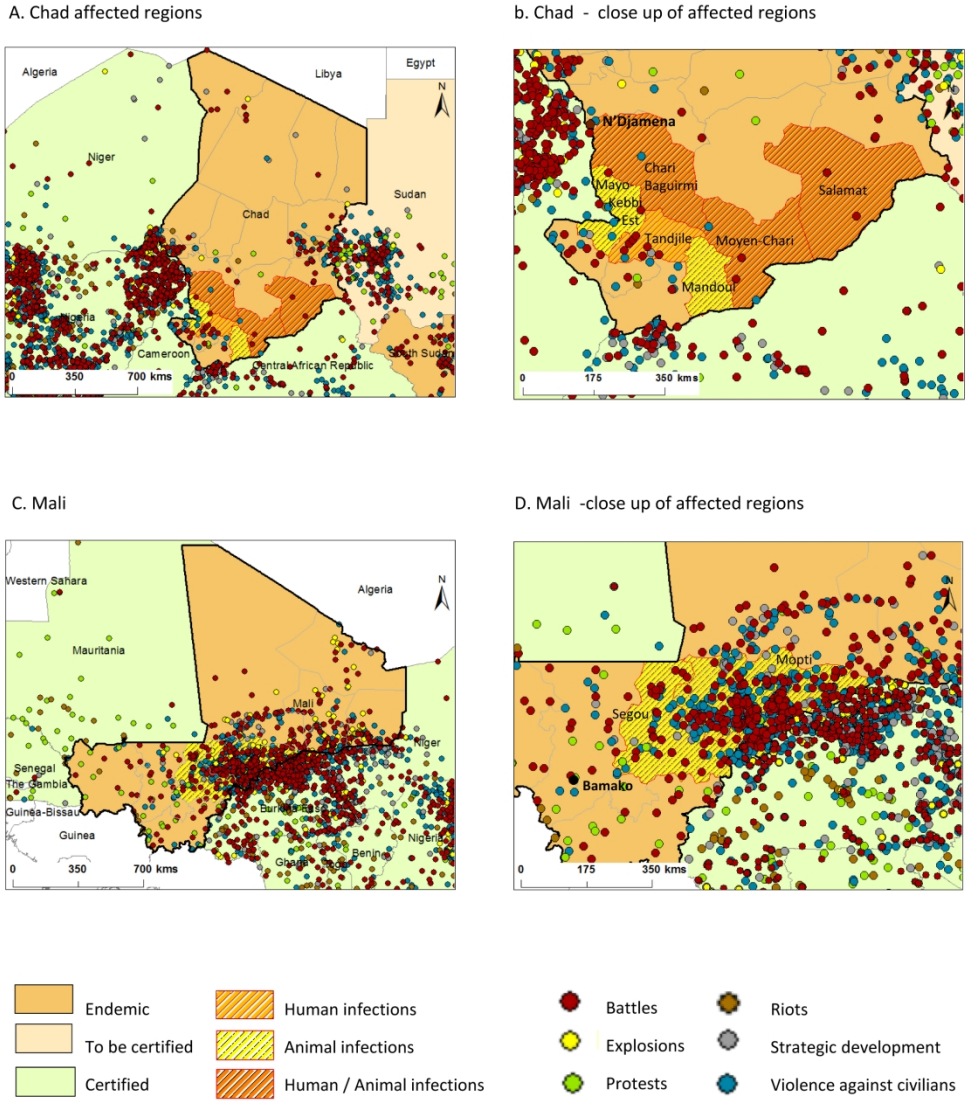

Figure 4

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S1. Data on the number of conflict events recorded in pre-certification and post-certification countries between 2000 – 2020

A. Pre-certification countries

Year	Angola	Chad	DRC	Ethiopia	Mali	South Sudan	Sudan	Total
2000	342	22	208	135	4		233	944
2001	325	11	331	57	5		233	962
2002	28	15	384	233	2		340	1002
2003	6	18	284	116	3		215	642
2004	7	47	232	124	3		562	975
2005	3	41	299	127	2		337	809
2006	6	116	330	89	10		211	762
2007	15	103	259	44	12		141	574
2008	10	75	438	113	21		318	975
2009	13	24	678	100	10		354	1179
2010	9	11	303	191	18		281	813
2011	20	6	839	83	29	58	334	1369
2012	14	8	1031	160	278	231	735	2457
2013	22	4	833	141	311	422	1039	2772
2014	8	20	1051	132	152	1004	1367	3734
2015	14	40	837	378	178	878	1358	3683
2016	45	40	969	1218	167	1008	1419	4866
2017	93	26	1063	494	473	1242	820	4211
2018	71	83	1805	892	751	900	749	5251
2019	63	210	2634	317	820	565	1593	6202
2020	88	128	2577	281	985	678	781	5518
Grand Total	**1202**	**1048**	**17385**	**5425**	**4234**	**6986**	**13420**	**49700**

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B. Post-certification countries

Year	Benin	Burkina Faso	Cameroon	CAR	Ghana	Côte d'Ivoire	Kenya	Mauritania	Niger	Nigeria	Senegal	Togo	Uganda	Total
2000	1	22	8	16	10	133	190	4	10	166	85	3	268	916
2001	3	6	5	43	8	34	165	1	9	114	61	4	138	591
2002	1	6	2	70	7	134	211	3	41	152	40	3	473	1143
2003	2	1	4	77	17	176	165	13	6	203	18	4	721	1407
2004	2	4	14	36	7	101	148	2	17	276	11	3	377	998
2005	2	6	18	21	3	45	160	9	9	198	11	25	289	796
2006	1	8	6	57	3	28	140	3	8	220	29	1	282	686
2007	3	1	20	101	5	6	421	5	31	194	24	1	96	908
2008	1	12	23	86	11	24	452	16	28	196	20	1	92	962
2009	2	1	19	97	17	5	143	10	16	225	22	4	119	680
2010	10	5	16	171	13	124	160	14	10	471	23	18	122	1157
2011	7	137	13	73	9	228	156	31	10	344	31	13	133	1185
2012	14	68	12	147	45	70	380	74	9	220	57	19	140	1955
2013	10	39	39	511	52	98	661	57	25	1049	60	52	121	2774
2014	7	123	122	1047	47	100	465	54	20	1513	130	14	114	3756
2015	8	116	135	352	86	71	322	39	71	2673	95	18	215	3201
2016	17	104	297	300	117	67	291	23	82	1410	55	10	245	3018
2017	35	204	401	448	114	105	943	56	56	1636	53	59	226	4336
2018	32	398	717	628	104	74	535	68	169	2036	88	45	364	5258
2019	60	883	815	300	187	228	352	128	370	2220	52	29	361	5985
2020	54	723	985	323	267	305	368	238	369	3647	72	68	484	6903
Total	**272**	**2867**	**3671**	**4904**	**1129**	**2156**	**6828**	**848**	**1366**	**17763**	**1037**	**394**	**5380**	**48615**

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	N/A
		(*b*) Describe any methods used to examine subgroups and interactions	6-7
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8-10
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-12
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	8-12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A

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		(*b*) Report category boundaries when continuous variables were categorized	8-12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-12
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13-
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13-14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	N/A

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Quantifying conflict zones as a challenge to certification of Guinea Worm Eradication in Africa – a new analytical approach

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Original Research

Title: Quantifying conflict zones as a challenge to certification of Guinea Worm Eradication in Africa – a new analytical approach

Authors: Louise A. Kelly-Hope[1,2] and David H. Molyneux[2]

Corresponding author: Dr Louise Kelly-Hope
Department of Livestock and One Health
Institute of Infection, Veterinary & Ecological Sciences
University of Liverpool, Liverpool, UK
Email: L.Kelly-Hope@liverpool.ac.uk

Institutional affiliation

1. Department of Livestock and One Health, Institute of Infection, Veterinary & Ecological Sciences, University of Liverpool, Liverpool, UK
2. Department of Tropical Disease Biology, Liverpool School of Tropical Medicine, Liverpool, UK

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Abstract

Objectives: To quantify conflict events and access across countries that remain to be certified free of transmission of *Dracunculus medinensis* (Guinea worm disease) or require post-certification surveillance as part of the Guinea Worm Eradication Program (GWEP).

Setting and participants: Populations living in Guinea worm affected areas across seven pre-certification countries and 13 post-certification Sub-Saharan African countries.

Outcome measures: The number of conflict events and rates per 100,000 population, the main types of conflict and actors reported to be responsible for events were summarised and mapped across all countries. Chad and Mali were presented as case studies. Guinea worm information was based on GWEP reports. Conflict data were obtained from the Armed Conflict Location and Event Data Project. Maps were created using ArcGIS 10.7 and access was measured as regional distance and time to cities.

Results: More than 98,0000 conflict events were reported between 2000-2020, with a significant increase since 2018. The highest number and rates were reported in pre-certification Mali (n=2556; 13.0 per 100,000), South Sudan (n=2143; 19.4), Democratic Republic of Congo (n=7016; 8.1), and post-certification Nigeria (n=6903; 3.4), Central Africa Republic (n=1251; 26.4), Burkina Faso (n=2004; 9.7). Violence against civilians, protests and battles were most frequently reported with several different actors involved including Unidentified Armed Groups and Boko Haram. Chad and Mali had contracting epidemiological and conflict situations with affected regions up to 700km from the capital or 10 hours to the nearest city.

Conclusions: Understanding the spatial-temporal patterns of conflict events, identifying hotspots, the actors responsible, and their sphere of influence is critical for the GWEP and other public health programmes to develop practical risk assessments, deliver essential health interventions, implement innovative surveillance, determine certification, and meet the goals of eradication.

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Strengths and limitations of this study

- This study is the first to analyse the impact, extent and challenges facing the Guinea Worm Eradication programme as a result of increased conflict in sub-Saharan Africa.
- The methodology employed is based on conflict data downloaded from the Armed Conflict Location and Event Data Project (ACLED) using geo-referenced location data on conflict event types.
- This real- time data can be used by both endemic countries and international organizations for planning programmatic activities for risk assessment purposes for surveillance and certification planning.
- Such data will inform the time scale for Guinea Worm Certification missions given that access to and information from areas where risk of conflict exists will require innovative approaches to acquire robust epidemiological data as a prerequisite for certification of absence of transmission in a country.

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Introduction

Guinea Worm or Dracunculiasis is one of two infections that have been designated formally by the World Health Assembly as diseases targeted for eradication, the other being poliomyelitis.[1–3] Yaws eradication has also been included as a target in the recently approved World Health Organization(WHO) Neglected Tropical Disease (NTD) Road Map 2021-2030.[4] Eradication requires Certification of each member state of the United Nations as being free of transmission of the infectious agent *Dracunculus medinensis*. The Guinea Worm Eradication Program (GWEP) has more recently adopted specific definitions approved by the International Commission for the Certification of Dracunculiasis Eradication (ICCDE), which reflect the criteria required to confirm the elimination from a country and following that the need for all countries to be free of transmission prior to Global Certification of Eradication by the World Health Assembly.[2]

> *Elimination of dracunculiasis is the confirmed absence of the emergence of adult female worms (the interruption of transmission of D. medinensis) in humans and animals for three consecutive years or longer from a country with such a low risk of reintroduction of the parasite that preventive measures could be reduced to a strict minimum. Worldwide eradication of dracunculiasis is the confirmed absence of the emergence of adult female worms (defined as compatible with the interruption of transmission of D. medinensis) in humans and animals for three years or longer at the global level.*[2]

Recently, the challenges of certifying elimination in countries and then eradication globally have been highlighted.[5,6] Whilst the numbers of human cases have declined by over 99% since the programme began in the late 1980s[7] from an estimated 3 million cases per year to some 27 cases reported to date in 2020,[3,8,9] the problems of animal infections, in particular in dogs, has arisen and in Chad new modes of transmission have been uncovered involving paratenic hosts in fish, predominantly small “fingerlings”.[10–13] Whilst Chad is the most serious challenge to global eradication given the high numbers of dogs reported infected annually (over 1900 in 2019 and 1500 in 2020),[14,15] dogs have been found infected consistently, albeit in small numbers in Mali, Ethiopia and Angola.[2,3] The problems of insecurity have been a continuing part of the GWEP for as long ago as 1995 when President Jimmy Carter personally negotiated a “Guinea Worm ceasefire” in South Sudan to enable all programme activities to recommence,[16] whilst Mali has experienced heightened insecurity over recent years making access to some endemic areas difficult.[17] In early 2021 the death of the President of Chad has destabilised the regime and some GWEP Chad programme staff have been evacuated from the country).[3]

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Whilst the challenge of animal infections is a recent phenomenon, all countries previously certified have not reported any animal infections despite surveillance in formerly endemic areas.[15] However, a significant further challenge is the problem of access to insecure areas due to conflict and violence.[5,6,15,18] Five endemic countries require to be certified together with the Democratic Republic of Congo (DRC) and Sudan , whilst not currently endemic, having not reported a human case since 1958 and 2002 respectively, require to be verified as free of transmission based on a visit from an International Certification Team (ICT). If access due to insecurity and conflict is curtailed or limited given the onus on any ICT is to "prove a negative" as far as is possible would be impaired and would limit the validity of any report which recommended that the country was free of transmission. "Proving a negative" is not possible in any public health or scientific endeavour hence the ICT missions have to balance judgements made on the basis of available information and data supplied by the country.

At present there is no standardised approach to evaluate the level of conflict risk in Guinea worm endemic countries which cover vast areas of Africa. This is critical, as conflict significantly disrupts the implementation of health service delivery, impact assessments, research and surveillance.[19–22] In this paper we present an approach to quantifying the risks in countries yet to be certified, as well as those already certified but require continuing surveillance until global eradication has been declared. Since elimination of transmission was confirmed by the ICCDE in some 13 countries in Africa, the security situation has changed. Civil unrest and insecurity will have impacted on the ability of countries to maintain a level of surveillance compatible with adequate post-certification scrutiny. This applies, in particular to Sahelian countries, where jihadist movements control large swathes of some countries and where national authorities have limited access or control. This is exemplified in Niger, Burkina Faso, Nigeria, Senegal, Mauritania and Cameroon whereas in Central African Republic (CAR) inter religious conflict prevents access to the area bordering Chad.[23,24] In the DRC there is significant conflict in eastern regions of the country and the border of South Sudan and Sudan has a high level of insecurity.

To address this challenge, we examined the number of conflict events from 2000 to 2020 to highlight long-term temporal trends in countries i) previously certified as free of transmission, ii) currently endemic (pre-certification countries) and iii) requiring certification but which have not recorded a case of the infection since the inception of the GWEP in the late 1980's. We quantified the number of conflict events and rates per 100,000 population for the most recent years, highlight the main types of conflict and the main actors responsible, as well as present specific data from Chad and Mali as case studies.

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Methods

Study area

The cross-sectional study included sub-Saharan African countries that were categorised as those in the pre-certification stage and those in the post-certification stage.

Pre-certification countries included those currently endemic for dracunculiasis, namely Angola, Chad, Ethiopia, Mali and South Sudan (from 2011 Independence onwards), and countries with historical evidence of Guinea worm but are yet to been certified as free from dracunculiasis, including the DRC and Sudan.

Post-certification countries included Benin, Burkina Faso, Cameroon, CAR, Cote d'Ivoire, Ghana, Kenya, Mauritania, Niger, Nigeria, Senegal, Togo and Uganda. The dates when these countries were certified free of transmission are provided in Molyneux et al..[5] See Figure 1 for the map of pre-certification and post-certification countries which cover vast geographical regions of sub-Saharan Africa covering more than 15 million square kilometres (km^2)[25] with poor accessibility to urban centres or cities.[26] The land area of each country is shown in Table 1 with Angola, Chad, DRC, Mali, Niger and Sudan more than 1.2 million km^2 in size.

Figure 1. Map of pre-certification and post-certification countries in sub-Saharan Africa

Data sources

To examine Guinea worm status in relation to spatial and temporal distribution of conflict events and regional access within each country, several data sources were obtained;

- Guinea worm information was based on World Health Organisation (WHO) annual reports and Dracunculiasis Eradication Portal,[2,15,27] and GWEP reports by The Carter Centre and the Centres for Disease Control and Prevention.[3,8]
- Conflict data were downloaded from the Armed Conflict Location and Event Data Project (ACLED),[28,29] including geo-referenced location data on conflict event types categorised as battles, riots, protests, strategic developments, explosions/remote violence and violence against civilians and actors i.e. groups of people or organisations reported to be responsible for the events (definitions available on ACLED website)[29] for the period from January 2000 to October 2020.
- Population data were obtained from the World Bank databank and based on 2019 estimates.[25]

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- Administrative boundary information was obtained from the United Nations Office for the Coordination of Humanitarian Affairs (OCHA).[30]
- Accessibility information was based on regional distance (kilometres (kms)) to the capital city and from modelled maps of 'Accessibility to cities', quantified as travel time in minutes (converted to hours) to the nearest high-density urban centre or city at a resolution of 1 x 1 km for 2015.[26]

These data sources represent the best available in the public domain, and it is acknowledged that there may be some missing cases and conflict event data, and differences in population estimates, country size and accessibility compared with other sources.

Patient and public involvement

No patient was included in this study.

Data analysis and mapping

Conflict and population data were downloaded, and collated, tabulated and graphed in Microsoft Excel (Microsoft Corporation, Redmond, WA) and the administrative boundary and accessibility to cities data were downloaded and imported into geographical information software (GIS) ArcGIS 10.7 (ESRI, Redlands, Ca) for mapping using the available GPS coordinates and descriptive analysis.

First, the number of conflict events for the pre-certification and post-certification countries were summarised for years from 2000 to 2020 to highlight long-term temporal trends and high-conflict Guinea worm countries.

Second, the overall number of conflict events and rates per 100,000 population for the most recent years, 2018 to 2020, were quantified for each country. The different types of conflict events were tabulated and mapped, and the countries with the most events and highest rates per population were identified as high-conflict countries. The main actors reported to be responsible for the highest number of events in the high-conflict countries were summarised.

Finally, the situation in Chad and Mali since 2018 was presented as contrasting case studies, and included a summary and maps of the number of Guinea worm human and/or animal cases and regions affected; the number of conflict events types and main actors in each region; and accessibility of each region measured as the distance (kms) between the centre of each region and

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each capital city using the Measure tool in ArcGIS, and the average time (hours) of each region to high-density urban centre or city based on data extracted using the Zonal Statistics tool in ArcGIS.

Results

Overall summary 2010-2020

The total number conflict events reported for pre-certification and post-certification countries between 2000-2020 is shown in Figure 2A and 2B (data available in Supplementary file 1). Overall, the temporal trends in conflict events across all countries were similar with a marked increase from 2010 onwards.

In the five endemic countries, a total of 18,895 conflict events were reported between 2000-2020 with the highest numbers in South Sudan (n=6986 from 2011 onwards) representing 37.0% of the total. In the first decade between 2000-2010, a total of 2437 events were reported, which increased 6.8-fold to 16,458 events between 2011-2020, with 41.5% reported in the last three years since 2018. In the two countries yet to be certified, a total of 30,805 events were reported with the highest numbers in DRC (n=17,385; 56.4%). Between 2000-2010, a total of 6387 events were reported, which increased 3.8-fold to 24,418 events between 2011-2020, with 41.5% reported in the last three years.

In the post-certification countries, a total of 48,615 events were reported with the highest numbers in Nigeria (n= 17,763) representing 36.5% of the total. In the first decade between 2000-2010, the 10,244 events were reported, which increased 3.7-fold to 38,371 events between 2011-2020, with around one third (37.3%) reported in the last three years.

Figure 2. Number of conflict events reported in pre-certification and post-certification countries between 2000 – 2020

Summary of conflict events in recent years 2018 – 2020

Pre-certification countries

In the five endemic countries where transmission of *D. medinensis* is ongoing, an overall total of 6,832 conflict events were reported between 2018-2020 (Table 1A; Figure 3). The highest numbers and rates per 100,000 population were reported in Mali (n=2556; 13.0 per 100,000) and South

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Sudan (n=2143; 19.4 per 100,000). Overall, the most frequently reported events included violence against civilians (n=2373), protests (n=993), and battles (n=2055) with South Sudan reporting the highest number violence incidents against civilians (39.1% of total) and battles (46.4%) and Ethiopia reporting the highest number of protests (49.8%). South Sudan also reported the highest rates of violence against civilians (8.4 per 100,000), and battles (8.6 per 100,000), and Mali the highest rates of protests (1.3 per 100,000). A summary of the actors reported to be responsible for the highest number and type of conflict events in the high-risk countries is shown in Table 2A. For Mali, the actors reported for the most events included JNIM: Group for Support of Islam and Muslims (n=661); Unidentified Armed Group (Mali) (n=434) and Protesters (n=261). For South Sudan, the actors included the Military Forces of South Sudan (2011-) (n=543), Unidentified Armed Group (South Sudan) (n=399) and the Sudan People's Liberation Movement-In Opposition (n=157).

In DRC and Sudan (two countries where transmission has not been reported recently but required to be certified), a total of 10,139 events were reported between 2018-2020 (Table 1B; Figure 3). The highest number and rate per 100,000 population were reported in DRC (n=7016; 8.1 per 100,000). The most frequently reported events included violence against civilians (n=3242) protests (n=2656), and battles (n=2628) with DRC reporting the highest number of these events representing 76.6%, 38.6% and 86.2% of the total respectively. The DRC also reported the highest rates of violence against civilians (2.9 per 100,000) and battles (2.6 per 100,000), and Sudan the highest rates of protests (3.8 per 100,000). A summary of the actors reported to be responsible is shown in Table 2A. The main actors associated with the two most reported events in both countries included an Unidentified Armed Group (DRC=1236; Sudan =233), and Protesters (DRC=975; Sudan=1590).

Figure 3. Location of conflict event types reported in endemic /pre-certified and certified countries between 2018 – 2020

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Table 1. Summary of conflict events reported in pre-certification and post-certification countries between 2018 – 2020

A. Pre-certification countries

Country	Land area (sq.km)	Population (millions)	Battles	Explosions Remote violence	Protests	Riots	Strategic develop-ments	Violence against civilians	Total number of events	Events per 100,000 population
Angola	1,246,700	31.8	8	4	108	37	12	53	222	0.7
Chad	1,259,200	15.9	125	36	63	41	57	99	421	2.6
Ethiopia	1,000,000	112.1	242	18	495	206	120	409	1490	1.3
Mali	1,220,190	19.7	727	319	259	123	245	883	2556	13.0
South Sudan	644,329	11.1	953	28	68	43	122	929	2143	19.4
Total	**5,370,419**	**191**	**2055**	**405**	**993**	**450**	**556**	**2373**	**6832**	**3.6**
Democratic Republic of Congo	2,267,050	86.8	2266	23	1025	574	645	2483	7016	8.1
Sudan	1,861,484	42.8	362	43	1631	197	131	759	3123	7.3
Total	**4,128,534**	**130**	**2628**	**66**	**2,656**	**771**	**776**	**3,242**	**10,139**	**7.8**
Overall total	**9,498,953**	**320**	**4683**	**471**	**3649**	**1221**	**1332**	**5615**	**16971**	**5.3**

B. Post-certification countries

Country	Land area (sq.km)	Population (millions)	Battles	Explosions Remote violence	Protests	Riots	Strategic develop-ments	Violence against civilians	Total number of events	Events per 100,000 population
Benin	112,760	11.8	20		32	50	9	35	146	1.2
Burkina Faso	273,600	20.3	498	139	289	73	273	732	2004	9.9
Cameroon	472,710	25.9	779	65	162	73	332	1106	2517	9.7
Central Africa Republic	622,980	4.7	352	9	85	61	282	462	1251	26.4
Cote d'Ivoire	318,000	25.7	51	1	235	252	23	45	607	2.4
Ghana	227,540	30.4	64		211	161	21	101	558	1.8
Kenya	569,140	52.6	177	39	368	319	50	302	1255	2.4
Mauritania	1,030,700	4.5	4	1	388	24	9	8	434	9.6
Niger	1,266,700	23.3	165	63	63	42	144	431	908	3.9
Nigeria	910,770	201	1654	360	1746	611	312	2220	6903	3.4
Senegal	192,530	16.3	12	3	119	55	11	12	212	1.3
Togo	54,390	8.1	12		55	43	10	22	142	1.8
Uganda	200,520	44.3	103	3	270	453	53	327	1209	2.7

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Total	**6,252,340**	**468.9**	**3891**	**683**	**4023**	**2217**	**1529**	**5803**	**18146**	**3.9**

Table 2. Summary of main actors reported to be responsible for the most conflict event type most in selected pre-certification and post-certification countries between 2018-2020

A. Pre-certification countries

Country Main Actor	**Battles**	**Explosions Remote violence**	**Protests**	**Riots**	**Strategic develop-ments**	**Violence against civilians**	**Total number**
Mali							
JNIM: Group for Support of Islam and Muslims	253	216			45	147	661
Unidentified Armed Group (Mali)	88	17		1	83	245	434
Protesters (Mali)			259		2		261
Fulani Ethnic Militia (Mali)	75	1			10	136	222
Military Forces of Mali (2013-2020)	48	8		1	30	78	165
Islamic State (Greater Sahara)	62	12			5	58	137
South Sudan							
Military Forces of South Sudan (2011-)	362	10		1	19	151	543
Unidentified Armed Group (South Sudan)	69	16			7	307	399
Sudan People's Liberation Movement-In Opposition	67	2			17	71	157
NAS: National Salvation Front	67				4	41	112
Murle Ethnic Militia (South Sudan)	33				1	60	94
Unidentified Communal Militia (South Sudan)	18				2	49	69
Democratic Republic of Congo							
Unidentified Armed Group (DRC)	248	9			85	894	1236
Protesters (DRC)			972		3		975
Military Forces of the DRC (2019-)	528	4		1	70	116	719
ADF: Allied Democratic Forces	201	5			8	332	546
Rioters (DRC)				534			534
Military Forces of the DRC (2001-2019)	302	2		2	43	58	407
Sudan							
Protesters (Sudan)			1590		7		1597
Unidentified Armed Group (Sudan)	24	13	2		8	186	233
Rioters (Sudan)			1	182			183
Military Forces of Sudan (1989-2019)	77	22	3	1	12	43	158
Military Forces of Sudan (1989-2019) Rapid Support Forces	28	4	4	3	17	90	146
Darfur Communal Militia (Sudan)	20				3	119	142
Unidentified Communal Militia (Sudan)	9			1	3	102	115

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B. Post-certification countries

Country Main Actor	Battles	Explosions Remote violence	Protests	Riots	Strategic developments	Violence against civilians	Total number
Nigeria							
Protesters (Nigeria)			1735				1735
Unidentified Armed Group (Nigeria)	181	9		1	53	789	1033
Military Forces of Nigeria (2015-)	552	261	2	1	105	44	965
Fulani Ethnic Militia (Nigeria)	90				22	590	702
Rioters (Nigeria)				605			605
Islamic State (West Africa) and/or Boko Haram - Jamatu Ahli is-Sunnah lid-Dawatai wal-Jihad	236	57			26	204	523
Cameroon							
Islamic State (West Africa) and/or Boko Haram - Jamatu Ahli is-Sunnah lid-Dawatai wal-Jihad	192	34			144	447	817
Military Forces of Cameroon (1982-)	272	2		1	59	308	642
Ambazonian Separatists (Cameroon)	224	9			55	175	463
Unidentified Armed Group (Cameroon)	30	18			26	121	195
Protesters (Cameroon)			161				161
Rioters (Cameroon)				72			72
Central Africa Republic							
Unidentified Armed Group (CAR)	71	5			66	129	271
UPC: Union for Peace in the CAR	64				37	54	155
FPRC: Popular Front for the Renaissance of Central Africa	25				19	51	95
Anti-Balaka	46				10	35	91
Protesters (CAR)			84		1		85
LRA: Lords Resistance Army	7				23	52	82
Burkina Faso							
JNIM: Group for Support of Islam and Muslims and/or Islamic State (Greater Sahara)	122	24			115	194	455
JNIM: Group for Support of Islam and Muslims	131	47			50	112	340
Protesters (Burkina Faso)			287		8		295
Military Forces of Burkina Faso (2015-)	40	26			25	89	180
Islamic State (Greater Sahara)	53	10			19	86	168
Unidentified Armed Group (Burkina Faso)	46	1		1	16	91	155

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Post-certification countries

In the post-certification countries, a total of 18,146 events (3.9 per 100,000) were reported between 2018-2020 (Table 1B; Figure 3). The highest numbers reported were in Nigeria (n=6903), Cameroon (n=2517), Burkina Faso (n=2004), and the highest rates in CAR (26.4 per 100,000), Burkina Faso (9.9 per 100,000) and Cameroon (9.7 per 100,000). The most frequently reported events included violence against civilians (n=5803) protests (n=4023), and battles (n=3891) with Nigeria reporting the highest number of these events representing 38.3%, 43.4% and 42.5% of the total respectively. The CAR reported the highest rates of battles (7.4 per 100,000), and violence against civilians (9.7 per 100,000), and Mauritania the highest number of protests (8.5 per 100,000).

A summary of the actors reported to be responsible for the highest number and type of conflict events in the high-risk countries is shown in Table 2B. For Nigeria, the actors associated with the two most reported events included Protesters (Nigeria) (n=1735) and an Unidentified Armed Group (n=1033). For Cameroon, the actors included the Islamic State (West Africa) and/or Boko Haram - Jamatu Ahli is-Sunnah lid-Dawatai wal-Jihad (n= 817) and Military Forces of Cameroon (1982-) (n=642). For CAR, the actors included an Unidentified Armed Group (CAR) (n=271) and the UPC: Union for Peace in the Central African Republic (n=155). For Burkina Faso, the actors included JNIM: Group for Support of Islam and Muslims and/or Islamic State (Greater Sahara) (n=455) and JNIM: Group for Support of Islam and Muslims (n= 340).

Chad case study

The capital N'Djamena and six regions reporting Guinea worm human cases and/or animal infections between 2018 and 2020 are shown in Figure 4A and 4 B, together with the conflict event types reported in Chad, and the neighbouring pre-certification country of Sudan and post-certification countries of Cameroon, CAR and Niger.

Guinea worm situation. Human disease cases were reported in 2018 (n=17), 2019 (n=48) and 2020 (n=13). The areas affected included the Chari Baguirmi region, in Bailli (2018; 2019), Bousso (2018; 2019; 2020), Dourbali (2019), Kouno (2019) and Mandelia (2018; 2020) districts; the Moyen Chai region, in Danamadji (2019), Korbal (2018; 2019) Kyabe and Sahr (2018; 2019; 2020) districts; the Salamat region, in Aboudeia (2018; 2019; 2020), Amtiman (2018; 2019) and Haraze (2019); the Tanjile region in Bere district (2018) and the Wadi-Fira region in Matadjana district (2020).

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Animal infections, predominately domesticated dog infections were high and reported in 2018 (n=1040), 2019 (n=1935) and 2020 (n=1464). The areas affected included the capital N'Djamena (2018) and the Chari Baguirmi (2018; 2019), Mandoul (2018), Moyen Chai (2018; 2019), Mayo-Kebbi Est (2018; 2019) and Salamat (2018; 2019) regions (Figure 4B).

Conflict events. The highest number of conflict events was reported in N'Djamena (n=104) (Table 3A), were predominately protests (44 events) with protestors reported as the main actors. In the other Guinea worm affected regions, the number of conflict events was lower and ranged from 0 - 13 events in 2018-2020. The main conflict event type in the Chari-Baguirmi region was of violence against civilians (3 events) with Military Forces, Police Forces and Moile Communal Militia the main actors; in Moyen-Chari was battles (2 events; Unidentified Communal Militia Chad); in Salamat was battles (2 events; Nomad and National Guard and Unidentified Communal Militia); in Tanjili was battles (10 events; Fulani Militia, Koutoune Communal Militia; Tandjile Communal militia and Unidentified Armed Group); and in Mayo-Kebbi Est was violence against civilians (4 events; Nomad and National Guard, Military Forces, Unidentified Armed Group (Cameroon and Chad)).

Regional access. The level of access in terms of distance (kms) to the capital N'Djamena and accessibility to a city in hours within Chad and in relation to Guinea worm status and conflict events is shown in Table 3A. Of the Guinea worm affected regions, Salamat (600-700kms) was the furthest from the capital and had the longest estimated time of 10 hours to the nearest city. Of the northerly non-endemic regions, the Lac (n=88), Quadd (n=57) and Tibesti (n=55) had the highest number of conflict events, with Tibesti (900-1000km) the furthest distance and had the longest estimated time of 42.1 hours to the nearest city.

Mali case study

The capital Bamako and two regions reporting Guinea worm animal infections in 2018-2020 are shown in Figure 4C and 4D, together with the conflict event types reported in Mali, and the neighbouring pre-certification countries of Burkina Faso, Niger and Mauritania.

Guinea worm situation. One human case was reported in early 2020 – the first human case reported since 2015. Animal infection, predominately domesticated dog infections were reported in 2018 (n=18), 2019 (n=8) and 2020 (n=9). The areas affected included the Mopti region, in Djenne (2018;

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2019; 2020) district, and the Segou region in Markal (2018), Tominian, Macina (2018; 2019; 2020) and Baroueli (2020) districts (Figure 4D).

Conflict events. The highest number of conflict events was reported in Mopti region (n=1206) (Table 3B), predominately violence against civilians (561 events) and battles (347 events) with Fulani Ethnic Militia, Groups for Support of Islam and Muslims, Unidentified Armed Group and/ or Military Forces reported as the main actors associated with these events. The main conflict events in the Segou region were battles (55 events) and violence against civilians (44 events) with Group for Support of Islam and Muslims reported as the main actors associated with battles and Military Forces of Mali and Dozo Communal Militia main actors for violence against civilians.

Regional access. The level of access in terms of distance to the capital Bamako and accessibility to a city in hours within Mali and in relation to case status and conflict events is shown in Table 3B. Of the Guinea worm affected regions, Mopti was the furthest from the capital Bamako, approximately 500-600 km, and had the longest accessibility time of 4.1 hours to the nearest city. Of the unaffected regions, Gao (n=503), and Tombouctou (n=264) had the highest number of conflict events, with Gao (1000-1100kms) the furthest away from the capital, and Tombouctou the longest estimated time of 62.9 hours to the nearest city.

Figure 3. Location of conflict event types reported in endemic /pre-certified and certified countries between 2018 – 2020

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Table 3. Summary of Guinea worm status, conflict events and regional access for case study countries

A. Chad case study

Region	Guinea worm status	Number of conflict events	Distance from N'Djamena (kms)	Accessibility to city (hrs)
N'Djamena	Dog	104	-	-
Chari-Baguirmi	Human/Animal	3	100-200	3.4
Moyen-Chari	Human/Animal	4	500-600	3.5
Salamat	Human/Animal	4	600-700	10.4
Tandjii	Human	13	300-400	3.7
Mayo-Kebbi Est	Dog	7	200-300	2.8
Mandoul	Dog	0	400-500	1.8
Barh-El-Gazel	No reports	1	300-400	11.2
Batha	No reports	3	400-500	8.6
Borkou	No reports	7	600-700	23.3
Ennedi Est	No reports	6	1000-1100	35.2
Ennedi Ouest	No reports	3	900-1000	30.8
Guera	No reports	1	400-500	4.9
Hadjer-Lamis	No reports	8	100-200	3.8
Kanem	No reports	3	300-400	14.1
Lac	No reports	88	100-200	4.9
Logone Occidental	No reports	8	300-400	1.9
Logone Oriental	No reports	6	400-500	1.9
Mayo-Kebbi Ouest	No reports	21	300-400	2.9
Ouadd	No reports	57	600-700	4.1
Sila	No reports	12	700-800	7.2
Tibesti	No reports	55	900-1000	42.1
Wadi Fira	Human	7	800-900	7.6

B. Mali case study

Region	Guinea worm status	Number of conflict events	Distance from Bamako (kms)	Accessibility to city (hrs)
Bamako	No reports	148	-	-
Mopti	Dog	1206	500-600	4.1
Segou	Dog	145	200-300	2.2
Gao	No reports	503	1000-1100	7.1
Kayes	No reports	62	200-300	3.8
Kidal	No reports	92	1200-1300	16.6
Koulikoro	No reports	63	100-200	3.7
Menaka	No reports	15	1200-1300	14.0
Sikasso	No reports	58	200-300	1.9
Tombouctou	No reports	264	900-1000	62.9

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Discussion

The GWEP has made remarkable progress since activities began in the late 1980's with the WHO reporting only tens of human cases in recent years. [15,27] This success has been driven by country commitment, the support from the WHO[2] and The Carter Center[3] and articulating the fundamental public health interventions to eliminate the transmission - case containment, control of copepods, access to safe drinking water (including filtration), regular reporting and surveillance, and instituting a reward system and the follow up of rumours.[5,7]

This paper, however, documents that over the past two decades, the numbers of incidents of conflict and violence have increased dramatically, especially in the last 3 years since 2018. This is not only of concern for endemic countries, but for the two countries yet to be certified, and the 13 countries that were previously endemic for the infection requiring ongoing surveillance.[2] The Guinea worm community have increasingly recognised that certification will face the challenges of acquiring comprehensive and reliable information in conflict zones and in accessing areas where national governments have limited control.[5,8,15] In addition, the porosity of international borders, extensive migration generated by insecurity, inter-country range of many of the actors responsible for violence, and the need for these geographically vast countries to ensure that any Guinea worm case is recognised and reported, highlights the immense challenges programmes face to satisfy the criteria for certifying the absence of transmission and the effectiveness of surveillance.[6]

The characteristics of the situation in areas of West and Central Africa are that there are many groups who are responsible for violence at both national and local levels and their motivations are different, even within the same region.[28,29] Understanding how these challenges for the GWEP can be overcome is essential if the country elimination objective and global eradication certification is to be achieved. Providing detailed data, as described in this paper, is necessary so risk assessments can be made to safely operationalise field work, especially in remote locations where access is limited.[20,31] This underscores the value of understanding the spatial and temporal patterns of conflict, identifying hotspots, the actors responsible and their sphere of influence. This information will allow the potential impact of violence on GWEP activities to be assessed consonant with the need to satisfy the robust criteria established by WHO a country to be certified by the ICCDE based on the information in the detailed national report submitted to WHO, and on which the ICT to base their assessments on the likelihood of the country being free of *D. medinensis* transmission. WHO and the Carter Center should avail itself of the real-time data available from ACLED to evaluate the challenges and risks to programme staff and in planning certification missions, WHO, should seek to acquire Guinea worm relevant information from areas designated to be of high security risk by

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country UN Security Advisors as innovative means of acquiring the necessary information for certification will be required.

We have summarised in detail the magnitude, geographical extent and increasing incidence of conflict and violence in those countries where Guinea worm remains a problem for those responsible for ensuring a successful endgame for eradication, which now has a target of 2030 for global certification.[4] The scale of the challenge can probably best be illustrated by the fact the that the total area of pre-certification countries is similar to continental USA.[25] This WHO NTD Road Map target implies that all countries that remain to be certified must have zero cases in humans and animals by 2026/7 as a minimum of three years is required of zero global cases must be reported over the period 2027- 2030. This will require intense integrated human and animal surveillance, in countries at present suffering conflict events, with a trend that is regrettably accelerating rather than diminishing. The Chad and Mali case studies highlight the multifaceted epidemiological and conflict situations, the challenging access and safety issues, which will require bespoke risk assessments and innovative strategies to reach certification. A One Health approach including human, animal and environmental components should be considered given the evolving modes transmission,[32,33] taking the cost-effectiveness[34] and conflict context into account.

The case and conflict event data used in this study are valuable resources to use as a first step in assessing a situation. However, as there are some limitations with using secondary data, it will be important to supplement this information with details from local, reliable sources and trusted partners on the ground, this may help to determine the actors motivations and identify areas that are considered “secure”. Further, it will be important that local GWEP staff have data management and analytical skills to access, download, examine, summarise and map the data in a meaningful way to inform the programmes. Mapping skills may be developed using user-friendly open sources GIS software such as QGIS (www.qgis.org), which is free to download, has many available online training tutorials available and a range of analytical tool that can produce the same results as presented in this paper.

The methodology and tools we have used in this paper provide a better understanding of the challenges the GWEP faces and are based on the recent studies undertaken to understand and address the risks for other NTD programmes.[35] These should be more widely promoted not only for Guinea worm, but as a management and risk assessment tool for other research and health programmes working in areas and countries of complex emergencies and insecurity.

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Contributors

LAKH and DHM conceptualised the paper. LAKH accessed data sources, applied analytical methods and produced the maps. Both authors contributed to the data interpretation, writing the first and final version of the manuscript.

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Competing interests

LAKH declares no competing interests. DHM is a member of the International Commission for the Certification of Dracunculiasis Eradication

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Data availability statement

All data are available in the paper, supplementary file and accessible from the public data sources.

Ethical Approval

No ethical approval was necessary for the paper as it does not involve work on human or animal subjects or experimental work and is based on using analysis of data available in the public domain.

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Figure legends

Figure 1. Map of pre-certification and certified countries in sub-Saharan Africa

Figure 2. Number of conflict events recorded in pre-certification and post-certification countries between 2000 – 2020

Figure 3. Location of conflict event types between 2018 – 2020 pre-certification and post-certification countries

Figure 4. Distribution of Guinea worm affected areas in relation to conflict event type between 2018 – 2020 in Chad and Mali

A. Chad affected regions

B. Chad - close up of affected regions

C. Mali affected regions

D. Mali - close up of affected regions

Supplementary files

S1. Data on the number of conflict events recorded in pre-certification and post-certification countries between 2000 – 2020

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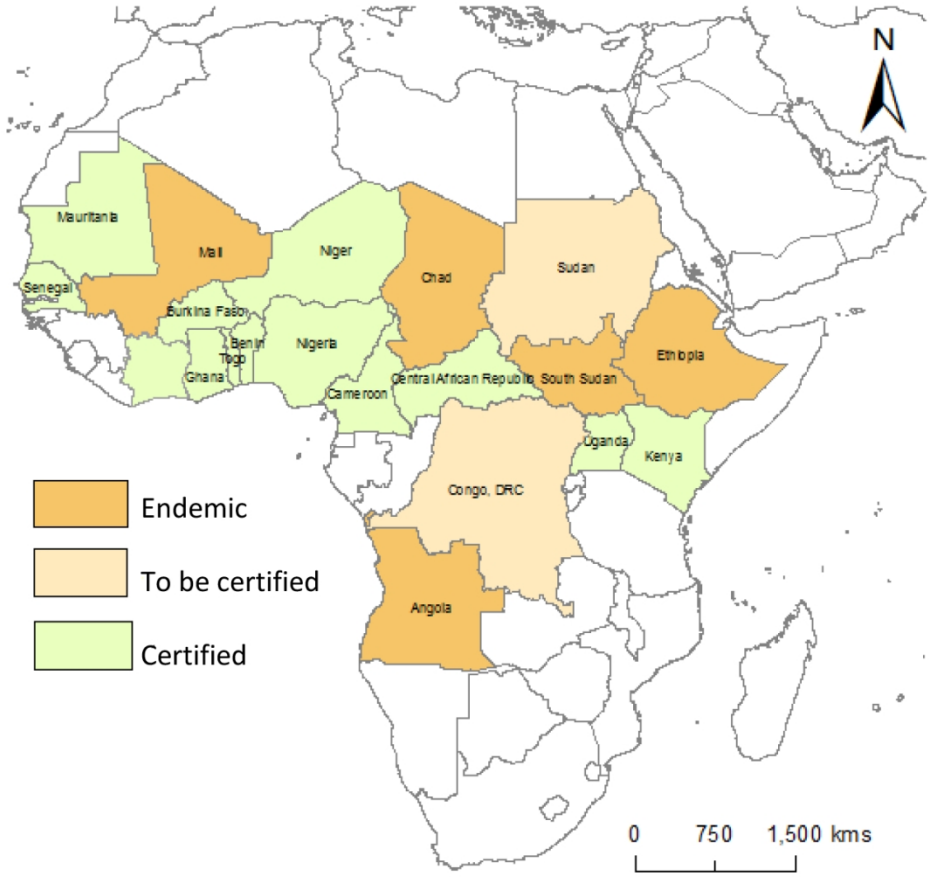

Figure 1

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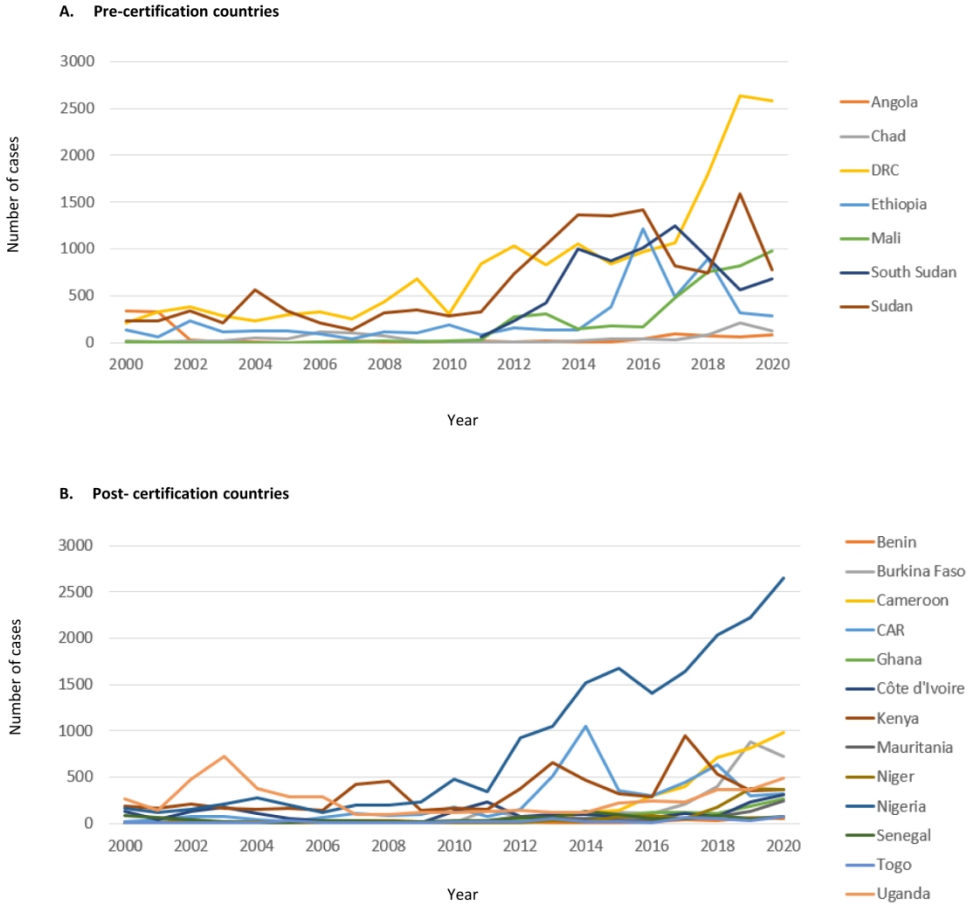

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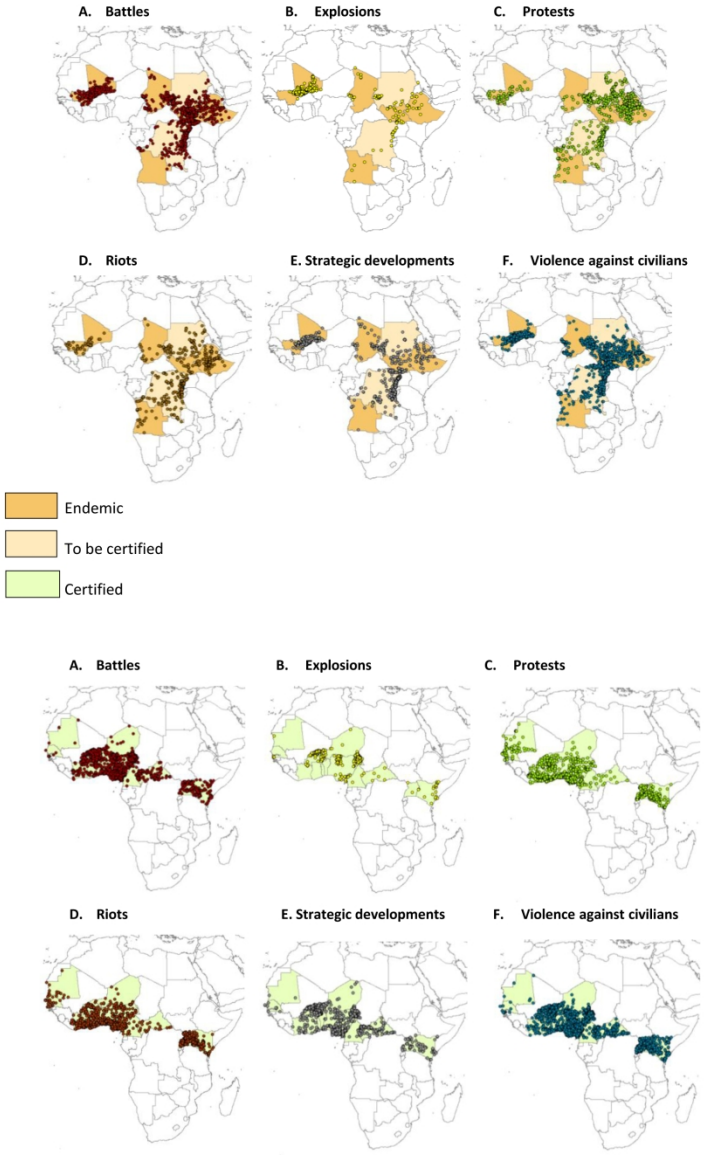

Figure 3

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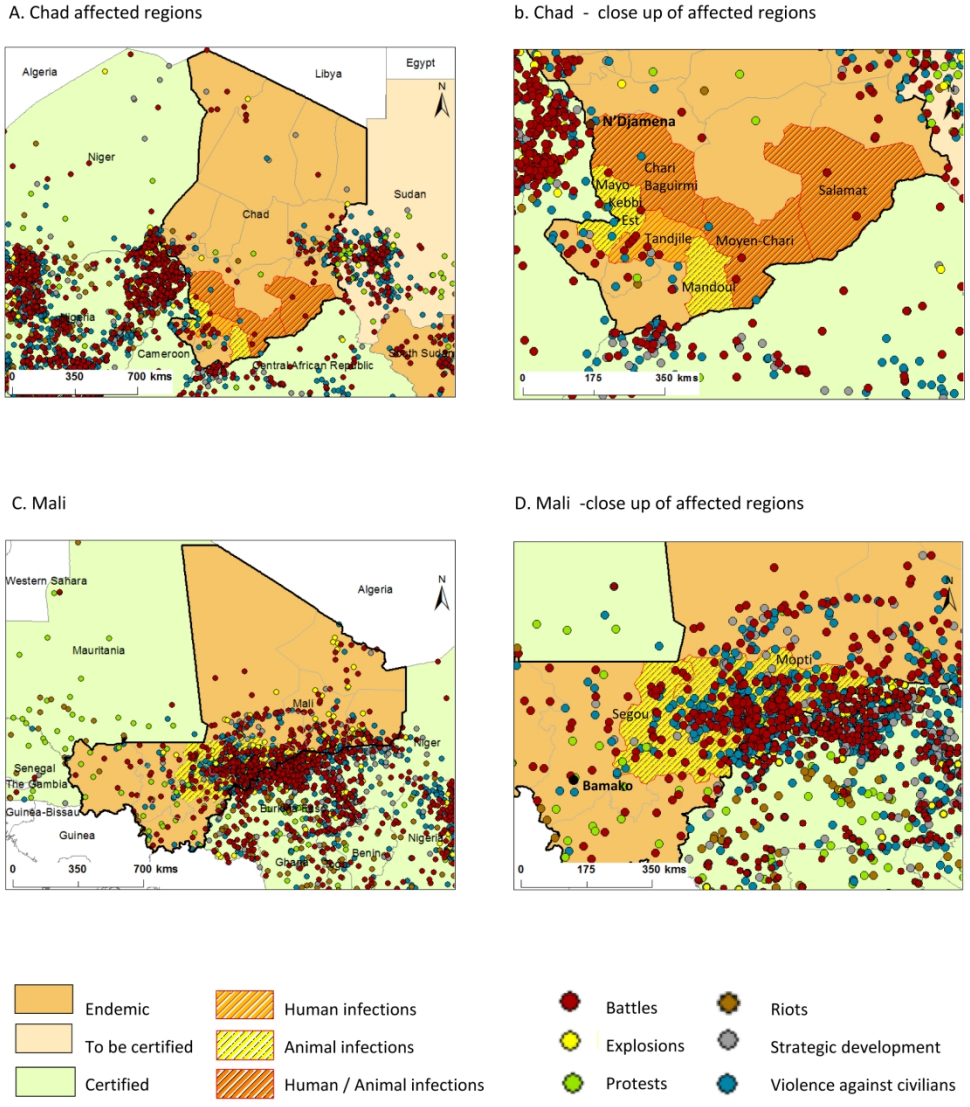

Figure 4

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S1. Data on the number of conflict events recorded in pre-certification and post-certification countries between 2000 – 2020

A. Pre-certification countries

Year	Angola	Chad	DRC	Ethiopia	Mali	South Sudan	Sudan	Total
2000	342	22	208	135	4		233	944
2001	325	11	331	57	5		233	962
2002	28	15	384	233	2		340	1002
2003	6	18	284	116	3		215	642
2004	7	47	232	124	3		562	975
2005	3	41	299	127	2		337	809
2006	6	116	330	89	10		211	762
2007	15	103	259	44	12		141	574
2008	10	75	438	113	21		318	975
2009	13	24	678	100	10		354	1179
2010	9	11	303	191	18		281	813
2011	20	6	839	83	29	58	334	1369
2012	14	8	1031	160	278	231	735	2457
2013	22	4	833	141	311	422	1039	2772
2014	8	20	1051	132	152	1004	1367	3734
2015	14	40	837	378	178	878	1358	3683
2016	45	40	969	1218	167	1008	1419	4866
2017	93	26	1063	494	473	1242	820	4211
2018	71	83	1805	892	751	900	749	5251
2019	63	210	2634	317	820	565	1593	6202
2020	88	128	2577	281	985	678	781	5518
Grand Total	**1202**	**1048**	**17385**	**5425**	**4234**	**6986**	**13420**	**49700**

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B. Post-certification countries

Year	Benin	Burkina Faso	Cameroon	CAR	Ghana	Côte d'Ivoire	Kenya	Mauritania	Niger	Nigeria	Senegal	Togo	Uganda	Total
2000	1	22	8	16	10	133	190	4	10	166	85	3	268	916
2001	3	6	5	43	8	34	165	1	9	114	61	4	138	591
2002	1	6	2	70	7	134	211	3	41	152	40	3	473	1143
2003	2	1	4	77	17	176	165	13	6	203	18	4	721	1407
2004	2	4	14	36	7	101	148	2	17	276	11	3	377	998
2005	2	6	18	21	3	45	160	9	9	198	11	25	289	796
2006	1	8	6	57	3	28	140	3	8	220	29	1	282	686
2007	3	1	20	101	5	6	421	5	31	194	24	1	96	908
2008	1	12	23	86	11	24	452	16	28	196	20	1	92	962
2009	2	1	19	97	17	5	143	10	16	225	22	4	119	680
2010	10	5	16	171	13	124	160	14	10	471	23	18	122	1157
2011	7	137	13	73	9	228	156	31	10	344	31	13	133	1185
2012	14	68	12	147	45	70	380	74	9	220	57	19	140	1955
2013	10	39	39	511	52	98	661	57	25	1049	60	52	121	2774
2014	7	123	122	1047	47	100	465	54	20	1513	130	14	114	3756
2015	8	116	135	352	86	71	322	39	71	2673	95	18	215	3201
2016	17	104	297	300	117	67	291	23	82	1410	55	10	245	3018
2017	35	204	401	448	114	105	943	56	56	1636	53	59	226	4336
2018	32	398	717	628	104	74	535	68	169	2036	88	45	364	5258
2019	60	883	815	300	187	228	352	128	370	2220	52	29	361	5985
2020	54	723	985	323	267	305	368	238	369	3647	72	68	484	6903
Total	**272**	**2867**	**3671**	**4904**	**1129**	**2156**	**6828**	**848**	**1366**	**17763**	**1037**	**394**	**5380**	**48615**

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STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6-7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-7
Bias	9	Describe any efforts to address potential sources of bias	6-7
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	N/A
		(*b*) Describe any methods used to examine subgroups and interactions	6-7
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	N/A
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8-10
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-12
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	8-12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A

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		(*b*) Report category boundaries when continuous variables were categorized	8-12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	11-12
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13-
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13-14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	N/A

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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