Supplementary text S1

HbS allele frequency

We sought national datasets reporting the prevalence of sickle haemoglobin (HbS) in Uganda to generate spatially resolved HbS allele frequency estimates.

Identification of candidate datasets

We searched PubMed for primary studies reporting population-level HbS or sickle cell trait data from Uganda. The search combined free-text terms and Medical Subject Headings (MeSH) for sickle cell disease and Uganda, restricted to human studies in English. A representative search string was:

("sickle cell" OR "sickle cell trait" OR "haemoglobin S" OR "HbS") AND Uganda.

Search results were exported to a reference manager and duplicate records were removed.

Study selection

Titles and abstracts were screened to exclude case reports, small facility-based series, interventional trials without baseline prevalence data, and studies restricted to subnational areas or narrowly defined clinical populations. Full texts were obtained for records that potentially reported national or near-national HbS prevalence or newborn screening data. Reference lists of included articles and relevant reviews were hand searched to identify additional reports. To capture national newborn screening work not indexed in PubMed, we conducted complementary searches of institutional repositories and grey literature using key phrases such as “Uganda”, “newborn screening”, and “sickle cell”.

Eligibility criteria

Studies were eligible if they: (i) reported primary data on HbS or sickle cell trait in Uganda, (ii) had national or near-national coverage, (iii) were based on systematic surveillance, screening, or large cross-sectional surveys, and (iv) contained sufficient information to derive district-level or comparable administrative aggregates. When eligibility could not be determined from the publication alone, we contacted the corresponding or senior author for clarification.

Included HbS datasets

This process identified two national HbS datasets that met the inclusion criteria. The first was the Uganda Sickle Surveillance Study (US3), reported by Ndeezi et al analysed dried blood spot samples from the national Early Infant Diagnosis programme, covering 112 districts with 97,631 genotyped infants [1]. We obtained the article and supplementary material from the journal website and extracted the published prevalence estimates, and the lead investigator (GN) proof read the published dataset. The second dataset originated from the national newborn screening programme reported by Kiyaga et al analysed dried blood spot samples from newborn screening activities, covering 122 districts with 12,009 genotyped newborns [2]. Similarly the originating investigator (CK) proofread the dataset.

Supplementary table S1.

Table S1. Ndeezi et al dataset

District	Samples_n	HbAA_n	HbAS_n	HbSS_n	Total_alleles	S_alleles

Bukomansimbi	579	499	76	4	1158	84
Butambala	417	357	55	5	834	65
Gomba	414	357	51	6	828	63
Kalangala	563	485	75	3	1126	81
Kalungu	922	788	130	4	1844	138
Lwengo	773	682	88	3	1546	94
Lyantonde	609	558	51	0	1218	51
Masaka	2298	1985	299	14	4596	327
Mpigi	1043	914	125	4	2086	133
Rakai	2223	1863	353	7	4446	367
Ssembabule	601	546	54	1	1202	56
Wakiso	4314	3758	539	17	8628	573
Buikwe	1665	1372	278	15	3330	308
Buvuma	328	277	47	4	656	55
Kayunga	692	565	118	9	1384	136
Kiboga	719	609	106	4	1438	114
Kyankwanzi	324	275	48	1	648	50
Luweero	1530	1299	213	18	3060	249
Mityana	1226	1051	166	9	2452	184
Mubende	2032	1801	221	10	4064	241
Mukono	1568	1350	209	9	3136	227
Nakaseke	546	464	78	4	1092	86

Nakasongola	505	413	82	10	1010	102
Bugiri	605	475	122	8	1210	138
Buyende	314	254	55	5	628	65
Iganga	932	735	183	14	1864	211
Jinja	1690	1331	330	29	3380	388
Kaliro	280	221	54	5	560	64
Kamuli	655	512	134	9	1310	152
Luuka	259	205	52	2	518	56
Mayuge	796	625	157	14	1592	185
Namayingo	739	578	152	9	1478	170
Namutumba	311	241	68	2	622	72
Kampala	13466	11541	1831	94	26932	2019
Budaka	167	137	29	1	334	31
Bududa	163	150	12	1	326	14
Bukwo	29	25	4	0	58	4
Bulambuli	196	179	16	1	392	18
Busia	522	413	99	10	1044	119
Butaleja	187	151	31	5	374	41
Kapchorwa	157	141	15	1	314	17
Kibuku	197	154	39	4	394	47
Kween	34	32	2	0	68	2
Manafwa	294	260	32	2	588	36

Mbale	1019	872	137	10	2038	157
Pallisa	312	260	51	1	624	53
Sironko	250	224	24	2	500	28
Tororo	1338	1055	262	21	2676	304
Agago	888	728	151	9	1776	169
Alebtong	351	260	84	7	702	98
Amolatar	450	369	77	4	900	85
Amuru	320	260	55	5	640	65
Apac	938	741	180	17	1876	214
Dokolo	382	304	73	5	764	83
Gulu	3014	2384	600	30	6028	660
Kitgum	1046	854	185	7	2092	199
Kole	438	343	87	8	876	103
Lamwo	543	440	101	2	1086	105
Lira	1778	1398	352	28	3556	408
Nwoya	532	421	104	7	1064	118
Otuke	431	336	85	10	862	105
Oyam	982	774	195	13	1964	221
Pader	667	542	117	8	1334	133
Buliisa	152	116	33	3	304	39
Bundibugyo	309	236	67	6	618	79
Hoima	1568	1346	209	13	3136	235

Kabarole	3038	2743	289	6	6076	301
Kamwenge	969	910	58	1	1938	60
Kasese	1215	1087	124	4	2430	132
Kibaale	1604	1424	167	13	3208	193
Kiryandongo	516	438	77	1	1032	79
Kyegegwa	796	719	73	4	1592	81
Kyenjojo	1763	1582	176	5	3526	186
Masindi	803	666	126	11	1606	148
Ntoroko	212	179	33	0	424	33
Abim	180	146	32	2	360	36
Amudat	34	29	5	0	68	5
Amuria	572	464	98	10	1144	118
Bukedea	273	238	35	0	546	35
Kaabong	114	106	8	0	228	8
Kaberamaido	516	426	87	3	1032	93
Katakwi	490	408	80	2	980	84
Kotido	90	78	11	1	180	13
Kumi	361	306	51	4	722	59
Moroto	102	87	15	0	204	15
Nakapiripirit	64	60	4	0	128	4
Napak	116	102	14	0	232	14
Ngora	210	168	41	1	420	43

Serere	451	363	78	10	902	98
Soroti	885	729	143	13	1770	169
Buhweju	142	137	5	0	284	5
Bushenyi	1211	1159	51	1	2422	53
Ibanda	864	813	49	2	1728	53
Isingiro	1157	1092	62	3	2314	68
Kabale	1076	1048	28	0	2152	28
Kanungu	745	716	26	3	1490	32
Kiruhura	916	861	52	3	1832	58
Kisoro	361	345	15	1	722	17
Mbarara	3012	2843	166	3	6024	172
Mitooma	397	387	10	0	794	10
Ntungamo	1315	1261	53	1	2630	55
Rubirizi	360	328	28	4	720	36
Rukungiri	1191	1146	45	0	2382	45
Sheema	902	861	40	1	1804	42
Adjumani	239	201	37	1	478	39
Arua	973	849	122	2	1946	126
Koboko	217	183	34	0	434	34
Maracha-Terego	93	86	7	0	186	7
Moyo	161	140	21	0	322	21

Nebbi	810	659	141	10	1620	161
Yumbe	212	193	19	0	424	19
Zombo	311	276	34	1	622	36

Supplementary table S2

Table S2. Kiyaga et al dataset

District	Samples_n	HbAA_n	HbAS_n	HbSS_n	Total_alleles	S_alleles	S_allele_freq
Bukomans imbi	100	84	15	1	200	17	0.085
Butambala	100	84	16	0	200	16	0.08
Gomba	100	95	5	0	200	5	0.025
Kalangala	100	93	7	0	200	7	0.035
Kalungu	100	88	10	2	200	14	0.07
Lwengo	99	95	4	0	198	4	0.02
Lyantonde	100	91	8	1	200	10	0.05
Masaka	100	90	10	0	200	10	0.05
Mpigi	100	95	5	0	200	5	0.025
Rakai	100	88	11	1	200	13	0.065
Kyotera	99	91	8	0	198	8	0.04
Sembabule	100	89	11	0	200	11	0.055
Kampala	100	93	6	1	200	8	0.04
Wakiso	99	85	12	2	198	16	0.081
Buikwe	98	83	12	3	196	18	0.092

Buvuma	100	84	16	0	200	16	0.08
Kayunga	99	79	19	1	198	21	0.106
Kiboga	99	90	9	0	198	9	0.045
Kyankwazi	100	94	6	0	200	6	0.03
Luwero	98	83	15	0	196	15	0.077
Mityana	100	98	2	0	200	2	0.01
Mubende	100	95	5	0	200	5	0.025
Mukono	100	91	9	0	200	9	0.045
Nakaseke	100	88	12	0	200	12	0.06
Nakasongola	100	82	16	2	200	20	0.1
Bugiri	99	88	11	0	198	11	0.056
Buyende	100	90	9	1	200	11	0.055
Iganga	97	78	18	1	194	20	0.103
Jinja	100	83	16	1	200	18	0.09
Kaliro	100	86	13	1	200	15	0.075
Kamuli	100	80	19	1	200	21	0.105
Luuka	100	79	21	0	200	21	0.105
Mayuge	99	87	12	0	198	12	0.061
Namayingo	99	79	19	1	198	21	0.106
Namutumba	98	80	17	1	196	19	0.097
Bukwo	100	96	4	0	200	4	0.02
Kween	79	75	4	0	158	4	0.025

Kapchorwa	100	98	2	0	200	2	0.01
Bulambuli	100	94	6	0	200	6	0.03
Sironko	100	88	8	4	200	16	0.08
Bududa	100	96	4	0	200	4	0.02
Mbale	98	86	12	0	196	12	0.061
Butebo	97	79	17	1	194	19	0.098
Pallisa	100	84	16	0	200	16	0.08
Kibuku	100	88	10	2	200	14	0.07
Budaka	100	82	18	0	200	18	0.09
Butaleja	100	84	15	1	200	17	0.085
Tororo	100	83	17	0	200	17	0.085
Manafwa	99	87	11	1	198	13	0.066
Namisindwa	98	80	19	1	196	21	0.107
Busia	99	84	15	1	198	17	0.086
Kaabong	100	98	2	0	200	2	0.01
Kotido	100	93	7	0	200	7	0.035
Moroto	47	40	5	2	94	9	0.096
Abim	100	84	14	2	200	18	0.09
Napak	86	81	5	0	172	5	0.029
Nakapiripi riti	100	97	3	0	200	3	0.015
Amudat	53	49	4	0	106	4	0.038
Amuria	100	83	17	0	200	17	0.085

Katakwi	99	87	12	0	198	12	0.061
Soroti	98	83	15	0	196	15	0.077
Kaberamai do	100	90	9	1	200	11	0.055
Serere	100	84	15	1	200	17	0.085
Ngora	99	76	21	2	198	25	0.126
Kumi	99	87	12	0	198	12	0.061
Bukedea	98	85	13	0	196	13	0.066
Lamwo	98	82	15	1	196	17	0.087
Kitgum	100	79	20	1	200	22	0.11
Amuru	100	92	8	0	200	8	0.04
Gulu	98	82	16	0	196	16	0.082
Agago	100	83	14	3	200	20	0.1
Pader	100	81	18	1	200	20	0.1
Omoro	100	75	24	1	200	26	0.13
Nwoya	100	72	27	1	200	29	0.145
Oyam	100	84	16	0	200	16	0.08
Lira	100	80	17	3	200	23	0.115
Otuke	100	84	16	0	200	16	0.08
Kole	99	83	16	0	198	16	0.081
Aleptong	99	83	16	0	198	16	0.081
Dokolo	100	83	17	0	200	17	0.085
Amolatar	100	84	16	0	200	16	0.08

Apac	99	72	24	3	198	30	0.152
Moyo	100	96	4	0	200	4	0.02
Yumbe	100	87	13	0	200	13	0.065
Adjumani	99	90	9	0	198	9	0.045
Koboko	100	96	4	0	200	4	0.02
Maracha	100	96	4	0	200	4	0.02
Arua	100	89	11	0	200	11	0.055
Zombo	98	84	14	0	196	14	0.071
Nebbi	100	80	18	2	200	22	0.11
Pakwach	98	82	16	0	196	16	0.082
Buliisa	100	83	15	2	200	19	0.095
Masindi	100	92	8	0	200	8	0.04
Hoima	99	85	13	1	198	15	0.076
Kiryandongo	99	85	14	0	198	14	0.071
Kakumiro	100	89	10	1	200	12	0.06
Kamwenge	99	93	6	0	198	6	0.03
Kibaale	100	90	10	0	200	10	0.05
Kagadi	100	93	7	0	200	7	0.035
Kyegegwa	98	90	8	0	196	8	0.041
Kyenjojo	99	92	7	0	198	7	0.035
Bunyangabu	100	91	9	0	200	9	0.045
Kabarole	100	86	11	0	200	11	0.055

Ntoroko	100	95	5	0	200	5	0.025
Bundibugyo	100	81	19	0	200	19	0.095
Kasese	99	90	7	2	198	11	0.056
Buhweju	100	98	1	1	200	3	0.015
Bushenyi	100	96	4	0	200	4	0.02
Ibanda	100	96	4	0	200	4	0.02
Isingiro	100	92	8	0	200	8	0.04
Kabale	100	98	2	0	200	2	0.01
Kanungu	99	93	6	0	198	6	0.03
Kiruhura	100	97	3	0	200	3	0.015
Kisoro	100	99	1	0	200	1	0.005
Mbarara	100	97	3	0	200	3	0.015
Mitooma	100	100	0	0	200	0	0
Ntungamo	98	94	4	0	196	4	0.02
Rubanda	100	99	1	0	200	1	0.005
Rubirizi	99	91	7	1	198	9	0.045
Rukiga	100	87	13	0	200	13	0.065
Rukungiri	100	96	4	0	200	4	0.02
Sheema	100	95	5	0	200	5	0.025

Supplementary table S3

Table S3. Combine dataset with district-level distribution of S-allele frequency (q)

District	HbAA_n_combined	HbAS_n_combined	HbSS_n_combined	Total_alleles_combined	S_alleles_combined	S_allele_freq_combined
Abim	230	46	4	560	54	0.096429
Adjumani	291	46	1	676	48	0.071006
Agago	811	165	12	1976	189	0.095648
Alebtong	260	84	7	702	98	0.139601
Aleptong	83	16	0	198	16	0.080808
Amolatar	453	93	4	1100	101	0.091818
Amudat	78	9	0	174	9	0.051724
Amuria	547	115	10	1344	135	0.100446
Amuru	352	63	5	840	73	0.086905
Apac	813	204	20	2074	244	0.117647
Arua	938	133	2	2146	137	0.06384
Budaka	219	47	1	534	49	0.09176
Bududa	246	16	1	526	18	0.034221
Bugiri	563	133	8	1408	149	0.105824
Buhweju	235	6	1	484	8	0.016529
Buikwe	1455	290	18	3526	326	0.092456
Bukedea	323	48	0	742	48	0.06469
Bukomansimbi	583	91	5	1358	101	0.074374
Bukwo	121	8	0	258	8	0.031008
Bulambuli	273	22	1	592	24	0.040541

Buliisa	199	48	5	504	58	0.115079
Bundibugyo	317	86	6	818	98	0.119804
Bunyangabu	91	9	0	200	9	0.045
Bushenyi	1255	55	1	2622	57	0.021739
Busia	497	114	11	1242	136	0.109501
Butaleja	235	46	6	574	58	0.101045
Butambala	441	71	5	1034	81	0.078337
Butebo	79	17	1	194	19	0.097938
Buvuma	361	63	4	856	71	0.082944
Buyende	344	64	6	828	76	0.091787
Dokolo	387	90	5	964	100	0.103734
Gomba	452	56	6	1028	68	0.066148
Gulu	2466	616	30	6224	676	0.108612
Hoima	1431	222	14	3334	250	0.074985
Ibanda	909	53	2	1928	57	0.029564
Iganga	813	201	15	2058	231	0.112245
Isingiro	1184	70	3	2514	76	0.030231
Jinja	1414	346	30	3580	406	0.113408
Kaabong	204	10	0	428	10	0.023364
Kabale	1146	30	0	2352	30	0.012755
Kabarole	2829	300	6	6276	312	0.049713
Kaberamaido	516	96	4	1232	104	0.084416

Kagadi	93	7	0	200	7	0.035
Kakumiro	89	10	1	200	12	0.06
Kalangala	578	82	3	1326	88	0.066365
Kaliro	307	67	6	760	79	0.103947
Kalungu	876	140	6	2044	152	0.074364
Kampala	11634	1837	95	27132	2027	0.074709
Kamuli	592	153	10	1510	173	0.11457
Kamwenge	1003	64	1	2136	66	0.030899
Kanungu	809	32	3	1688	38	0.022512
Kapchorwa	239	17	1	514	19	0.036965
Kasese	1177	131	6	2628	143	0.054414
Katakwi	495	92	2	1178	96	0.081494
Kayunga	644	137	10	1582	157	0.099241
Kibaale	1514	177	13	3408	203	0.059566
Kiboga	699	115	4	1636	123	0.075183
Kibuku	242	49	6	594	61	0.102694
Kiruhura	958	55	3	2032	61	0.03002
Kiryandongo	523	91	1	1230	93	0.07561
Kisoro	444	16	1	922	18	0.019523
Kitgum	933	205	8	2292	221	0.096422
Koboko	279	38	0	634	38	0.059937
Kole	426	103	8	1074	119	0.110801

Kotido	171	18	1	380	20	0.052632
Kumi	393	63	4	920	71	0.077174
Kween	107	6	0	226	6	0.026549
Kyankwanzi	275	48	1	648	50	0.07716
Kyankwazi	94	6	0	200	6	0.03
Kyegegwa	809	81	4	1788	89	0.049776
Kyenjojo	1674	183	5	3724	193	0.051826
Kyotera	91	8	0	198	8	0.040404
Lamwo	522	116	3	1282	122	0.095164
Lira	1478	369	31	3756	431	0.11475
Luuka	284	73	2	718	77	0.107242
Luweero	1299	213	18	3060	249	0.081373
Luwero	83	15	0	196	15	0.076531
Lwengo	777	92	3	1744	98	0.056193
Lyantonde	649	59	1	1418	61	0.043018
Manafwa	347	43	3	786	49	0.062341
Maracha	96	4	0	200	4	0.02
Maracha-Terego	86	7	0	186	7	0.037634
Masaka	2075	309	14	4796	337	0.070267
Masindi	758	134	11	1806	156	0.086379
Mayuge	712	169	14	1790	197	0.110056
Mbale	958	149	10	2234	169	0.075649

Mbarara	2940	169	3	6224	175	0.028117
Mitooma	487	10	0	994	10	0.01006
Mityana	1149	168	9	2652	186	0.070136
Moroto	127	20	2	298	24	0.080537
Moyo	236	25	0	522	25	0.047893
Mpigi	1009	130	4	2286	138	0.060367
Mubende	1896	226	10	4264	246	0.057692
Mukono	1441	218	9	3336	236	0.070743
Nakapiripi riti	97	3	0	200	3	0.015
Nakapiripirit	60	4	0	128	4	0.03125
Nakaseke	552	90	4	1292	98	0.075851
Nakasongola	495	98	12	1210	122	0.100826
Namayingo	657	171	10	1676	191	0.113962
Namisindwa	80	19	1	196	21	0.107143
Namutumba	321	85	3	818	91	0.111247
Napak	183	19	0	404	19	0.04703
Nebbi	739	159	12	1820	183	0.100549
Ngora	244	62	3	618	68	0.110032
Ntoroko	274	38	0	624	38	0.060897
Ntungamo	1355	57	1	2826	59	0.020878
Nwoya	493	131	8	1264	147	0.116297
Omoro	75	24	1	200	26	0.13

Otuke	420	101	10	1062	121	0.113936
Oyam	858	211	13	2164	237	0.109519
Pader	623	135	9	1534	153	0.099739
Pakwach	82	16	0	196	16	0.081633
Pallisa	344	67	1	824	69	0.083738
Rakai	1951	364	8	4646	380	0.081791
Rubanda	99	1	0	200	1	0.005
Rubirizi	419	35	5	918	45	0.04902
Rukiga	87	13	0	200	13	0.065
Rukungiri	1242	49	0	2582	49	0.018978
Sembabule	89	11	0	200	11	0.055
Serere	447	93	11	1102	115	0.104356
Sheema	956	45	1	2004	47	0.023453
Sironko	312	32	6	700	44	0.062857
Soroti	812	158	13	1966	184	0.093591
Ssembabule	546	54	1	1202	56	0.046589
Tororo	1138	279	21	2876	321	0.111613
Wakiso	3843	551	19	8826	589	0.066735
Yumbe	280	32	0	624	32	0.051282
Zombo	360	48	1	818	50	0.061125

Supplementary table S4.

Table S4. List of active newborn sickle cell screening health facilities in Uganda 2023.

1.	Jinja R R Hospital
2.	Mbale R R Hospital
3.	Lira R R Hospital
4.	Lubaga Hospital
5.	Atutur Hospital
6.	Soroti R R Hospital
7.	Masafu Hospital
8.	Kayunga Hospital
9.	Iganga Hospital
10.	Apac Hospital
11.	Nsambya Hospital

12.	Kamuli District Govt Hospital
13.	Entebbe Hospital MCH General
14.	Masaka Health Care Centre (Uganda Cares-Masaka)
15.	Masaka R R Hospital
16.	Luweero General Hospital
17.	Mjap (Iss Clinic) Mulago
18.	Amuria General Hospital
19.	Amolatar H/C IV
20.	Kamuli Mission Hospital
21.	Katakwi Hospital
22.	Nakaseke Hospital
23.	Komamboga H/C III
24.	Villa Maria Hospital

25.	Kalongo Hospital
26.	FortPortal R R Hospital
27.	China Uganda Friendship Hospital- Naguru
28.	Mubende R R Hospital
29.	Buyinja H/C IV
30.	St Balikuddembe Market/Uganda Cares AHF
31.	Dr Charles Farthing Memorial Clinic
32.	Gracious Clinic
33.	Mityana Hospital
34.	Alive Medical Services H/C III
35.	Ngora H/C IV
36.	Serere H/C IV
37.	Mulago National Hospital-MUJHU Clinic

38.	Hoima R R Hospital
39.	Health Initiatives Association
40.	Kalisizo Hospital
41.	Mengo Hospital Counselling & HomeCare
42.	Kawempe National Referral Hospital
43.	Budaka H/C IV
44.	Paluda H/C III
45.	Kigandalo H/C IV
46.	Nurture Africa H/C III
47.	Lyantonde Hospital
48.	Lacor Hospital
49.	Alebtong H/C IV
50.	St Joseph Hospital Kitgum

51.	Kidera H/C IV
52.	IDI Mulago
53.	Nsambya Home Care
54.	Kitgum General Hospital
55.	Anyeke H/C IV
56.	TASO Entebbe
57.	Bugiri Hospital
58.	Busiu H/C IV
59.	Bumanya H/C IV
60.	Kamacha H/C III
61.	Lukaya Health Care Centre (Uganda Cares)
62.	CPHL
63.	Dokolo H/C IV

64.	Kibuku H/C IV
65.	Ngora Freda car Hospital (NGO)
66.	TASO Jinja
67.	Tororo District Hospital
68.	Kaberamaido General Hospital
69.	Kiryandongo Hospital
70.	Kiswa H/C IV
71.	Nsinze H/C IV
72.	Mukongoro H/C III
73.	Busolwe Hospital
74.	TASO Masaka
75.	Oseera H/C II
76.	Lira PAG Mission Hospital H/C IV

77.	Rugazi H/C IV
78.	Kalagala H/C IV
79.	Lalogi H/C IV
80.	TASO Gulu
81.	Kawempe Home Care
82.	Gulu R R Hospital
83.	Olimai Community H/C III
84.	Kassanda H/C IV
85.	Lwala Hospital
86.	Kisiita H/C III
87.	Bukedea H/C IV
88.	Mpigi H/C IV
89.	Dabani Hosipital

90.	Nabweru H/C III
91.	Pallisa General Hospital
92.	St Stephens Hospital (Mpererwe)
93.	Family Hope Centre Jinja
94.	Namutumba H/C III (Namutumba)
95.	STD/MARPI Clinic-Mulago
96.	Laguti H/C III
97.	Kitebi H/C III
98.	Double Cure Medical Centre
99.	Family Hope Centre Kampala
100.	Buikwe Hospital (St Charlse Lwanga)
101.	Hope Clinic Lukuli
102.	Namwendwa H/C IV

103.	Kinoni H/C III (Lwengo)
104.	Mulagi H/C III
105.	Nabiganda H/C III
106.	Akide H/C II
107.	Buwenge H/C IV
108.	Omiya Anyima H/C III
109.	Alanyi H/C III
110.	Bududa Hospital
111.	Rakai Hospital
112.	Bujubuli H/C III
113.	Apapai H/C IV (Serere)
114.	Lokung H/C III
115.	Mubende Rehabilitation Centre

116.	Kumi Hospital
117.	Nawanyago H/C III
118.	Amach H/C IV
119.	Abako Elim H/C II
120.	TASO Soroti
121.	Kangulumira H/C IV
122.	Dr Ambrosolic Memorial Hospital
123.	Kamwokya Christian Caring Community
124.	Kasese Municipal Council H/C III (KMC)
125.	Butebo H/C IV
126.	Namakwekwe H/C III
127.	Abim Hospital
128.	Anaka Hospital

129.	Namugongo H/C III (kaliro)
130.	Ngetta H/C III
131.	Pajule H/C IV
132.	Abia H/C II
133.	Kagando Hospital
134.	Kiyunga H/C IV (Luuka)
135.	Nabisoigi H/C III
136.	Kangai H/C III
137.	Magala H/C III
138.	Adwir H/C II
139.	Busaru H/C IV
140.	Sekiwunga H/C III
141.	Nakasongola H/C IV

142.	St Francis Mbiriizi H/C III
143.	Relife Family Medical Center
144.	Banda H/C III (Namayingo)
145.	Kibuli Muslim Hospital
146.	Meeting Point Kampala
147.	Omoro H/C III (Alebtong)
148.	PIDC (Baylor-Mulago)
149.	Butabika Hospital
150.	CDC-Kiruddu
151.	Lacor H/C III (Amuru)
152.	ST JOSEPH H/ C III(Madudu)
153.	St Matia Mulumba H/C III -Irundu(Buyende)
154.	Buluba Hospital St Francis

155.	Kiganda H/C IV
156.	Bugobero H/C IV
157.	Charis H/C III
158.	Kiboga Hospital
159.	Mukono General Hospital
160.	Koboko General Hospital
161.	JOY Medical Centre
162.	Lufuka Valley Health Centre III
163.	Mifumi H/C III
164.	Buwaiswa H/C III
165.	Nakitoma H/C III
166.	TASO Mulago
167.	Acowa H/C III

168.	Amuca SDA H/C III
169.	Kawolo Hospital
170.	Lacor Opit H/C III (Omoro)
171.	Nankoma H/C IV
172.	Aboke H/C IV
173.	Gombe Hospital
174.	Kityerera H/C IV
175.	Kwera H/C III
176.	Rakai Health Sciences Program
177.	Baitambogwe H/C III
178.	Biikira H/C III
179.	Kadama H/C III
180.	Ssunga H/C III

181.	St Francis Acumet
182.	Abei H/C II
183.	Atanga H/C III
184.	Military Police H/C III (Makindye)

Supplementary figure S1

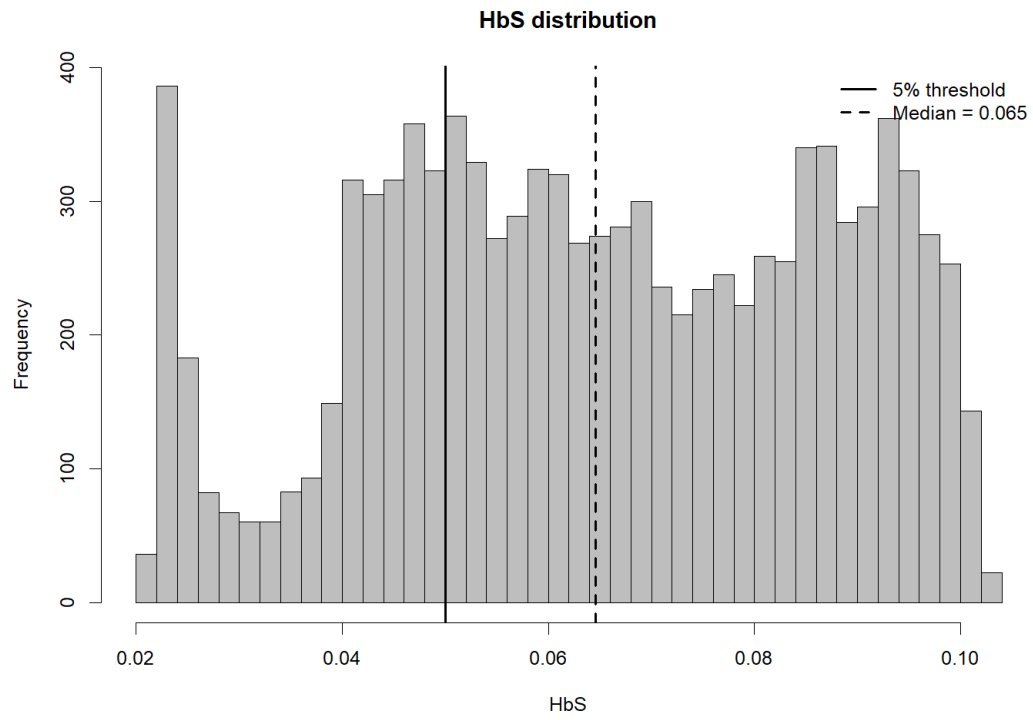

Figure S1. Distribution of HbS values. Histogram of pixelwise HbS on the 5 km grid with vertical lines at the 5% program threshold (solid) and the national median (dashed). Summary: median = 0.065; IQR = 0.048–0.085; 72.2% of pixels ≥ 0.05.

Supplementary table S5.

Table S5. National mean, interquartile range, and area share above 0.01, 0.05, and 0.10 thresholds.

Metric	Value
HbS_median	0.064609
HbS_IQR_Q1	0.04825
HbS_IQR_Q3	0.084607
HbS_pct_pixels_ge_5pct	72.22989
HbS_pct_pixels_ge_10pct	1.626577
PfPR_area_weighted_mean	0.26049
PfPR_pct_land_ge_0.30	94.37193
CoRisk_p95	0.040742
Pct_land_CoRisk_ge_0.20	93.64605

Supplementary figure S2

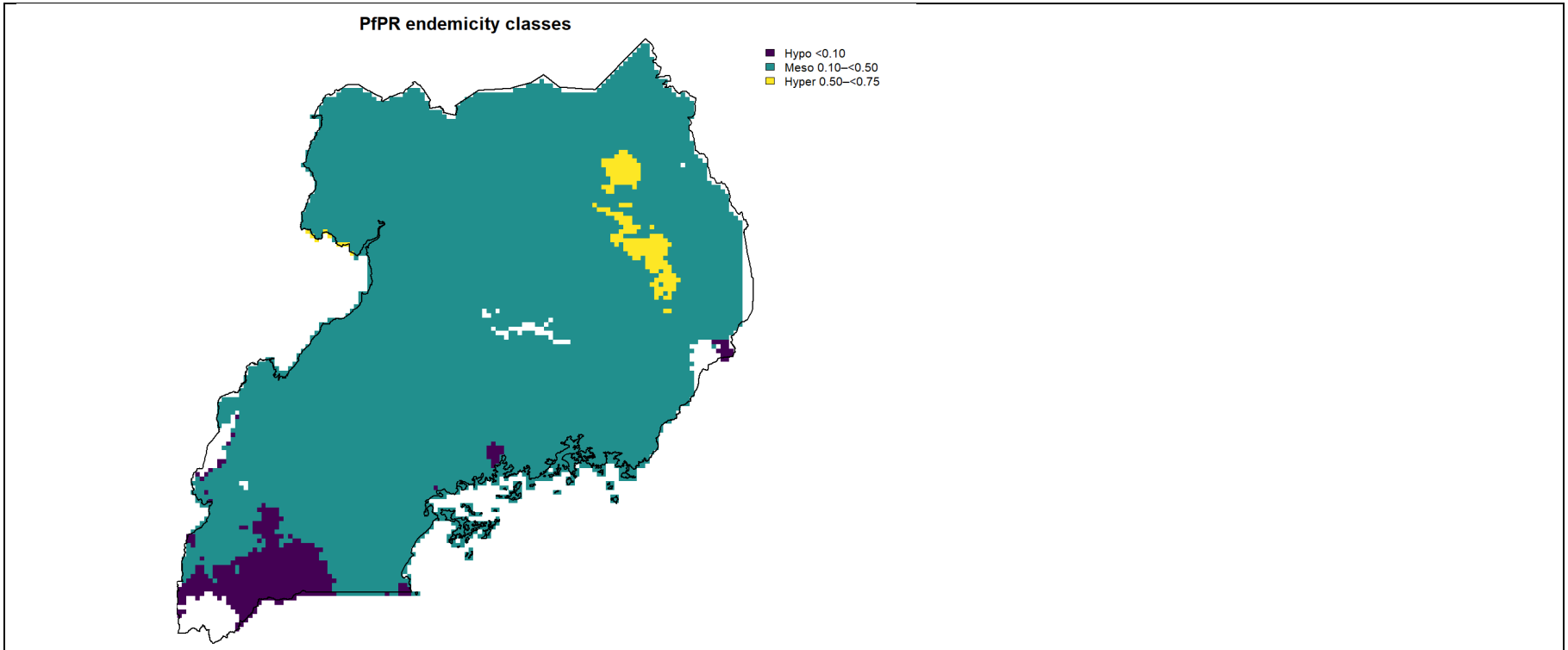

Figure S2. PfPR endemicity classes (classical bands). PfPR decade mean reclassified into hypo (<0.10), meso (0.10–<0.50), hyper (0.50–<0.75), and holo (≥0.75) on the 5 km grid. National area shares: 4.5% hypo, 88.0% meso, 1.9% hyper, 0.0% holo.

Supplementary table S6.

Table S6. Endemicity bands (Cell counts and percent of national area in hypoendemic, mesoendemic, hyperendemic, and holoendemic classes based on the decade mean).

Class	Area (km²)	Share (%)

Hypo < 0.10	9,827.5	4.5
Meso 0.10–<0.50	194,226.9	88
Hyper 0.50–<0.75	4,121.3	1.9
Holo ≥ 0.75	0	0

Supplementary figure S3

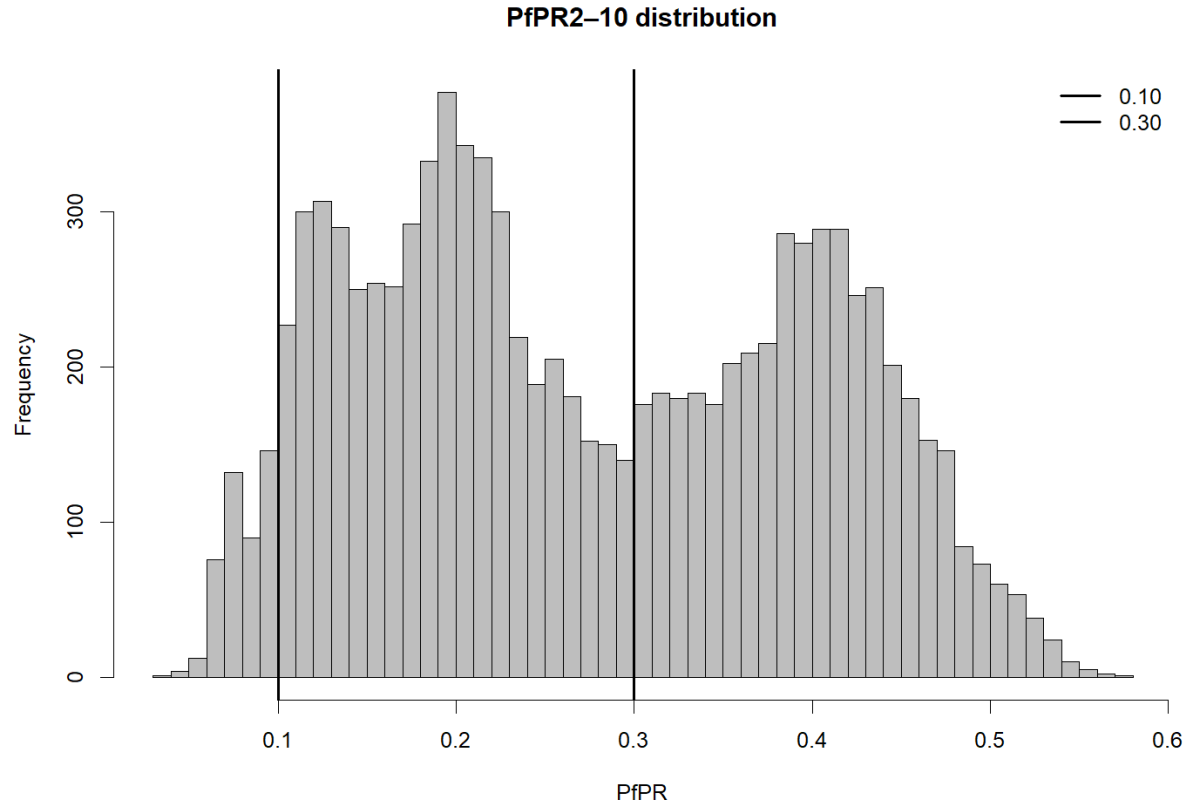

Figure S3. PfPR distribution with program cutoffs. Histogram of PfPR decade-mean pixel values; vertical lines at 0.10 and 0.30 illustrate canonical and programmatic thresholds. (By area, 100% of land is ≥ 0.30 on this dataset.)

Supplementary figure S4

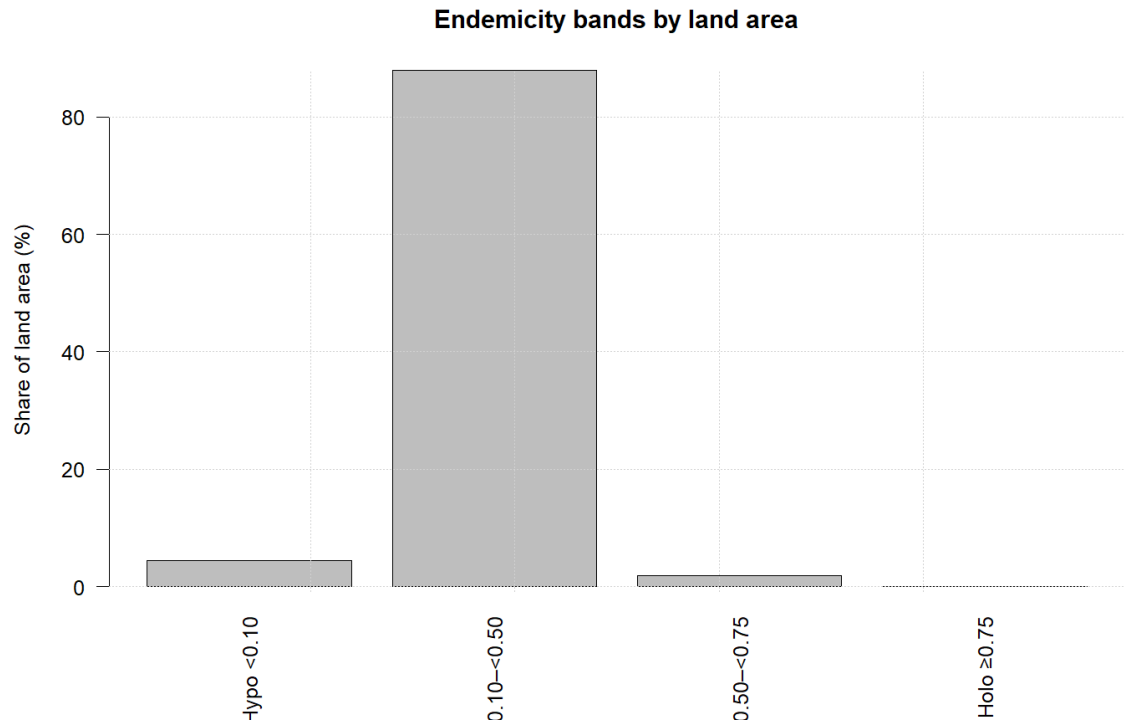

Figure S4. Endemicity bands by land area. Bar chart of national land-area share in each endemicity class derived from Figure 3B (4.5% hypo; 88.0% meso; 1.9% hyper; 0.0% holo).

Supplementary figure S5

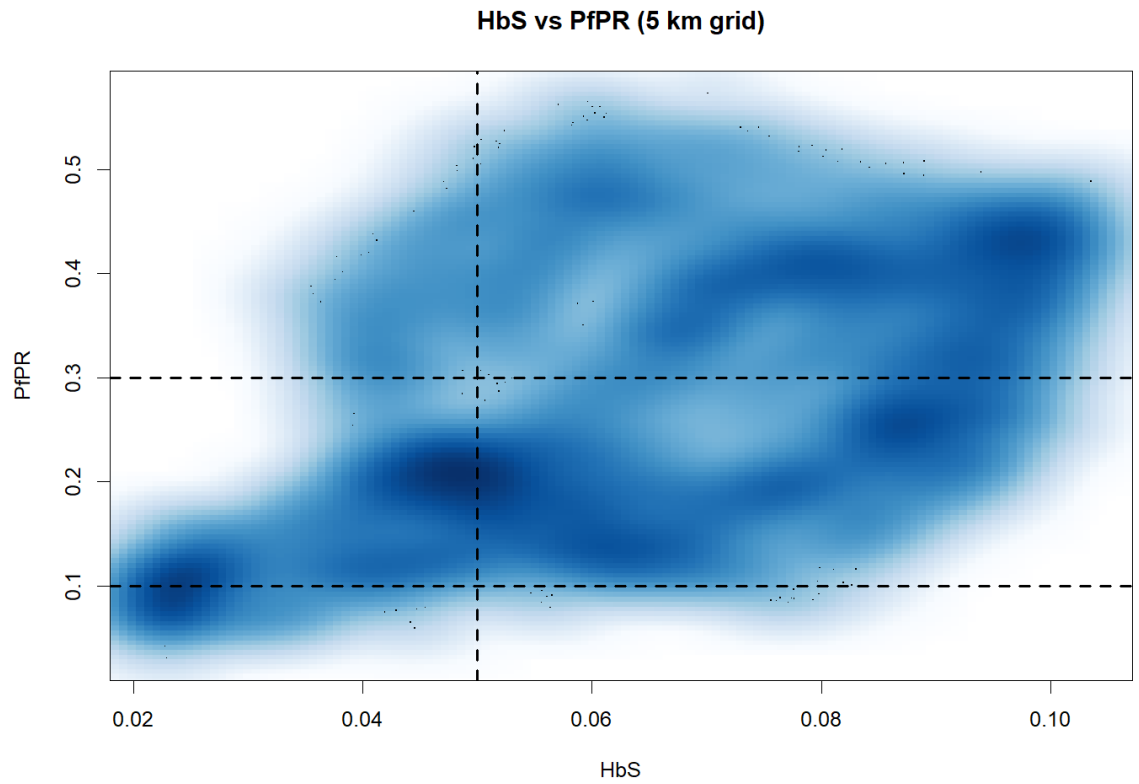

Figure S5. HbS vs PfPR. Smoothed bivariate scatter of paired HbS and PfPR pixels on the 5 km grid with reference lines at HbS 0.05 and PfPR 0.10 and 0.30

Supplementary table S7.

Table S7. Unserved baseline after existing coverage (National sums and percent reduction after masking existing coverage.)

Metric	Total co-risk	Unserved co-risk	Absolute reduction	Percent reduction
Simple sum	190.6418	113.6674	76.97445	40.37647
Area weighted_km2	4070.841	2427.163	1643.679	40.37688

Supplementary table S8.

Table S8. Greedy placement of 50 sites at 25 km (Rank, easting and northing in meters (EPSG:32636), longitude and latitude (WGS84), co-risk captured at pick, cumulative captured, and percent of baseline captured).

Rank	Longitude	Latitude	Co-risk at pick	Co-risk captured cum	% of baseline
1	32.88188	2.41665	0.050653	0.050653	0.044563
2	32.59103	2.333002	0.047282	0.097935	0.08616
3	32.17546	2.458197	0.046777	0.144712	0.127312
4	32.5909	2.750961	0.046756	0.191469	0.168446
5	33.08967	2.625638	0.045074	0.236543	0.208101
6	32.84029	2.709224	0.044753	0.281296	0.247473
7	32.1756	2.20744	0.044385	0.325681	0.286521
8	33.87839	0.243153	0.044106	0.369787	0.325324

9	32.42474	2.541918	0.043299	0.413086	0.363417
10	33.17285	3.001799	0.042989	0.456076	0.401237
11	33.33906	2.709187	0.042828	0.498903	0.438915
12	32.84026	2.960004	0.041158	0.540061	0.475124
13	32.8819	2.165868	0.040743	0.580805	0.510969
14	33.29725	1.371702	0.040337	0.621141	0.546455
15	31.76018	2.20715	0.040172	0.661314	0.581797
16	33.13121	2.374852	0.039742	0.701056	0.616761
17	33.71327	2.959785	0.039381	0.740438	0.651407
18	33.46366	2.458372	0.039236	0.779674	0.685926
19	32.38299	2.918049	0.038676	0.81835	0.719951
20	32.21685	2.70898	0.037521	0.855871	0.752961
21	33.04807	1.413518	0.03738	0.893252	0.785847
22	33.50475	0.15958	0.03683	0.930081	0.818248
23	33.71294	2.374674	0.036538	0.96662	0.850393
24	31.17861	2.2901	0.036219	1.002838	0.882257
25	33.50511	2.165788	0.036146	1.038984	0.914057
26	31.67687	2.457794	0.035528	1.074512	0.945313
27	33.29764	3.252548	0.035418	1.10993	0.976472
28	33.54637	1.120884	0.034539	1.144469	1.006858
29	32.59077	3.085327	0.034208	1.178676	1.036952
30	33.96215	2.249148	0.034002	1.212678	1.066865

31	33.58811	1.914987	0.033893	1.246571	1.096683
32	33.92092	2.708883	0.033601	1.280171	1.126243
33	33.21453	3.503346	0.03319	1.313362	1.155443
34	33.58802	1.62242	0.033131	1.346492	1.18459
35	33.83736	1.956676	0.032963	1.379456	1.21359
36	31.71817	2.708553	0.032573	1.412029	1.242246
37	32.29969	3.168761	0.032535	1.444564	1.270869
38	31.96728	2.959532	0.032434	1.476998	1.299403
39	32.63272	1.706066	0.032102	1.509099	1.327645
40	33.54717	3.294238	0.031733	1.540832	1.355562
41	33.25582	2.124054	0.031724	1.572556	1.383471
42	32.71582	1.455298	0.031509	1.604065	1.411192
43	32.71539	3.503327	0.031158	1.635223	1.438603
44	34.0865	1.831163	0.03115	1.666373	1.466008
45	31.59436	1.830939	0.031136	1.697508	1.493399
46	33.50481	0.870115	0.031065	1.728573	1.520729
47	32.88197	1.037338	0.030908	1.75948	1.54792
48	32.34195	1.789578	0.030373	1.789854	1.574641
49	33.96269	2.959596	0.030333	1.820187	1.601327
50	32.84038	1.915081	0.03028	1.850467	1.627966

Supplementary table S9.

Table S9. Candidate screening hub locations matched to existing health facilities

Proposed rank	Proposed lon	Proposed lat	Facility name	Type	Ownership	Authority	Status	Facility lon	Facility lat
1	32.88188	2.41665	Ogur HC IV	HC IV	Government	MOH	Functional	32.93588	2.44195
2	32.59103	2.333002	Agulurude HC III	HC III	Government	MOH	Functional	32.6103	2.2945
5	33.08967	2.625638	Okwang HC III	HC III	Government	MOH	Functional	33.14869	2.6032
6	32.84029	2.709224	Awere HC III	HC III	Government	MOH	Functional	32.79421	2.68842
7	32.1756	2.20744	Diima HC III	HC III	Government	MOH	Functional	32.22003	2.16412
8	33.87839	0.243153	Buyinja HC IV	HC IV	Government	MOH	Functional	33.87629	0.3358
9	32.42474	2.541918	Opit HC III	HC III	Government	UCMB	Functional	32.47537	2.61763
11	33.33906	2.709187	Patongo HC III	HC IV	Government	MOH	Functional	33.30378	2.778143
13	32.8819	2.165868	Ober HC III	HC III	Government	MOH	Functional	32.87364	2.25697
16	33.13121	2.374852	Apala HC III	HC III	Government	MOH	Functional	33.04103	2.40401
17	33.71327	2.959785	Alerek HC III	HC III	Government	MOH	Functional	33.73088	2.95626
18	33.46366	2.458372	Olilim HC III	HC III	Government	MOH	Functional	33.50511	2.4486
19	32.38299	2.918049	Awach HC IV	HC IV	Government	MOH	Functional	32.40077	2.97058
20	32.21685	2.70898	Ongako HC III	HC III	Government	MOH	Functional	32.22965	2.67768
24	31.17861	2.2901	Parombo HC III	HC III	Government	MOH	Functional	31.19591	2.30068
25	33.50511	2.165788	Morungatuny HC III	HC III	Government	MOH	Functional	33.47681	2.17372

27	33.29764	3.252548	Omiya Anyima HC III	HC III	Government	MOH	Functional	33.20667	3.27004
28	33.54637	1.120884	Namwiwa HC III	HC III	Government	MOH	Functional	33.55064	1.08656
31	33.58811	1.914987	Tubur HC III	HC III	Government	MOH	Functional	33.51942	1.95525
34	33.58802	1.62242	Asuret HC III	HC III	Government	MOH	Functional	33.59892	1.628748
35	33.83736	1.956676	Abarilela HC III	HC III	Government	MOH	Functional	33.81817	1.962
41	33.25582	2.124054	Alanyi HC III	HC III	Private Not For Profit	UCMB	Functional	33.26303	2.13244
43	32.71539	3.503327	Padibe West HC III	HC III	Government	MOH	Functional	32.81643	3.4872
46	33.50481	0.870115	Namugongo HC III	HC III	Government	MOH	Functional	33.48277	0.89568
47	32.88197	1.037338	Bbaale HC IV	HC IV	Government	MOH	Functional	32.88569	1.1056
48	32.34195	1.789578	Akokoro HC III	HC III	Government	MOH	Functional	32.39149	1.69949
49	33.96269	2.959596	Lokitelaebu HC III	HC III	Government	MOH	Functional	34.00117	2.98911
50	32.84038	1.915081	Abedober HC III	HC III	Private Not For Profit	UCMB	Functional	32.8508	1.94593

Supplementary table S10.

Table S10. Coverage curve and marginal returns (Percent of baseline co-risk captured at 10, 20, 30, 40, and 50 sites).

Sites	Percent captured
10	19.65101
20	33.57185
30	45.17405
40	57.51306
50	65.5775

Supplementary table S11.

Table S11. Equity and spatial concentration of benefits (Captured co-risk by district, district rank, and share of district baseline captured after 50 screening hubs).

Rank	District	Captured	Share of total
1	Pader	5.242049	7.03251
2	Oyam	3.812487	5.11467
3	Lamwo	3.697246	4.960068
4	Kitgum	3.602888	4.833481
5	Nwoya	3.558846	4.774396
6	Amuru	3.477403	4.665135

7	Kotido	3.354674	4.500488
8	Gulu	3.143004	4.216521
9	Omoro	2.990208	4.011536
10	Kiryandongo	2.838674	3.808244
11	Otuke	2.544894	3.414121
12	Alebtong	2.442642	3.276945
13	Katakwi	2.409669	3.232709
14	Lira	2.406753	3.228797
15	Agago	2.305701	3.09323
16	Kole	2.02612	2.718156
17	Buyende	1.97818	2.653841
18	Serere	1.886197	2.530441
19	Masindi	1.882711	2.525765
20	Amuria	1.862115	2.498134
21	Kapelebyong	1.855297	2.488988
22	Napak	1.637628	2.196972
23	Soroti	1.53615	2.060834
24	Amolatar	1.483244	1.989857
25	Abim	1.248141	1.674453
26	Kayunga	1.038341	1.392994
27	Kwania	0.897218	1.203669
28	Kaliro	0.815275	1.093738

29	Nakasongola	0.69625	0.934059
30	Namayingo	0.674003	0.904213
31	Adjumani	0.581003	0.779448
32	Apac	0.481229	0.645596
33	Buliisa	0.475962	0.63853
34	Dokolo	0.462699	0.620737
35	Namutumba	0.454736	0.610055
36	Nebbi	0.368423	0.494261
37	Buvuma	0.352111	0.472378
38	Pakwach	0.315842	0.42372
39	Luwero	0.302074	0.40525
40	Pallisa	0.28177	0.378011
41	Nabilatuk	0.280291	0.376027
42	Kaberamaido	0.222661	0.298712
43	Mayuge	0.162582	0.218113
44	Kibuku	0.140797	0.188888
45	Karenga	0.096298	0.12919
46	Kamuli	0.089006	0.119407
47	Ngora	0.056584	0.075911
48	Busia	0.041093	0.055129
49	Iganga	0.031065	0.041675
50	Amudat	0	0

51	Arua	0	0
52	Budaka	0	0
53	Bududa	0	0
54	Bugiri	0	0
55	Bugweri	0	0
56	Buhweju	0	0
57	Buikwe	0	0
58	Bukedea	0	0
59	Bukomansimbi	0	0
60	Bukwo	0	0
61	Bulambuli	0	0
62	Bundibugyo	0	0
63	Bunyangabu	0	0
64	Bushenyi	0	0
65	Butaleja	0	0
66	Butambala	0	0
67	Butebo	0	0
68	Gomba	0	0
69	Hoima	0	0
70	Ibanda	0	0
71	Isingiro	0	0
72	Jinja	0	0

73	Kaabong	0	0
74	Kabale	0	0
75	Kabarole	0	0
76	Kagadi	0	0
77	Kakumiro	0	0
78	Kalaki	0	0
79	Kalangala	0	0
80	Kalungu	0	0
81	Kampala	0	0
82	Kamwenge	0	0
83	Kanungu	0	0
84	Kapchorwa	0	0
85	Kasese	0	0
86	Kassanda	0	0
87	Kazo	0	0
88	Kibaale	0	0
89	Kiboga	0	0
90	Kikuube	0	0
91	Kiruhura	0	0
92	Kisoro	0	0
93	Kitagwenda	0	0
94	Koboko	0	0

95	Kumi	0	0
96	Kween	0	0
97	Kyankwanzi	0	0
98	Kyegegwa	0	0
99	Kyenjojo	0	0
100	Kyotera	0	0
101	Luuka	0	0
102	Lwengo	0	0
103	Lyantonde	0	0
104	Madi Okollo	0	0
105	Manafwa	0	0
106	Maracha	0	0
107	Masaka	0	0
108	Mbale	0	0
109	Mbarara	0	0
110	Mitooma	0	0
111	Mityana	0	0
112	Moroto	0	0
113	Moyo	0	0
114	Mpigi	0	0
115	Mubende	0	0
116	Mukono	0	0

117	Nakapiripirit	0	0
118	Nakaseke	0	0
119	Namisindwa	0	0
120	Ntoroko	0	0
121	Ntungamo	0	0
122	Obongi	0	0
123	Rakai	0	0
124	Rubanda	0	0
125	Rubirizi	0	0
126	Rukiga	0	0
127	Rukungiri	0	0
128	Rwampara	0	0
129	Sheema	0	0
130	Sironko	0	0
131	Ssembabule	0	0
132	Tororo	0	0
133	Wakiso	0	0
134	Yumbe	0	0
135	Zombo	0	0

Supplementary figure S6

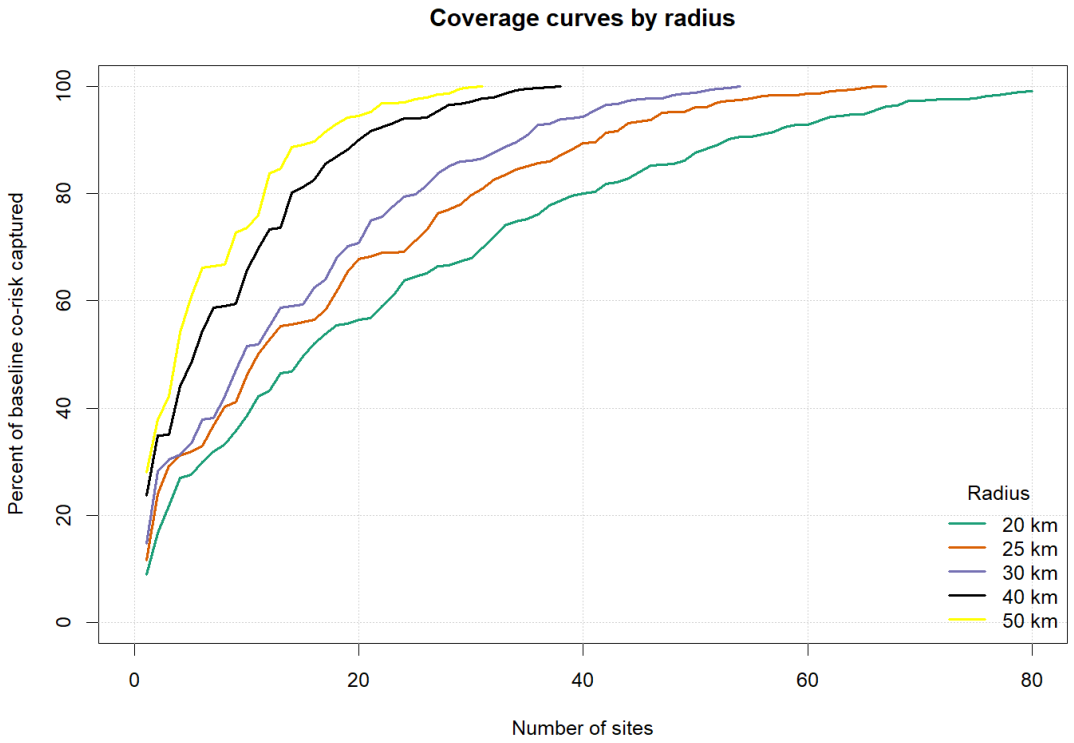

Figure S6. Coverage curves by radius (Percent of baseline co-risk captured for radii of 20, 25, 30, 40, and 50 km).

Supplementary table S12.

Table S12. Radius sensitivity milestones (Minimum number of sites needed to reach 60, 70, and 80 percent capture for each radius).

Radius km	Number of sites for 60% cappture	Number of sites for 70% cappture	Number of sites for 80% cappture
20	23	32	40
25	18	25	31
30	16	19	26
40	10	12	14
50	5	9	12

Supplementary figure S7a-S7d

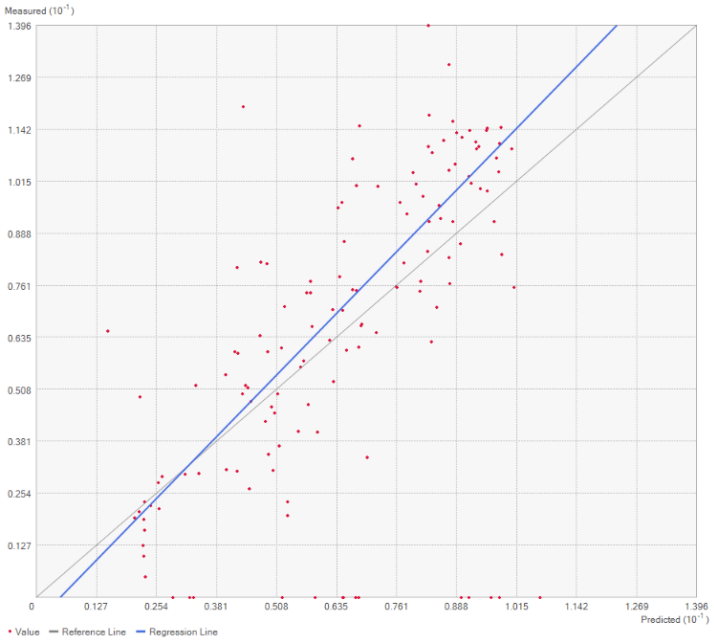

Figure S7a. Observed vs predicted with 1:1 reference and fitted regression;

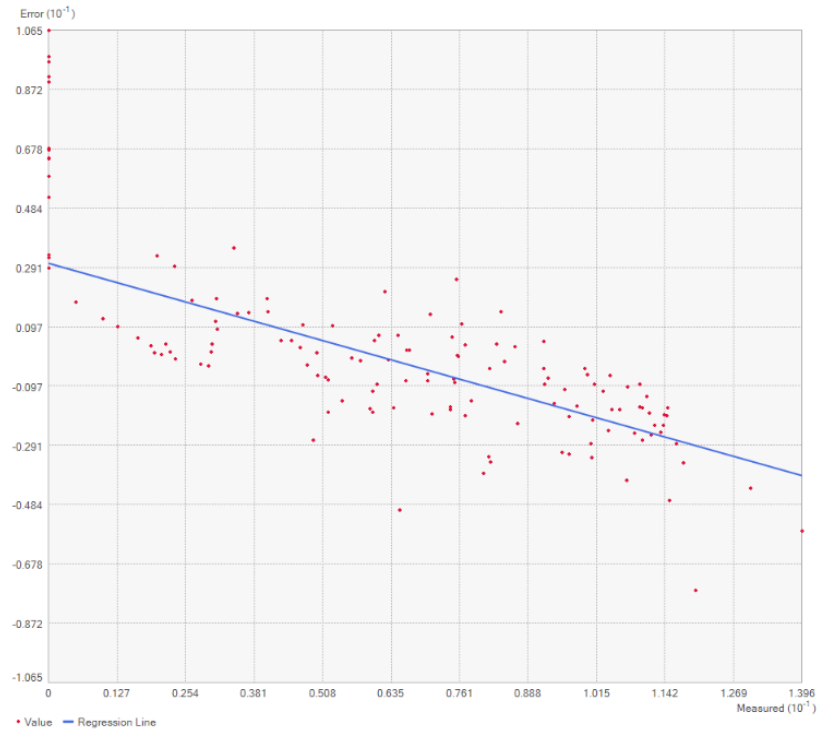

Figure S7b. Residual error vs measured;

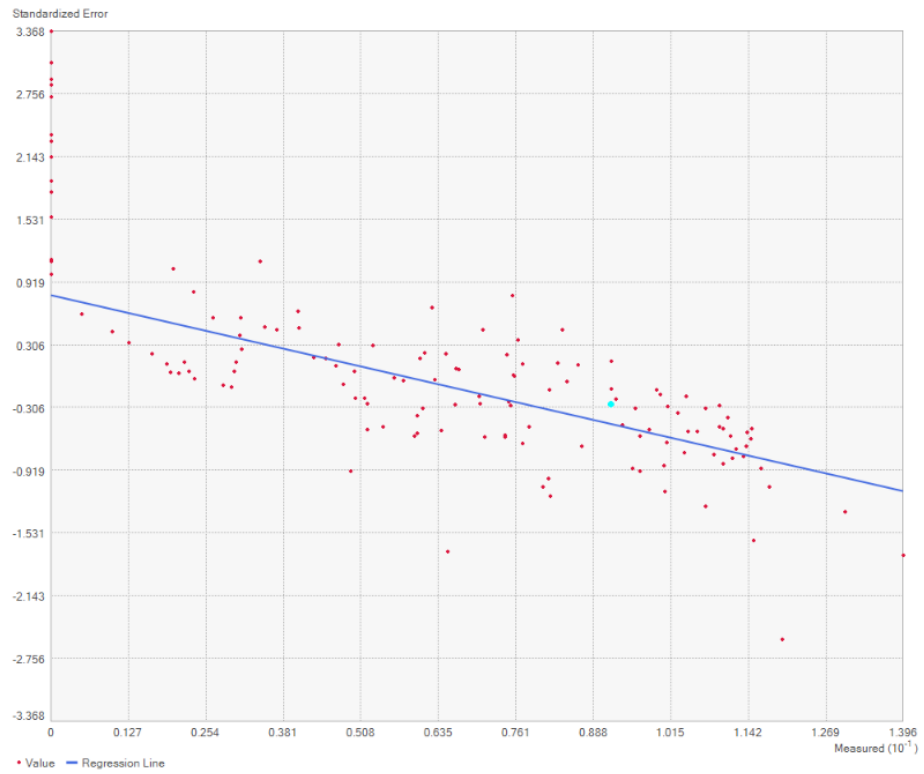

Figure S7c. Standardized residuals vs measured;

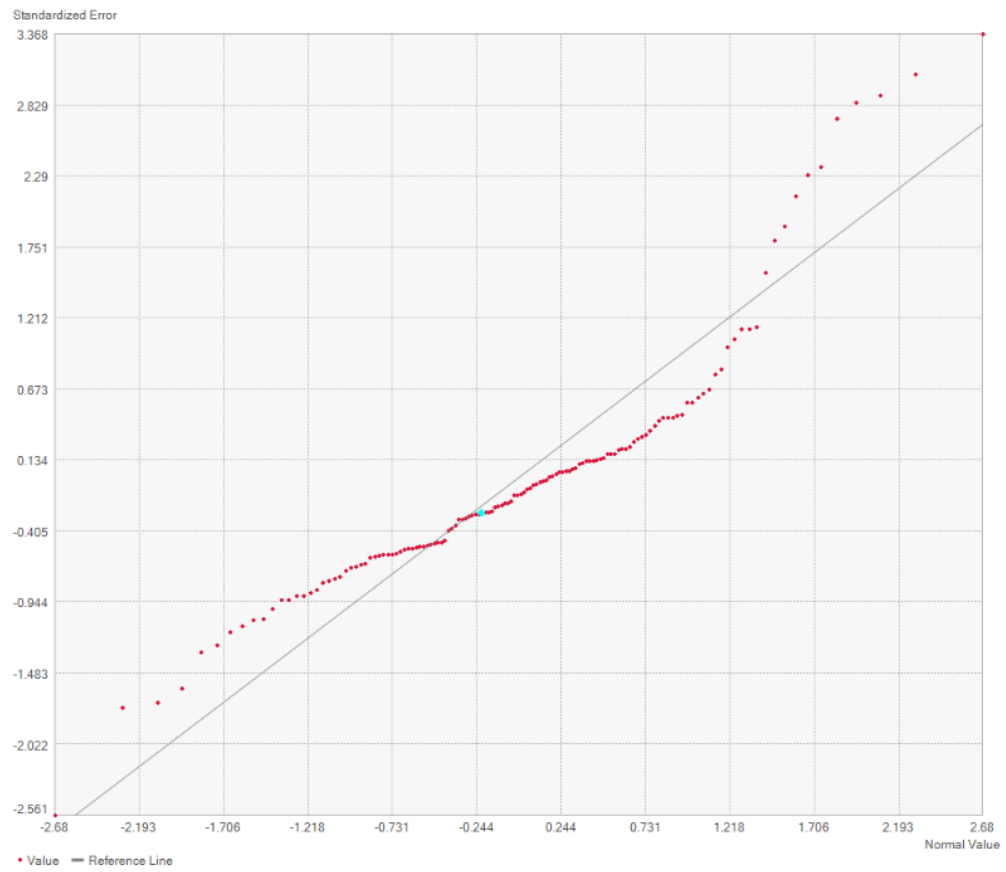

Figure S7d. Standardized-error Q-Q plot;

Supplementary table S13.

Table S13. EBK cross-validation statistics.

Metric	**Value**
Count	136
Average CRPS	0.015820
Inside 90 Percent Interval (%)	90.4
Inside 95 Percent Interval (%)	93.4
Mean Error	0.000005
Root-Mean-Square Error (RMSE)	0.029916
Mean Standardized Error	0.000582
Root-Mean-Square Standardized Error (RMSSE)	0.948309
Average Standard Error (ASE)	0.031099

Supplementary text S2: Two-step floating catchment area (2SFCA) computation and polygon generation

The two-step floating catchment area method, 2SFCA, was applied to produce time-based service areas for Health Centre III and IV facilities and to create governance polygons for assigning optimized hub locations to named facilities. The main analysis used the standard binary kernel. An enhanced step-decay variant, E2SFCA, was prepared for sensitivity checks [3-6].

Inputs and notation

Facilities ($j \in \{1, \dots, J\}$) were Health Centre III or IV or tertiary hospital points with unique IDs, level, ownership, and WGS 84 coordinates reprojected to EPSG:32636.

Population ($i \in \{1, \dots, I\}$a) comprised WorldPop 2020 under-five cells at 100 m resolution; P_i denoted the under-five population at cell i [7].

Least-cost travel time (t_{ij}) from facility j to population cell i was computed on a 100 m anisotropic friction surface in AccessMod 5.x that integrated road class, slope, land cover, hydrology and administrative barriers [8, 9].

The catchment threshold was $T_0 = 60$ minutes.

Facility capacity (S_j) was set to 1 in the primary analysis, a unit-capacity assumption that yields auditable polygons.

The within-catchment weight function $W(\cdot)$ controlled distance decay. The primary analysis used a binary kernel.

Facility-side reachable population set $\mathcal{C}_j = \{i: t_{ij} \leq T_0\}$. Population-side reachable facility set $\mathcal{F}_i = \{j: t_{ij} \leq T_0\}$.

Step 1, facility-side provider-to-population ratio

For each facility j, a ratio compared nominal supply to the demand pool reachable within T_0:

$$R_j := \frac{S_j}{\sum_{i \in \mathcal{C}_j} P_i \, W(t_{ij})}.$$

Binary kernel, main analysis. $W(t_{ij}) = \mathbb{1}[t_{ij} \leq T_0]$.

Enhanced 2SFCA, sensitivity. A step-decay kernel down-weighted population by travel-time bands, for example (0–20), (20–40), (40–60) minutes with non-increasing weights ($w_1 \geq w_2 \geq w_3 > 0$). The ratio became

$$R_j^{\mathrm{E2}} := \frac{S_j}{\sum_{i \in \mathcal{C}_j} P_i \; w(b(i,j))},$$

where $b(i,j)$ mapped t_{ij} to band index (1,2,3) [4].

Step 2, population-side accessibility

For each population cell i, accessibility aggregated Step-1 ratios from all facilities reachable within T_0:

$$A_i := \sum_{j \in \mathcal{F}_i} R_j \; W(t_{ij}).$$

With the binary kernel, A_i was the unweighted sum of contributing facility ratios. With E2SFCA, each contribution was multiplied by the band weight w_k associated with t_{ij} [3, 5, 6].

Conversion of accessibility to governance polygons

Accessibility values were converted to a non-overlapping partition that could support program assignment.

A_i was computed for all population cells within ADM0.

For each cell i, the facility j^* that maximized the cell-level contribution $R_j W(t_{ij})$ over $j \in \mathcal{F}_i$ was identified. With the binary kernel, this reduced to selecting the facility with the largest R_j among those within 60 minutes.

Cell i was assigned to j^*. Assigned cells were dissolved by facility ID to produce single-part polygons.

Ties were resolved by facility level, hospital preferred to HC IV to HC III, then by smaller t_{ij}.

This procedure produced a countrywide set of non-overlapping governance polygons that respected travel time. The approach is consistent with facility catchment applications in health geography [3].

Travel-time computation and sparsity strategy

Travel times (t_{ij}) were generated with least-cost analysis on the 100 m friction surface in AccessMod 5.6. Candidate pairs were limited to $t_{ij} \leq T_0$ to create a sparse matrix and to improve performance, which is standard practice for large-scale 2SFCA computations. The friction surface used class-specific road speeds, slope penalties derived from a national DEM, land-cover costs, and water barriers. Global evidence supports friction-surface travel time as a robust proxy for realized access at scale [9, 10].

Implementation details that affect results

Capacity (S_j). A unit-capacity assumption ($S_j = 1$) was used because reliable service capacity by facility was not available.

Kernel ($W(\cdot)$). The binary kernel was chosen for transparency and audit. The E2SFCA kernel was reserved for robustness checks because it reduces sharp cut-offs in peri-urban belts [4].

Threshold (T_0). A 60-minute threshold matched a program-relevant access standard and common practice in accessibility studies [8].

Edge handling. Isochrones and governance polygons were clipped to ADM0. Major water bodies were treated as barriers.

Quality control

Topology was validated after each stage. The union of governance polygons was checked to equal the union of all 60-minute isochrones. Polygons crossing major lakes without a mapped ferry were flagged for correction. Attribute tables stored facility ID, level, ownership, polygon area, under-five population by zonal aggregation, mean and 90th percentile modeled travel time, and the kernel used. All parameter values, friction-surface reclassification tables, and AccessMod run settings were recorded in a run log.

References

1. Ndeezi, G., et al., *Burden of sickle cell trait and disease in the Uganda Sickle Surveillance Study (US3): a cross-sectional study.* Lancet Glob Health, 2016. **4**(3): p. e195-200.
2. Kiyaga, C., *The Epidemiology of Childhood Sickle Cell Anaemia and the Disease Modifying Effects of the-α3. 7Deletional form Of α-Thalassaemia and the Glucose-6-phosphate Dehydrogenase G202t Allele in Uganda*. 2024, Open University (United Kingdom).
3. Delamater, P.L., *Spatial accessibility in suboptimally configured health care systems: a modified two-step floating catchment area (M2SFCA) metric.* Health Place, 2013. **24**: p. 30-43.
4. Luo, W. and Y. Qi, *An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians.* Health & Place, 2009. **15**(4): p. 1100-1107.
5. Luo, W. and F. Wang, *Measures of Spatial Accessibility to Health Care in a GIS Environment: Synthesis and a Case Study in the Chicago Region.* Environment and Planning B: Planning and Design, 2003. **30**(6): p. 865-884.
6. Wang, F., *Measurement, Optimization, and Impact of Health Care Accessibility: A Methodological Review.* Annals of the Association of American Geographers, 2012. **102**(5): p. 1104-1112.
7. *WorldPop :: Age and sex structures*.
8. *AccessMod: geographic access to health care*.
9. Ray, N. and S. Ebener, *AccessMod 3.0: computing geographic coverage and accessibility to health care services using anisotropic movement of patients.* International Journal of Health Geographics, 2008. **7**(1): p. 63.
10. Weiss, D.J., et al., *Global maps of travel time to healthcare facilities.* Nature Medicine, 2020. **26**(12): p. 1835-1838.