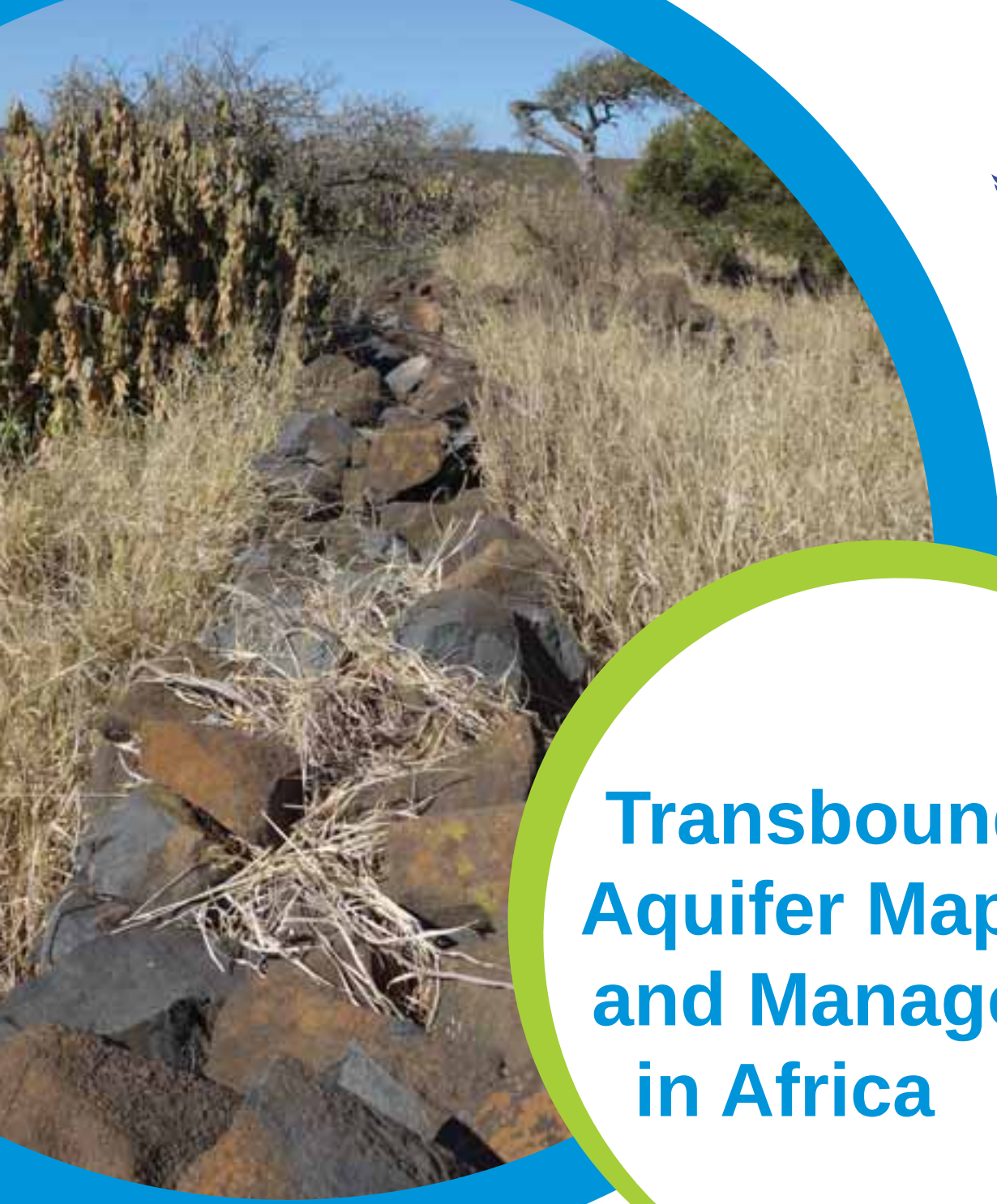

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RESEARCH PROGRAM ON Water, Land and Ecosystems

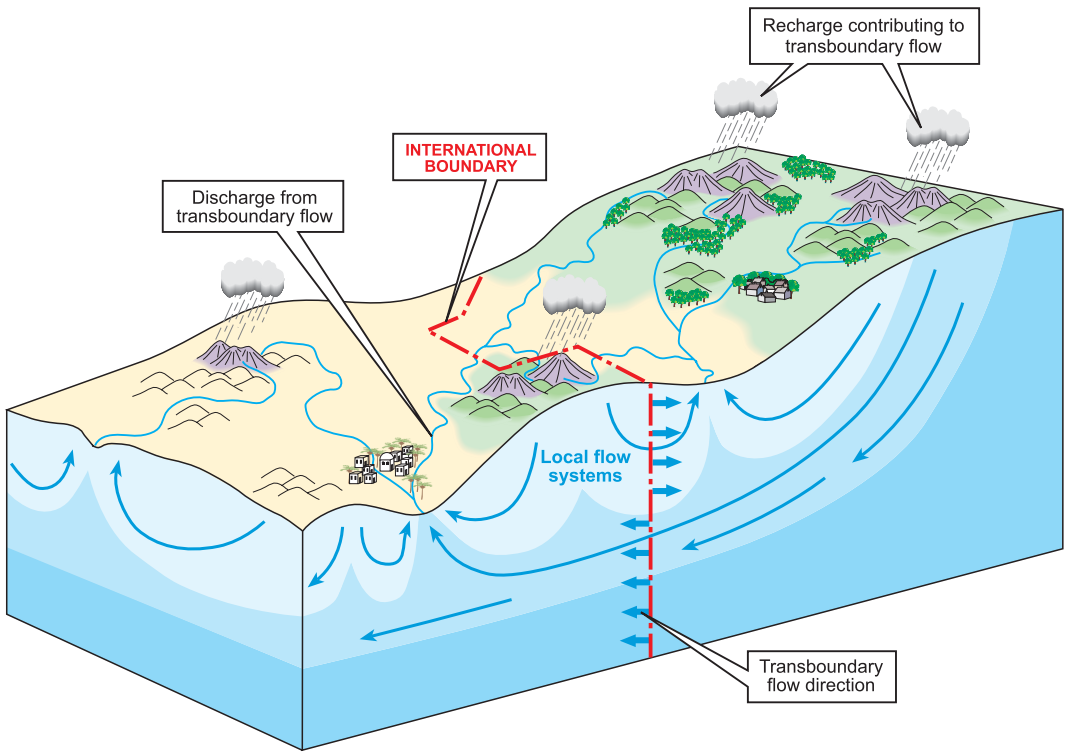
Led by: IWMI International Water Management Institute

Transboundary Aquifer Mapping and Management in Africa

Africa is heavily reliant on groundwater resources, with an estimated 75% of the population dependent on this resource for basic water supplies. However, with population growth, climate change and the need to combat growing food insecurity, the demand for groundwater is set to increase in the future. The focus on transboundary aquifers (TBAs) comes from the recognition of this increasing stress on available water resources.

For the purpose of this study, a TBA (Figure 1) refers to an aquifer or an aquifer system, parts of which are situated in different states. In practical identification and verification of a TBA, the spatial delimitation, hydrogeological similarity, recharge and discharge mechanisms and zones, and significant hydraulic connectivity between the national compartments of the TBA are all important factors and should be established and agreed upon between the aquifer-sharing states.

Figure 1. Schematic illustration of a transboundary aquifer.



Source: UNESCO 2004

Figure 2 builds on previous maps created by the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP) and the International Groundwater Resources Assessment Centre (IGRAC), and shows the presently known TBAs in Africa. It includes 80 aquifers and aquifer systems, which are shared internationally, superimposed on 63 international river basins. The mapping proposes a new nomenclature for the TBAs, based on three subregions, reflecting the leading regional economic communities (RECs) as shown in Table 4. The map illustrates that TBAs cover approximately 42% of the continental area and 30% of the population.

Table 1. Evolution of the number of TBAs in Africa, inventoried and mapped by various efforts and subdivided into regions.

AFRICAN REGION[a]	UNESCO 2004	WHYMAP 2006	IGRAC 2009	IGRAC 2012	Altchenko and Villholth 2013
Northern Africa	6	6	7	9	15
Western and Middle Africa (except countries in the SADC region[b])	9	9	9	22	22
Eastern Africa (except countries in the SADC region)	5	5	5	6	8
Southern Africa (SADC countries)	18	20	20	34	35
TOTAL	38	40	41	71	80

Notes: [a] According to the United Nations division of regions and subregions (UNdata 2013)
[b] SADC - Southern African Development Community

Figure 2. Transboundary aquifers and international river/lake basins in Africa.

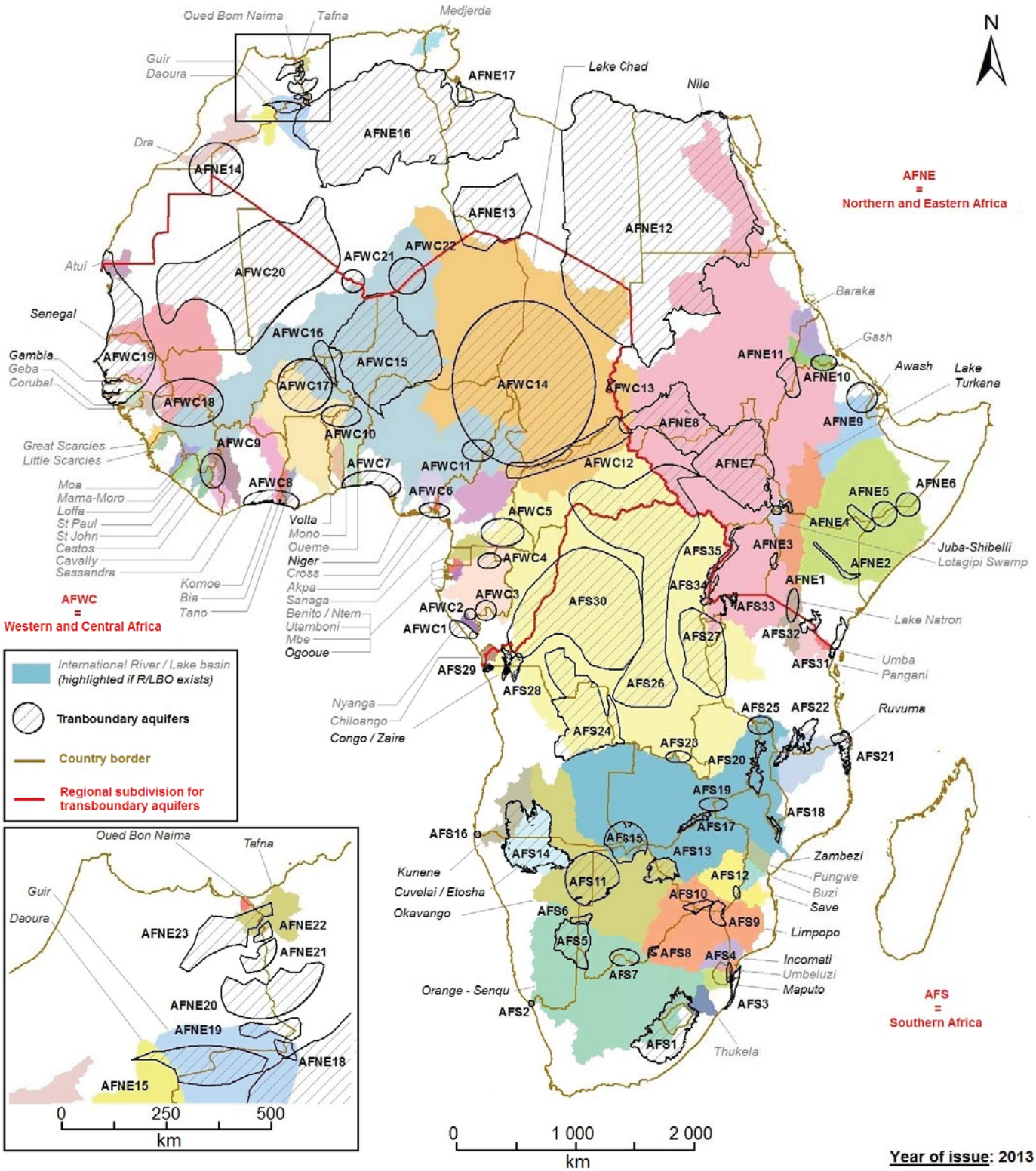


Table 2. Inventory of transboundary aquifers in Africa.

ID	Name	Countries sharing the aquifer	Population (inhabitants)	Area (km^2)	Aquifer type	Rainfall (mm/year)	Annual recharge (WHYMAP)
AFS1	Karoo sedimentary aquifer	Lesotho/South Africa	5,568,000	166,000	Consolidated sedimentary rocks	350 – 1,200	VL to M
AFS2	Coastal sedimentary basin 5	Namibia/South Africa	7,900	1,700	Quaternary and consolidated sedimentary rocks	45 – 55	VL to M
AFS3	Coastal sedimentary basin 6	Mozambique/South Africa	548,000	11,700	Quaternary and consolidated sedimentary rocks	700 – 1,200	M to H
AFS4	Rhyolite-Breccia aquifer	Mozambique/South Africa/Swaziland	206,000	5,500	Volcanic/Quaternary	600 – 850	VL to M
AFS5	Southwest Kalahari/Karoo basin	Botswana/Namibia/South Africa	15,500	85,000	Kalahari groups aquifer and Karoo supergroup aquifers	200 – 350	VL to M
AFS6	Ncojane aquifer	Botswana/Namibia	2,300	10,300	Consolidated sedimentary rocks	300 – 350	VL to M
AFS7	Khakhea/Bray dolomite	South Africa/Botswana	57,000	30,000	Dolomite	300 – 450	VL to M
AFS8	Ramotswa dolomite basin	Botswana/South Africa	135,500	3,200	Malmani subgroup of the Transvaal supergroup	500 – 550	VL to M
AFS9	Limpopo basin	Mozambique/South Africa/Zimbabwe	313,800	20,000	Volcanic and basement rocks	400 – 700	VL to L
AFS10	Tuli Karoo sub-basin	Botswana/South Africa/Zimbabwe	70,600	14,330	Volcanic and basement rocks	300 – 450	VL to L
AFS11	Northern Kalahari/Karoo basin	Angola/Botswana/Namibia/Zambia	35,900	144,400	Consolidated sedimentary rocks	380 – 550	VL to H
AFS12	Save alluvial aquifer	Mozambique/Zimbabwe	32,600	4,500	Alluvial	400 – 600	VL to M
AFS13	Eastern Kalahari/Karoo basin	Botswana/Zimbabwe	54,300	39,600	Upper Karoo Sandstone	400 – 600	VL to M
AFS14	Cuvelai and Etosha basin	Angola/Namibia	1,032,400	202,000	Consolidated sedimentary rocks	300 – 900	L to M
AFS15	Nata Karoo sub-basin	Botswana/Namibia/Zimbabwe	195,000	91,000	Ecca sequence	500 – 750	VL to M
AFS16	Coastal sedimentary basin 4	Angola/Namibia	20	2,200	Quaternary and consolidated sedimentary rocks	100 – 150	VL to M
AFS17	Medium Zambezi aquifer	Mozambique/Zambia/Zimbabwe	50,800	10,700	Quaternary and consolidated sedimentary rocks	720 – 780	VL to M
AFS18	Shire Valley aquifer	Malawi/Mozambique	527,000	6,200	Tertiary/Quaternary	780 – 900	M to VH
AFS19	Arangua Alluvial	Mozambique/Zambia	12,500	21,200	Alluvial	700 – 1,100	VL to M
AFS20	Sand and gravel aquifer	Malawi/Zambia	2 233,000	25,300	Unconsolidated intergranular aquifer and weathered basement complex	800 – 1,200	VL to VH
AFS21	Coastal sedimentary basin 3	Mozambique/Tanzania	794,000	23,000	Quaternary and consolidated sedimentary rocks	930 – 1,200	H
AFS22	Karoo-Sandstone aquifer	Mozambique/Tanzania	214,500	40,000	Consolidated sedimentary rocks	900 – 1,700	M to VH
AFS23	Kalahari/Katangian basin	DRC/Zambia	1,006,000	15,600	Katangian and Kalahari sequence	1,200 – 1,300	H to VH
AFS24	Congo Intra-cratonic	Angola/DRC	1,920,000	317,200	Consolidated sedimentary rocks	1,200 – 1,650	H
AFS25	Weathered basement	Malawi/Tanzania/Zambia	852,000	25,842	NI	900 – 2,000	M to VH
AFS26	Karoo Carbonate	CAR/Congo/South Sudan	9,400,000	941,100	Limestone/Sandstone	1,000 – 1,800	H to VH
AFS27	Tanganyika aquifer	Burundi/DRC/Tanzania/Rwanda	11,940,000	222,300	Fractured basalt and granite	800 – 1,800	VL to VH
AFS28	Dolomitic aquifer	Angola/DRC	750,600	21,300	Karst weathered dolomite	1,100 – 1,450	H to VH
AFS29	Coastal sedimentary basin 2	Angola/DRC	34,000	2,250	Quaternary and consolidated sedimentary rocks	800 – 1,000	VL to H
AFS30	Cuvette Centale	Congo/DRC	14,000,000	814,800	Alluvial Sandstones	1,400 – 2,100	H to VH
AFS31	Coastal sedimentary basin 1	Kenya/Tanzania	2,150,000	16,800	Quaternary and consolidated sedimentary rocks	850 – 1,250	M to H
AFS32	Kilimanjero aquifer	Kenya/Tanzania	1,396,000	14,600	Volcanic alluvium	600 – 1,600	VL to M
AFS33	Kagera aquifer	Rwanda/Tanzania/Uganda	493,500	5,800	Alluvial unconsolidated sand and gravels	930 – 1,800	VL to M
AFS34	Mgahinga	DRC/Rwanda/Uganda	1,451,000	4,400	Volcanic	1,250 – 1,650	VL to M
AFS35	Western Rift valley sediment	DRC/Uganda	1,151,000	29,500	Volcanic	800 – 1,250	VL to H
AFWC1	NN	Congo/Gabon	13,300	23,000	NI	1,400 – 1,750	M to VH
AFWC2	NN	Congo/Gabon	48,500	7,100	NI	1,650 – 1,950	H to VH
AFWC3	NN	Congo/Gabon	41,000	23,500	NI	1,750 – 1,950	H to VH
AFWC4	NN	Congo/Gabon	1,700	19,600	NI	1,600 – 1,750	H to VH
AFWC5	NN	Cameroon/CAR/Gabon	178,000	66,400	NI	1,550 – 1,650	H to VH
AFWC6	Rio Delrey	Cameroon/Nigeria	3,300,000	24,000	Upper Miocene to Quaternary	2,500 – 3,130	VH
AFWC7	Keta basin	Benin/Nigeria/Togo	16,896,000	55,400	Quaternary (sand, silt, clay)	950 – 2,450	H to VH
AFWC8	Tano basin	Côte d'Ivoire/Ghana	4,740,000	43,000	Quaternary Terminal Continental and Maestrichtien Aquifer	1,300 – 1,930	H to VH
AFWC9	NN	Côte d'Ivoire/Guinea/Liberia	2,370,000	47,300	NI	1,400 – 2,050	H to VH
AFWC10	Kandi sedimentary basin	Benin/Burkina Faso/Ghana/Togo	1,143,000	47,800	Cambro-Ordovicien and alluvial	850 – 1,100	VL to VH
AFWC11	Garoua - Chari	Cameroon/Nigeria	1,870,000	38,400	Sandstone - Clay	950 – 1,400	H to VH
AFWC12	NN	Cameroon/CAR/Chad/Sudan	716,000	155,400	Sedimentary	700 – 1,600	H to VH

(Continued)

Table 2. Inventory of transboundary aquifers in Africa (Continued)

ID	Name	Countries sharing the aquifer	Population (inhabitants)	Area (km^2)	Aquifer type	Rainfall (mm/year)	Annual recharge (WHYMAP)
AFWC13	Disa	Chad/Sudan	74,300	1,500	Sandstone	500 – 550	VL to M
AFWC14	Lake Chad	CAR/Cameroon/Chad/Niger/Nigeria	22,419,100	1,300,500	Sedimentary: the Upper Quaternary, the Lower Pliocene and the TC	40 – 1,400	VL to H
AFWC15	Irhazer-Iullemeden	Algeria/Mali/Niger/Nigeria	12,888,600	545,400	Sedimentary deposit including IC and TC	80 – 900	VL to VH
AFWC16	NN	Burkina Faso/Mali/Niger	333,000	3,500	NI	250 – 600	VL to M
AFWC17	Liptako-Gourma aquifer	Burkina Faso/Niger	7,758,300	159,500	Fractured metamorphic	400 – 900	VL to H
AFWC18	NN	Guinea/Mali/Senegal	4,250,000	185,500	Birrimien	850 – 1,650	VL to VH
AFWC19	Senegalo-Mauritanian basin	Gambia/Guinea-Bissau Mauritania/Senegal	11,930,000	331,450	Maestrichtien	20 – 1,850	VL to VH
AFWC20	Taoudeeni basin	Algeria/Mali/Mauritania	82,400	936,000	Multilayers	10 – 350	VL to L
AFWC21	L'air Cristalline aquifer	Algeria/Mali	84	28,400	NI	60 – 100	VL to M
AFWC22	Tin Seririne	Algeria/Nigeria	520	73,700	NI	20 – 50	VL to L
AFNE1	Rift aquifer	Kenya/Tanzania/Uganda	279,000	21,150	Volcanic	450 – 1,100	VL to M
AFNE2	Merti aquifer	Kenya/Somalia	129,000	13,500	Semi-consolidated sedimentary	350 – 750	L to M
AFNE3	Mount Elgon	Kenya/Uganda	806,550	5,400	Volcanic	1,000 – 1,300	VL to M
AFNE4	Dawa	Ethiopia/Kenya/Somalia	223,150	24,000	Volcanic rocks, alluvials and Precambrian basement	300 – 650	VL to L
AFNE5	Juba aquifer	Ethiopia/Kenya/Somalia	197,600	34,600	Aquifers in Precambrian and intrusive rocks	270 – 450	VL to L
AFNE6	Shabelle aquifer	Ethiopia/Somalia	334,000	31,000	Sedimentary and minor volcanic aquifers	280 – 400	VL to L
AFNE7	Sudd basin	Ethiopia/Kenya South Sudan/Sudan	2,926,500	331,600	Precambrian and volcanic rocks with patches of alluvials/ sedimentary	450 – 1,100	M
AFNE8	Baggara basin	CAR/South Sudan/Sudan	2,433,500	239,300	Umm Ruwaba (overlain the Nubian Formation)	300 – 900	L to M
AFNE9	Awash Valley aquifer	Djibouti/Eritrea/Ethiopia	627,400	50,700	Volcanic	110 – 350	VL to L
AFNE10	Mareb aquifer	Eritrea/Ethiopia	1,827,900	22,800	Precambrian and intrusive rocks	450 – 550	VL to M
AFNE11	Gedaref	Eritrea/Ethiopia Sudan	732,000	38,700	Precambrian and volcanic rocks with patches of alluvials/sedimentary	400 – 950	VL to M
AFNE12	Nubian Sandstone aquifer system	Chad/Egypt/Libya/Sudan	67,320,000	2,608,000	Nubian and Post-Nubian	1 – 550 (mainly < 30)	Mainly VL (VL to VH)
AFNE13	Mourzouk-Djado basin	Algeria/Libya/Nigeria	108,000	286,200	Sedimentary	< 20	Mainly VL (VL to M)
AFNE14	Tindouf aquifer	Algeria/Mauritania/Morocco	107,000	160,000	Alternating series of calcareous rocks and sand	30 – 200	VL to M
AFNE15	Errachidia basin	Algeria/Morocco	156,300	18,500	Sandstone, calcareous, dolomite	80 – 200	VL to L
AFNE16	North Western Sahara Aquifer system	Algeria/Libya/Tunisia	4,000,000	1,190,000	Sand, Sandstone, sandy clay, calcareous, dolomite	10 – 300 (mainly < 50)	VL to L
AFNE17	Djaffar Djeffara	Libya/Tunisia	262,400	15,800	NI	130 – 250	L
AFNE18	Figuig	Algeria/Morocco	32,300	1,500	Phreatic Aquifer, Porous	100 – 170	VL to L
AFNE19	Chott Tigri-Lahouita	Algeria/Morocco	26,800	4,700	Porous, Karst, Dolomite Limestone and Sandstone	180 – 250	VL to L
AFNE20	Ain Beni mathar	Algeria/Morocco	23,100	20,000	Karstic, Dolomite Limestone and Dolomite	260 – 350	VL to M
AFNE21	Angad	Algeria/Morocco	25,600	3,500	Porous, Plio-Quaternary	350 – 450	VL to M
AFNE22	Jbel El Hamra	Algeria/Morocco	40,100	1,250	Karstic	440 – 500	VL to L
AFNE23	Triffa	Algeria/Morocco	920,000	13,100	PorousVillafranchian and Quaternary	370 – 450	M

Notes: NN = No name referenced; NI = No information; TC = Terminal Continental; IC = Intercalary Continental;
VL = Very low (0 - 2 mm/year); L = Low (2 - 20 mm/year); M = Medium (20 - 100 mm/year); H = High (100 - 300 mm/year); VH = Very high (> 300 mm/year)

The management of TBAs has only recently been addressed as part of transboundary water management. It is critical to implement frameworks for managing already stressed, shared groundwater resources and associated dependent ecosystems, as well as for enhancing the sustainable development of 'new' groundwater resources. While a harmonised approach is advocated, it is also acknowledged that flexible and hybrid institutional models that build on the present customary approach of making the river and lake basin organisations (R/LBOs) responsible may be necessary, as illustrated in Table 3 and Figure 3.

Table 3. Configuration of TBA location in relation to international river/lake basin (R/LB) as described in Figure 3.

Geographical type	Intersection of TBA with R/LB	Number of cases in Africa (number of cases where R/LBO exists)[a]	Example of TBA with no R/LBO
1	None	3 (-)	Ain Beni Mathar (AFNE20)
2	TBA partly inside a single R/LB	20 (13)	Coastal Sedimentary Basin 1 (AFS31)
3	TBA partly inside two or more R/LBs	12 (7)	Tano Basin (AFWC8)
4	TBA fully inside a single R/LB	23 (22)	Figuig (AFNE18)
5	TBA fully inside two R/LBs	18 (17)	Errachidia Basin (AFNE15)
6	TBA fully inside three or more R/LBs	4 (3)	AFWC9[b]

Notes: [a] A distinction is made between international R/LBs with and without a formalised basin organisation.
[b] TBA has no name, according to IGRAC 2012.

Figure 3. Conceptual configuration of TBA location in relation to international river and lake basins (R/LBs); polygons represent river/lake basins, squares represent TBAs.

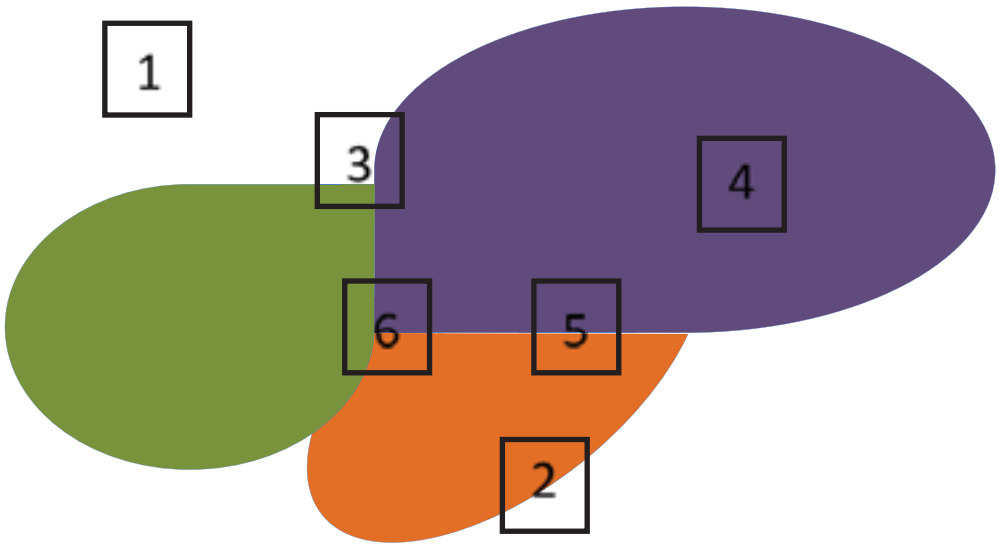


Table 4. The proposed regional subdivision for TBA nomenclature in Africa.

Subdivision zone name (code name)	Countries in the African continent	Regional economic communities (RECs) concerned
Northern and Eastern Africa (AFNE)	Algeria, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Morocco, Somalia, South Sudan, Sudan, Tunisia, Uganda and Western Sahara	IGAD[a***] COMESA[b**] CEN-SAD[c**] CEN-SAD[c**] EAC[d**] AMU/UMA[e*]
Western and Central Africa (AFWC)	Benin, Burkina Faso, Cameroon, Central African Republic (CAR), Chad, Republic of the Congo, Côte d'Ivoire, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo	ECOWAS[f***] ECCAS[g**] CEN-SAD[**] AMU/UMA[*]
Southern Africa (AFS)	Angola, Botswana, Burundi, Democratic Republic of the Congo (DRC), Lesotho, Madagascar, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe	SADC[h***] COMESA[**] EAC[**]

Notes: [***] active, [**] poorly active and [*] non-active in transboundary water resources management, according to NEPAD, AU and AfDB 2011.
[a] IGAD – Intergovernmental Authority on Development; [b] COMESA – Common Market for Eastern and Southern Africa; [c] CEN-SAD – The Community of Sahel-Saharan States; [d] EAC – East African Community; [e] AMU/UMA – Arab Maghreb Union; [f] ECOWAS – Economic Community of West African States; [g] ECCAS – Economic Community of Central African States; [h] SADC – Southern African Development Community.

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