International Water Management Institute

Technical Brief

Access to Water Tool: A framework for Mapping Inequalities in Water Access Across Africa

The Challenge

Access to safe water remains one of Sub-Saharan Africa's most persistent challenges—only 64% of people use improved water sources compared to 90% globally. Yet these averages mask vast spatial and seasonal inequalities. Traditional assessments, often based on household surveys, produce static snapshots that overlook fluctuations in availability, infrastructure degradation, and the time and effort required for daily water collection.

The ACWA Solution

The Access to Water in Africa (ACWA) Tool introduces a transformative, spatially explicit approach to assessing water accessibility. Moving beyond aggregated statistics, it integrates multiple water sources with walking-only and motorized travel scenarios to estimate monthly service levels at community scales. Built on a three-tier framework—water resource assessment, accessibility modeling, and service classification—ACWA aligns with WHO, JMP, and Sphere standards to directly support SDG 6.1.1 monitoring.

Ghana Pilot Implementation

A pilot study in Ghana illustrates ACWA's ability to expose hidden disparities in water access. Under walking-only conditions, 86–90% of rural populations experience inadequate access during the dry season. Motorized transport, however, significantly improves service levels, underscoring how mobility constraints—not just resource scarcity—define water security outcomes. This finding highlights the crucial role of transportation infrastructure in shaping equitable access.

Strategic Impact

As climate change and population growth intensify water stress, ACWA provides decision-makers with a dynamic, data-driven framework for understanding spatial and seasonal accessibility. By integrating mobility constraints, cost–benefit analysis, and infrastructure prioritization, the tool enables early warning for displacement risk and targeted investment planning. ACWA shifts water security assessment from static coverage reporting to real-time accessibility analysis, offering the temporal and spatial precision needed for evidence-based interventions that address the root causes of water insecurity in Africa

Introduction

Access to safe water remains one of Sub-Saharan Africa's most persistent development challenges—only 64% of people have access to improved water sources compared to 90% globally (World Bank, 2024). Yet these averages conceal deep spatial and seasonal disparities. Traditional assessments based on household surveys offer static coverage estimates that fail to reflect seasonal variability, infrastructure degradation, and physical accessibility constraints affecting daily water collection.

Water access extends beyond infrastructure to include travel time and mobility. Many households, especially in rural areas, face "travel time poverty," where physical distance or terrain limits access despite theoretical service availability. In contrast, populations with motorized transport enjoy markedly better access, underscoring mobility as a critical determinant of water security.

The ACWA Tool addresses these limitations through the integration of high-resolution geospatial data, accessibility modeling, and international service-level standards. By accounting for seasonal variation, transport modes, and climate-driven water availability, ACWA produces spatially explicit assessments that enable evidence-based planning, humanitarian response, and SDG 6.1.1 monitoring.

Methodological Framework

The ACWA tool operates through a three-tier analytical framework systematically addressing water resource assessment, accessibility modeling, and service classification (Figure 1). This hierarchical approach captures complex interactions between water availability, infrastructure, and human mobility for actionable decision-making.

Groundwater Potential Analysis

Assessment employs multi-criteria analysis with Analytical Hierarchy Process weighting generating a Groundwater Suitability Index. Integration includes depth, storage capacity, productivity, and recharge sustainability using British Geological Survey (British Geological Survey, 2021a, 2021b) and PCR-GLOBWB datasets. AHP prioritizes productivity (borehole yield relationship), followed by recharge

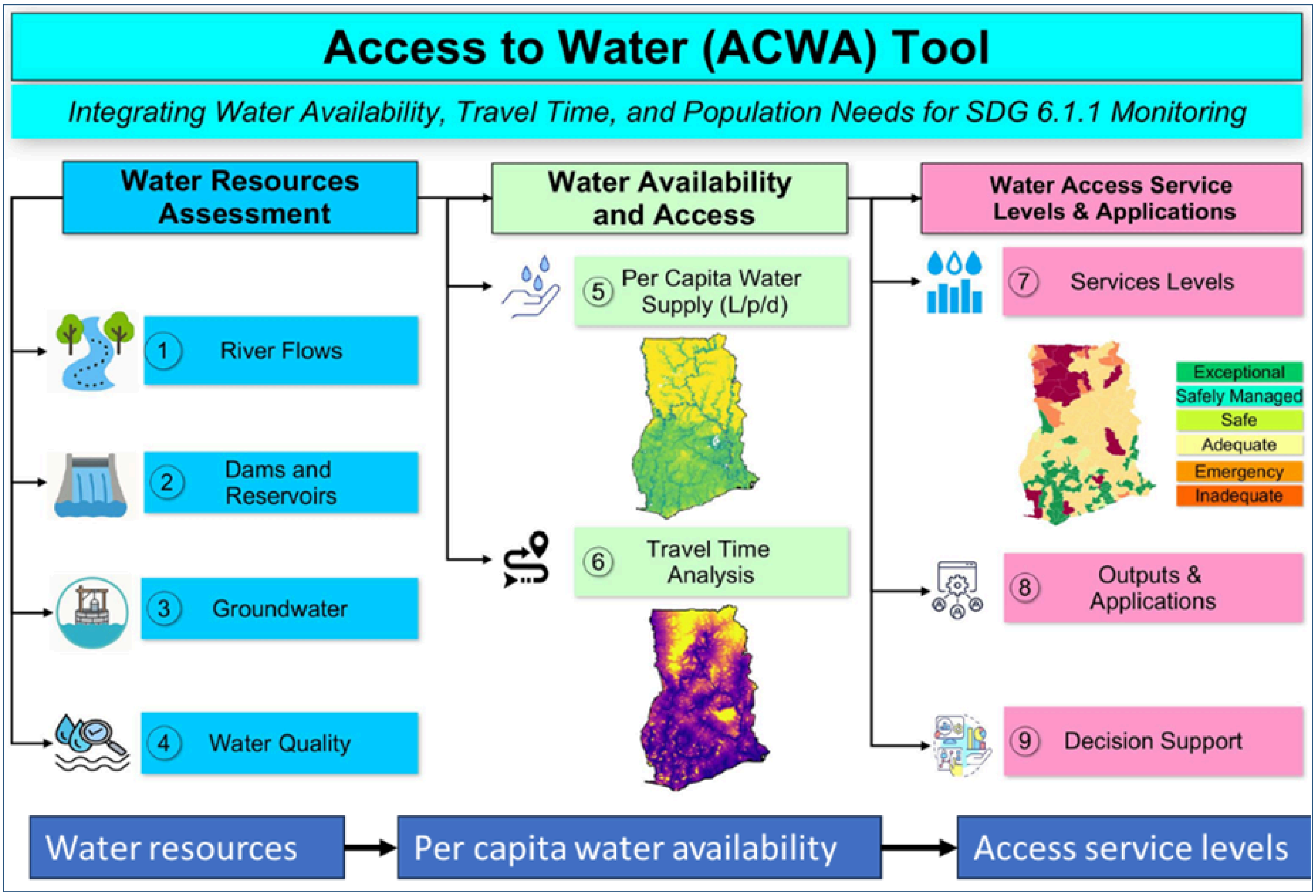


Figure 1. Conceptual framework of the Access to Water in Africa (ACWA) Tool showing the three-tier analytical approach integrating water resource assessment, water availability and accessibility analysis, and service level classification with decision support applications.

Water Resource Assessment

River Discharge

Surface water assessment utilizes VegDischarge v2, providing monthly discharge estimates at 1km resolution across over 650,000 river segments—a significant enhancement from 64,000 segments (Akpoti et al., 2024) (Figure 2). The methodology reserves 30% of discharge for environmental flows, converting monthly data to volume estimates compared against population demand to determine per-capita availability.

Reservoirs and Dams

Assessment integrates Northern Ghana studies (Siabi et al., 2023), OpenStreetMap inventories (2018-2024), and satellite measurements. Volume calculations use empirically validated area-volume relationships for small African reservoirs (Liebe et al., 2005), excluding reservoirs <0.02 hectares as insufficient for basic community needs (20 L/person/day for 2000 people). Methodology accounts for seasonal storage variations, critical in northern Ghana's dry periods.

sustainability, storage capacity, and depth accessibility, distinguishing reliable long-term potential from depletion-vulnerable areas (Figure 3).

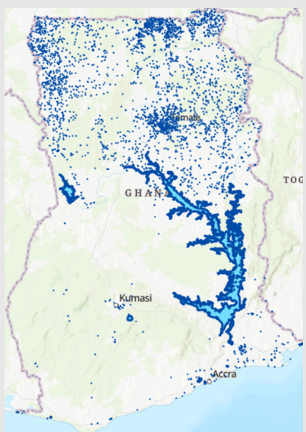
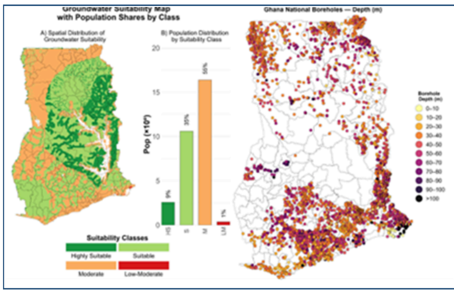


Figure 2. Spatial distribution of small reservoirs and dams across Ghana included in the ACWA analysis.

Boreholes and Wells Infrastructure

Infrastructure assessments incorporate existing databases evaluating groundwater suitability-infrastructure relationships. High potential/limited infrastructure areas represent priority investment zones, while adequate infrastructure/declining yield regions require alternative development or aquifer management. This ensures accessibility assessments reflect realistic procurement scenarios rather than theoretical availability.



Depth (m)	Wells (n)	%
0–10	3,369	29%
10–20	231	2%
20–30	1,287	11%
30–40	2,262	20%
40–50	1,894	16%
50–60	1,383	12%
60–70	702	6%
70–80	278	2%
80–90	65	1%
90–100	54	0.5%
>100	54	0.5%
Total Wells	**11,579**	**100%**

Figure 3. Groundwater potential and infrastructure distribution in Ghana showing (A) spatial distribution of groundwater suitability classes with corresponding population shares by suitability category, and (B) national borehole inventory displaying depth distribution and frequency.

Travel Time and Accessibility Modeling

The accessibility component represents ACWA's most innovative contribution (Figure 4). Traditional approaches assume uniform accessibility or apply simple distance buffers failing to account for topographic barriers and infrastructure. ACWA employs least-cost path analysis integrating landscape movement factors (Weiss et al., 2018). The methodology utilizes Global Friction Surface 2019, providing standardized travel time estimates at 1km resolution integrating roads, railways, waterways, topography, and land cover (Weiss et al., 2020). This ensures estimates reflect complex African rural movement realities (Nelson, 2008).

The methodology models two transportation scenarios capturing mobility constraints. Walking-only scenarios (Figure 5) represent rural populations lacking motorized transport, while motorized scenarios (Figure 6) reflect urban/peri-urban conditions. This dual-scenario approach reveals stark access disparities hidden under uniform assumptions.

Cost-distance calculations utilize Dijkstra's algorithm implementation through the gdistance package (van Etten, 2017), with careful attention to geo-correction procedures that account for latitude-dependent variations in cell distances (Hijmans & van Etten, 2014). Monthly processing cycles ensure that seasonal variations in water source availability are properly reflected in accessibility assessments (Weiss et al., 2018).

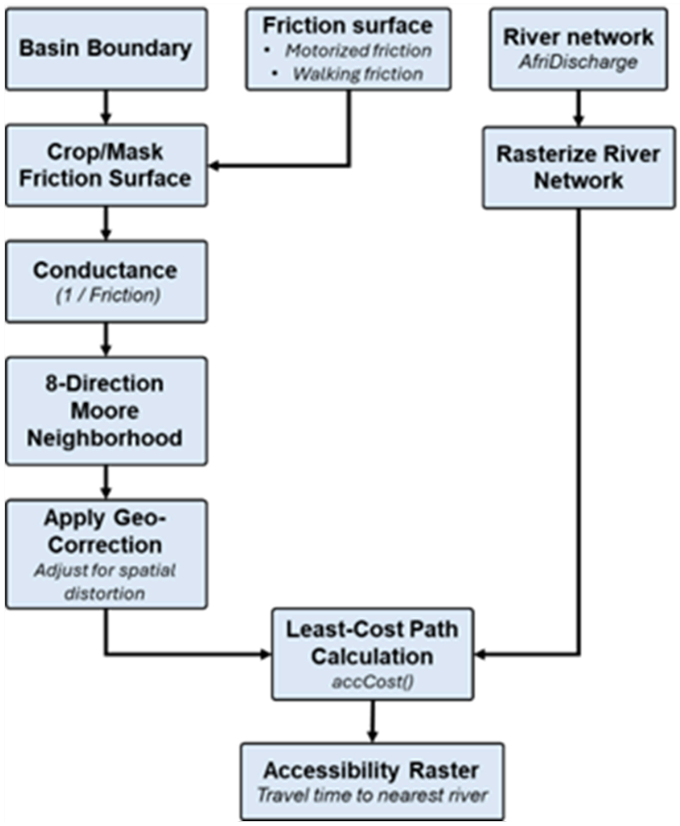


Figure 4. Example workflow diagram for accessibility modeling to river networks within the ACWA framework.

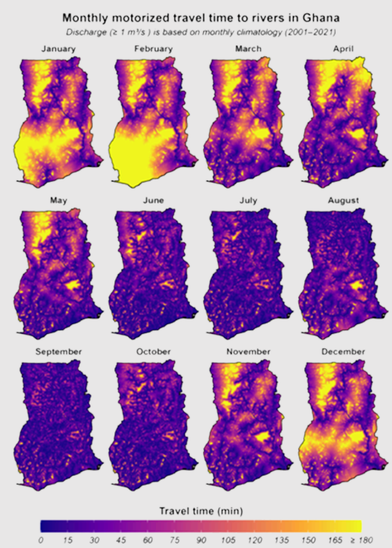


Figure 5. Monthly walking-only travel time to rivers in Ghana based on river discharge ≥1 m³/s from monthly climatology (2001-2021).

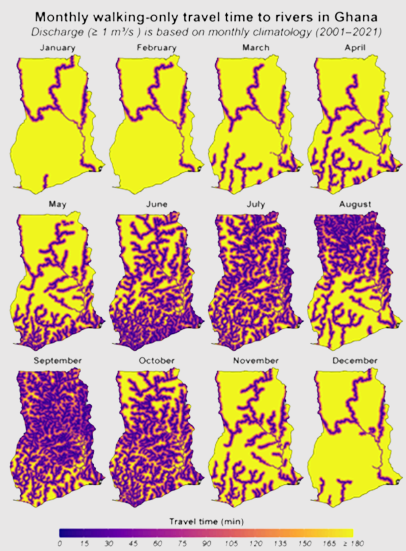


Figure 6. Monthly motorized travel time to rivers in Ghana based on river discharge ≥1 m³/s from monthly climatology (2001-2021).

Services Level Classification

ACWA classification synthesizes quantity and travel time through internationally recognized standards (Figure 7). Drawing from WHO basic needs assessments (WHO, 2017), JMP service ladders (WHO/UNICEF, 2021), and Sphere humanitarian standards (Sphere Association, 2018), ensuring SDG 6.1 monitoring consistency. Eight service levels range from exceptional access exceeding health targets to inadequate access with health risks.

Each level incorporates quantity thresholds (liters/person/day) and maximum travel times, following 30-minute collection guidelines for basic service (WHO/UNICEF, 2017). Integration includes WHO 15-20 L/person/day requirements with emergency 15 L/person/day survival thresholds (Sphere Association, 2018). Temporal aggregation identifies the most frequent service levels experienced annually.

Water Quality Integration

ACWA incorporates quality assessment through turbidity-based risk evaluation using Modified Universal Soil Loss Equation modeling predicting sediment yields and turbidity levels. Methodology translates erosion assessments into turbidity predictions through empirically calibrated rating curves relating sediment loads to water clarity. Quality classifications follow WHO guidelines identifying 5 NTU operational threshold for effective disinfection and 10 NTU treatment failure risk. Sources exceeding thresholds receive penalty scores downgrading overall classifications regardless of quantity/accessibility metrics.

Seasonal Water Accessibility in Ghana

Ghana serves as an ideal pilot for the ACWA Tool given its diverse climatic zones, varied water systems, and well-documented access challenges. The implementation analyzed multiple water sources, transport modes, settlement types, and administrative units to capture spatial and temporal disparities in water accessibility.

Results reveal strong contrasts across UN-Habitat settlement classes—rural areas, urban clusters, and urban centers. Rural zones dominate spatially (6.8 million people),

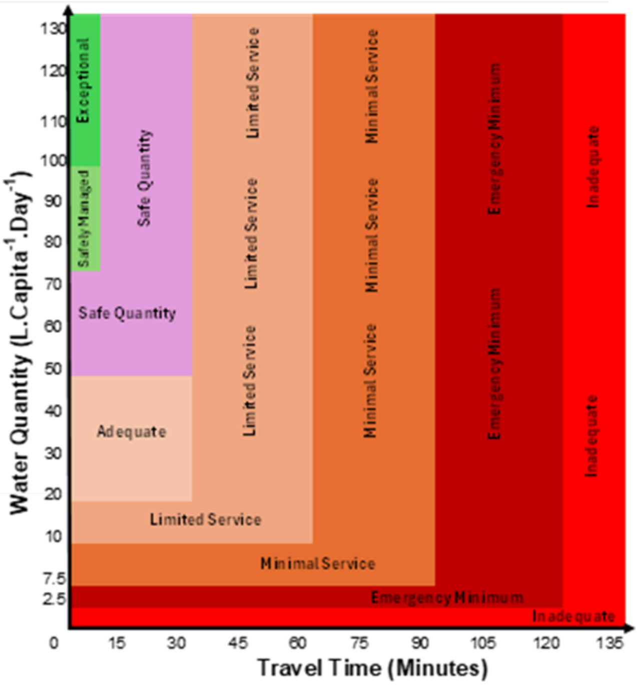


Figure 7. Water access classification matrix integrating quantity and travel time standards for the ACWA Tool.

while urban clusters (8.7 million) and centers (18.6 million) concentrate around cities. Monthly assessments under walking-only and motorized scenarios highlight the decisive role of mobility in determining access.

Under walking-only conditions, inadequate surface-water access affects over 90% of rural populations during the dry season, with minor improvements in wetter months. In contrast, motorized transport dramatically improves accessibility, enabling many communities to reach adequate or exceptional service levels even in dry periods. These results show that transportation infrastructure—not just water availability—is a critical driver of water security, underscoring the need for integrated planning that links mobility and water access.

Box 1. Access to drinking water in Ghana

Despite progress in providing potable water, reliable water access is still recognized as an economic risk. In Ghana, 8% of households still spend over 30 minutes —often well over an hour collecting water (Amankwaa et al., 2024; UNICEF Ghana, 2024). Boreholes/tubewells supply 33.6% of rural households, while rivers and reservoirs provide water for 14.7% of rural populations, compared to 7.4% and 1% in urban areas, respectively (Figure 8).

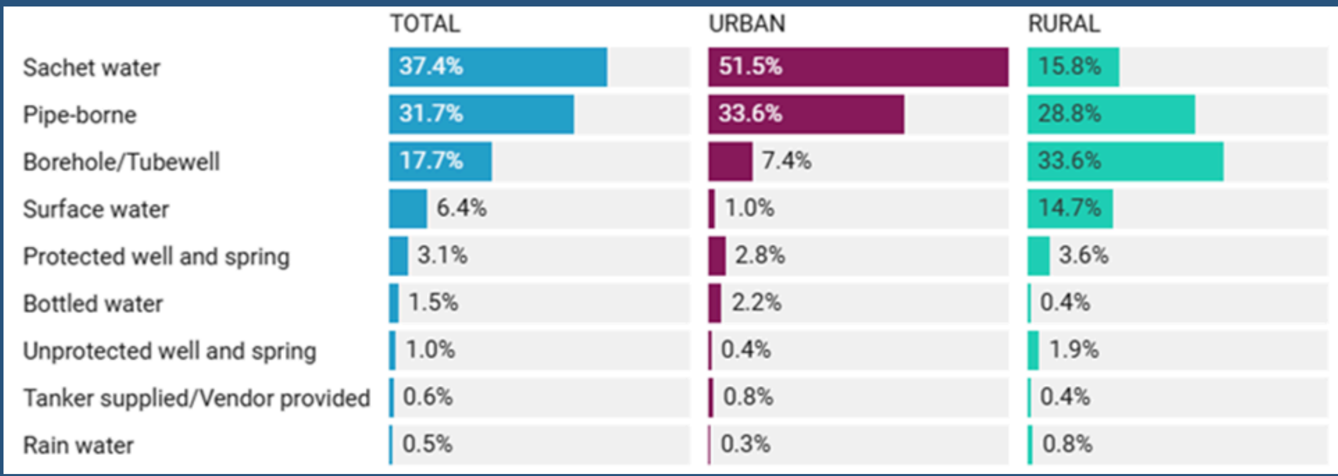


Figure 8. Main sources of drinking water by types of localities in Ghana (Ghana Statistical Service. (2021)).

In Ghana, households already devote about 3 % of annual expenditure to WASH services, and when the unpaid time spent collecting water is valued at the minimum wage this hidden cost rises to 4.3 %, disproportionately burdening women and low-income families (UNICEF, 2021). At the same time, Ghana's economy looses US$290 million, 1.6 percent of GDP each year due to poor water and sanitation access (World Bank, 2012). Across developing economies, inadequate water supply and sanitation shave roughly US $260 billion—or 1.5 % of GDP—every year through lost productivity, health costs and premature deaths (World Bank, 2012). Looking ahead, climate-amplified droughts, floods and storms could wipe out US $5.6 trillion of global GDP by 2050 if resilience measures lag, signalling systemic exposure for governments, businesses. These figures underscore that closing SDG 6 gaps is not only a social imperative but also a strategic hedge against escalating financial losses.

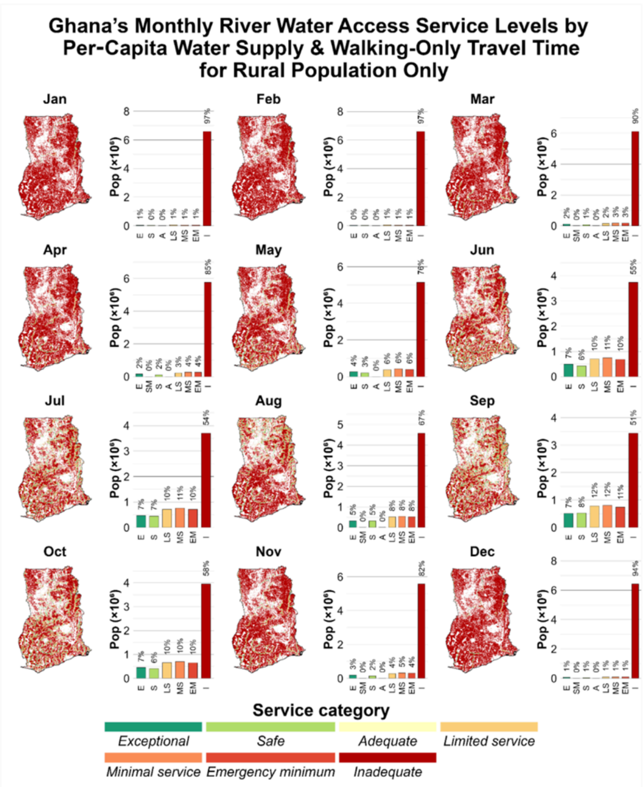


Figure 11. Monthly river water access service levels for rural populations in Ghana under walking-only travel scenarios, showing population distribution across eight service categories from exceptional to inadequate access.

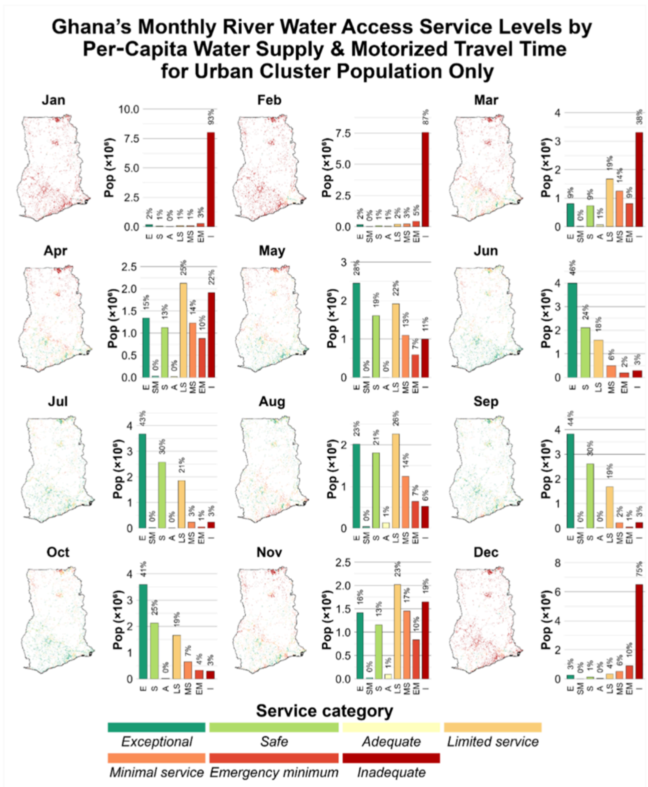


Figure 12. Monthly river water access service levels for urban cluster populations in Ghana under motorized travel scenarios, demonstrating dramatically improved accessibility compared to rural walking-only conditions.

Applications and Impact

The ACWA Tool introduces major methodological advances in assessing water accessibility. By integrating multiple water sources into a unified geospatial framework, it moves beyond single-source approaches and static coverage maps. Its explicit incorporation of transportation scenarios exposes how mobility constraints often pose greater barriers to access than water availability itself. The tool's monthly temporal resolution captures seasonal dynamics, while reliability assessments identify areas prone to seasonal service failures requiring alternative supply strategies.

Future Development Directions

Planned enhancements include expanding water quality modeling to cover bacterial and chemical contamination, assessing water point functionality, and incorporating social and economic barriers to access. Integration of climate scenarios will support long-term planning, while real-time and mobile-based monitoring could provide continuous updates from communities. These innovations will further strengthen ACWA's capacity for dynamic, inclusive water management.

Conclusion

ACWA delivers a new standard for mapping and understanding water access in Africa—combining spatial precision, temporal sensitivity, and multi-source integration consistent with international monitoring standards. Its pilot implementation demonstrates value for development planning, emergency response, and climate adaptation, revealing disparities invisible to conventional methods.

As climate pressures and population growth intensify, ACWA's open and modular framework positions it as a cornerstone for achieving universal and equitable water access across the continent.

References

Akpoti, K., Velpuri, N. M., Mizukami, N., Kagone, S., Leh, M., Mekonnen, K., ... & Seid, A. (2024). Advancing water security in Africa with new high-resolution discharge data. *Scientific Data*, 11(1), 1195. https://doi.org/10.1038/s41597-024-03908-1

Amankwaa, G., Abrefa Busia, K., Agbadi, P., Duah, H. O., & Arthur-Holmes, F. (2024). Access heterogeneities and collection time inequalities of drinking water sources in Ghana: implications for water and development policy. *Local Environment*, 29(3), 263-278. *https://doi.org/10.1080/13549839.2024.2306596*

British Geological Survey. (2021). *Africa groundwater atlas*. https://www2.bgs.ac.uk/groundwater/international/africangroundwater/mapsDownload.html

British Geological Survey. (2021). *Groundwater recharge in Africa*. https://webapps.bgs.ac.uk/services/ngdc/accessions/index.html#item139265

Ghana Statistical Service. (2021). *2021 Population and Housing Census General Report* Volume 3M Water and Sanitation. Ghana Statistical Service. https://census2021.statsghana.gov.gh/subreport.php?readreport=NjMzMzk0MDg5LjAzNg==&Volume-3M-Water-and-Sanitation

Hijmans, R. J., & van Etten, J. (2014). raster: *Geographic data analysis and modeling* [R package version 2.3-12]. https://CRAN.R-project.org/package=raster

Liebe, J., Van De Giesen, N., & Andreini, M. (2005). Estimation of small reservoir storage capacities in a semi-arid environment: A case study in the Upper East Region of Ghana. *Physics and Chemistry of the Earth*, Parts A/B/C, 30(6-7), 448-454. https://doi.org/10.1016/j.pce.2005.06.011

Nelson, A. (2008). *Estimated travel time to the nearest city of 50,000 or more people in year 2000*. Global Environment Monitoring Unit - Joint Research Centre of the European Commission. https://forobs.jrc.ec.europa.eu/products/gam/

Siabi, E. K., Akpoti, K., & Zwart, S. J. (2023). Small reservoirs in the northern regions of Ghana and their vulnerability to drying. *Water Resources Research*, 59(8), e2022WR033842. https://doi.org/10.1029/2022WR033842

Sphere Association. (2018). *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response* (4th ed.). Sphere Association. https://spherestandards.org/handbook-2018/

UNICEF. (2021). *Assessing the affordability of water, sanitation and hygiene: Ghana country case study*. UNICEF. https://www.unicef.org/media/97476/file/WASH%20affordability%20case%20study-Ghana.pdf

UNICEF Ghana. (2024). *Water*. UNICEF Ghana. https://www.unicef.org/ghana/water

van Etten, J. (2017). R package gdistance: Distances and routes on geographical grids. *Journal of Statistical Software*, 76(13), 1-21. https://doi.org/10.18637/jss.v076.i13

Weiss, D. J., Nelson, A., Gibson, H. S., Temperley, W., Peedell, S., Lieber, A., Hancher, M., Poyart, E., Belchior, S., Fullman, N., Mappin, B., Dalrymple, U., Rozier, J., Lucas, T. C. D., Howes, R. E., Tusting, L. S., Kang, S. Y., Cameron, E., Bisanzio, D., ... & Gething, P. W. (2018). A global map of travel time to cities to assess inequalities in accessibility in 2015. *Nature*, 553(7688), 333-336. https://doi.org/10.1038/nature25181

Weiss, D. J., Nelson, A., Vargas-Ruiz, C. A., Gligorić, K., Bavadekar, S., Gabrilovich, E., Bertozzi-Villa, A., Rozier, J., Gibson, H. S., Shekel, T., Kamath, C., Lieber, A., Schulman, K., Shao, Y., Qarkaxhija, V., Nandi, A. K., Keddie, S. H., Rumisha, S., Amratia, P., ... & Gething, P. W. (2020). Global maps of travel time to healthcare facilities. *Nature Medicine*, 26(12), 1835-1838. https://doi.org/10.1038/s41591-020-1059-1

WHO. (2017). *Guidelines for drinking-water quality: Fourth edition incorporating the first addendum*. World Health Organization. https://apps.who.int/iris/handle/10665/254637

WHO/UNICEF. (2017). *Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines*. World Health Organization and United Nations Children's Fund Joint Monitoring Programme for Water Supply, Sanitation and Hygiene. https://apps.who.int/iris/handle/10665/258617

WHO/UNICEF. (2021). *Progress on household drinking water, sanitation and hygiene 2000-2020: Five years into the SDGs*. World Health Organization and United Nations Children's Fund Joint Monitoring Programme for Water Supply, Sanitation and Hygiene. https://apps.who.int/iris/handle/10665/345081

World Bank. (2024). *World Water Day: Two billion people still lack access to safely managed water*. World Bank Blogs. https://blogs.worldbank.org/en/opendata/world-water-day-two-billion-people-still-lack-access-safely-managed-water

WorldPop. (2024). *Ghana 100m population 2024*. WorldPop, University of Southampton. https://www.worldpop.org/geodata/summary?id=49888

The authors

Komlavi Akpoti, Naga Velpuri, Eric Mortey , Mansoor Leh and Abdulkarim Seid work with the International Water Management Institute (IWMI).

Acknowledgements

The authors gratefully acknowledge The Leona M. and Harry B. Helmsley Charitable Trust for their financial support. The authors' views are their own and do not necessarily reflect the views of the funding agency. The support provided by Tanmoy Bhaduri (Communication Specialist, IWMI) for designing it is acknowledged.

Disclaimer

Citation

Library will generate

Contacts

Please send inquiries and comments to:

Komlavi Akpoti, Researcher, Remote Sensing and Hydrologic Modeling - Water Data Science for Action (WDSA), IWMI-Ghana (k.akpoti@cgiar.org)
Naga Velpuri, Research Group Leader - Water Data Science for Action (WDSA), IWMI, Sri Lanka (n.velpuri@cgiar.org)
Eric Mortey, National Researcher - Geospatial Hydrologist- Water Data Science for Action (WDSA), IWMI-Ghana (E.Mortey@cgiar.org)
Mansoor Leh, Senior Researcher - Spatial Hydrology- Water Data Science for Action (WDSA), IWMI, Sri Lanka (M.Leh@cgiar.org)
Abdulkarim Seid, Project Leader (DIWASA) and Country Representative, IWMI-Ethiopia (a.seid@cgiar.org)

IWMI Ghana office

PMB CT 112 Cantonments, Accra, Ghana
Tel: +233 302784753, +233 302784754, +233 544088277
Fax: +233 302784752
E: iwmi-ghana@cgiar.org

International Water Management Institute (IWMI)

Headquarters
127 Sunil Mawatha,Pelawatta,
Battaramulla, Sri Lanka

Mailing address:
P. O. Box 2075, Colombo, Sri Lanka
Tel: +94 11 2880000
Fax: +94 11 2786854
Email: iwmi@cgiar.org
www.iwmi.org