HydroAtlas

A Team

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Contents

Chapter 1

Introduction

This is a regionally customized compilation of standardized and readily-available hydro-environmental attribute information for all catchments and rivers in Angola, Botswana, Namibia, Lesotho, Malawi, Mozambique, South Africa, Swaziland, Zambia and Zimbabwe.

This version has been compiled from the global HydroAtlas version 1.0 The data layers contain 56 hydro-environmental variables at sub-basin and river reach level, broken down into 256 individual attributes. This data represents data on
* Hydrology * Climate * Physiography * Land cover and Use * Soils and Geology
* Anthropogenic influences

Please consult the Technical Documentation Version 1.0 guidance on database structure and content.

Technical Documentation Version 1.0

##Background and introduction The goal of HydroATLAS is to provide a broad user community with a standardized compendium of hydro-environmental attribute information for all watersheds and rivers of the world at high spatial resolution. Version 1.0 of HydroATLAS offers data for 56 variables, partitioned into 281 individual attributes and organized in six categories: hydrology; physiography; climate; land cover & use; soils & geology; and anthropogenic influences (Table 1 and Appendix 1). HydroATLAS derives the hydro-environmental attributes by reformatting original data from well-established 2 global digital maps. The attributes are then linked to hierarchically nested sub-basins at multiple scales, as well as to individual river reaches, both extracted from the global HydroSHEDS database at 15 arc-second (~500 m) resolution. The sub-basin and river reach information is offered in two companion datasets: BasinATLAS and RiverATLAS. The standardized format of HydroATLAS ensures easy applicability while the inherent topological information supports basic network functionality such as identifying up- and downstream connections. HydroATLAS is fully compatible with other products of the overarching HydroSHEDS project enabling versatile hydro-ecological assessments. Updates of HydroATLAS are envisioned as new data become available. The HydroATLAS documentation is organized in two parts: Part 1 (this document) provides an overview of the database and general explanations. Part 2 is provided in two alternative files: 'BasinATLAS_Catalog' or 'RiverATLAS_Catalog'. Each catalog file first provides a summary table listing all hydro-environmental variables and their basic characteristics. This is followed by detailed information on each individual variable, including source data descriptions, units, conversion methodology, and citations. Each variable is presented on one standardized sheet which includes a map at global extent indicating the spatial distribution of values of the respective variable. Note that the summary table and information sheets are hyperlinked within each catalog. The development of HydroATLAS is fully described in Linke et al. (2019). For data citations and acknowledgements see section 4.4 below. General citations of HydroATLAS should refer to:

Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M.,

Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., Thieme, M. (2019). Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Scientific Data 6: 283. DOI: 10.1038/s41597-019-0300-6.

Table1. Categories of hydro-environmental variables offered in the HydroATLAS database.

Identifier	Category	Description
H	Hydrology & hydrography	Hydrological and hydrographic characteristics related to quantity, quality, location and extent of terrestrial water *Examples: natural runoff and discharge, groundwater table depth, lake cover*
P	Physiography	Topographic characteristics related to terrain, relief or landscape position *Examples: elevation, slope*
C	Climate	Climatic characteristics *Examples: mean temperature, climate moisture index, global aridity*
L	Land cover & land use	Land cover and land use characteristics including biogeographic regions *Examples: land cover classes, permafrost extent, freshwater ecoregions*
S	Soils & geology	Soil and geology related characteristics including substrate types and soil conditions *Examples: percentage clay in soil, soil water stress, lithography, soil erosion*
A	Anthropogenic influences	Anthropogenic characteristics including demographic and socioeconomic aspects *Examples: population density, human footprint, GDP per capita*

1.1 Methods and data characteristics

The methods used to create HydroATLAS are fully described in Linke et al. (2019). All spatial units of HydroATLAS, i.e. either sub-basin polygons or river reach lines, were extracted from World Wildlife Fund's HydroSHEDS database (Lehner et al. 2008; Lehner and Grill 2013) at a grid resolution of 15 arc-seconds (approx. 500 m at the equator). For more information please refer to the Technical Documentation of HydroSHEDS at . HydroATLAS consists of two complementary parts: BasinATLAS and RiverATLAS. BasinATLAS provides hydro-environmental attributes for sub-basins (polygons). RiverATLAS provides hydro-environmental attributes for stream and river reaches (line segments). Basin and sub-basin delineations have been pre-processed as a derivative of HydroSHEDS at 15 arc-second resolution and are available as a stand-alone product termed HydroBASINS (for details see). The HydroBASINS dataset offers a suite of 12 layers, each containing nested sub-basins that were subdivided and coded using the topological concept of the Pfafstetter system, which provides a methodology for the breakdown of sub-basins at different scales in a hierarchical and systematic manner (Figure 1a). It should be noted, however,that at the lowest Pfafstetter levels (i.e. 1-3) multiple river basins may be lumped into larger regions, and for coastal sub-basins (at any level) multiple smaller rivers may be lumped into one sub-basin—in these cases, the association of some particular attributes (such as river discharge) is ambiguous and the assigned attribute value may refer to only one river within the sub-basin unit. Also, a global river network delineation has been extracted from HydroSHEDS at 15 arc-second resolution and is available as a stand-alone product termed HydroRIVERS (for details see). For this network, rivers have been defined to start at all pixels where the accumulated upstream catchment area exceeds 10 km2, or where the long-term average natural discharge exceeds 0.1 cubic meters per second, resulting in a line network consisting of individual stream and river reaches (Figure 1b).

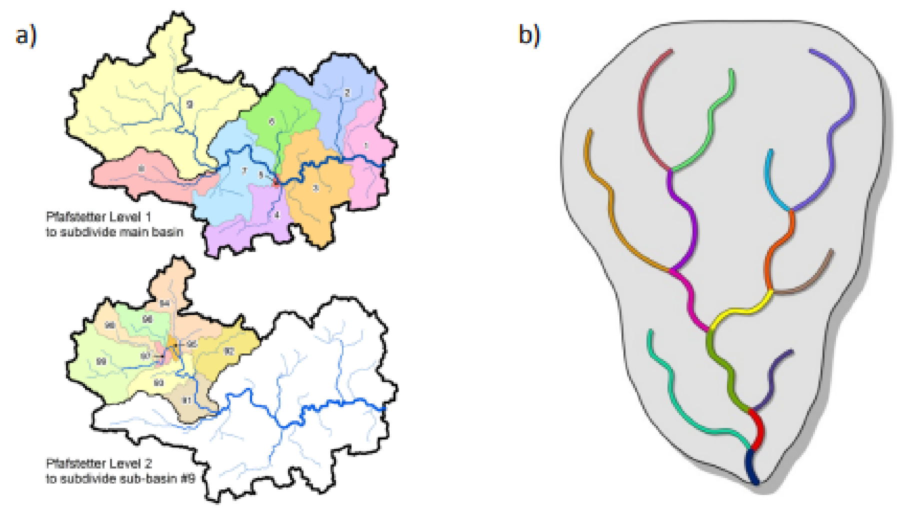

Figure 1.1: **Figure 1: Overview of Pfafstetter sub-basin coding scheme used in BasinATLAS (a); and river reach concept used in RiverATLAS (b). Sub-basins are nested within 12 hierarchical levels. A river reach is defined as a stretch between two tributaries, or between the start/end of the network and a tributary.**

It should be noted that the quality of HydroSHEDS data is significantly inferior for regions above 60 degrees northern latitude as there are no underlying SRTM elevation data available and thus a coarser scale DEM has been inserted (HYDRO1k provided by USGS).

1.1.1 Data format and distribution

a) Data format and projection
HydroATLAS is publicly available for download at and from the figshare data repository at. All map data layers, including attribute tables, are provided in ESRI© Geodatabase and Shapefile formats. The data are projected in a Geographic Coordinate System using the World Geodetic System 1984 (GCS_WGS_1984). The attribute table can also be accessed as a stand-alone file in dBASE format which is included in the Shapefile format. HydroATLAS

data are available electronically in compressed zip file format. To use the data files, the zip files must first be decompressed. Each zip file includes a copy of the HydroATLAS Technical Documentation.

b) Layer name syntax and spatial coverage

HydroATLAS data layers are provided in two spatial extents: * primarily as a seamless, fully global coverages; * but for some datasets also (or only) as regional tiles (see Figure 2 for definition of regions).

The layer names follow the syntax:
* **BasinATLAS_v10_levXX** (for BasinATLAS layers with global coverage), where XX indicates the Pfafstetter level (1-12); * **RiverATLAS_v10** (for RiverATLAS layer with global coverage); or * **RiverATLAS_v10_YY** (for RiverATLAS layers in regional tiles), where YY indicates the region.
The regional extents are defined by a two-digit identifier:

Identifier	*Region*
af	Africa
ar	North American Arctic
as	Central and South-East Asia
au	Australia and Oceania
eu	Europe and Middle East
gr	Greenland
na	North America and Caribbean
sa	South America
si	Siberia

Note that the Shapefile format is limited to a maximum file size of 2 GB; therefore the RiverATLAS data in Shapefile format are only provided in regional tiles (with further subdivisions into north and south parts where needed). Currently, all other data layers are provided in full global coverage,but more versatile regional breakdowns and data packages may be offered in future iterations.

c) Available columns and column name syntax
The attribute tables of HydroATLAS contain the pre-existing columns of HydroBASINS and HydroRIVERS, respectively (see their Technical Documentations at for details). The hydro-environmental attributes are then appended in a series of additional columns. This section provides information on the column name syntax used for the identification of each sub-basin or river reach attribute provided in the HydroATLAS database. All existing attributes and their associated column names are summarized in Appendix 1 and at the beginning of the BasinATLAS and RiverATLAS catalogs.

Each hydro-environmental attribute column name has 10 digits (for example 'dis_m3_syr') and its syntax is as follows:

```
__<Layer name key>_<Unit key>_<Spatial key>< Dimension key>__
```

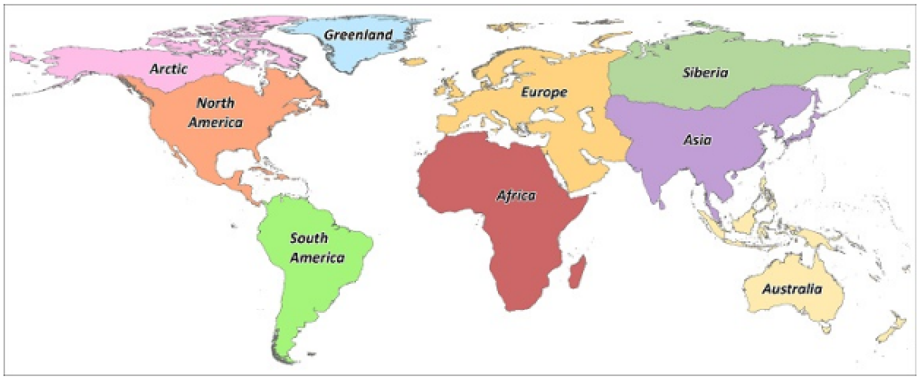

Figure 1.2: **Figure 2: Spatial extent of regional tiles of HydroATLAS layers.**

Layer name key: Three digits that describe the name of the attribute. The layer name key is unique to the attribute it represents. *Example: 'dis' for discharge.*

Unit key:
Two digits that describe the units of the attribute value. See Table 2 for possible keys.

Table 2: Unit keys. Note that some values are stored in factors of the given units (to efficiently store them as integers without losing precision), e.g. temperature is stored in tenths of degrees; these factors are listed in the respective data sheet of each variable in the BasinATLAS or RiverATLAS catalogs.

Key	Unit of values
cl	Classes
cm	Centimeters
ct	Count (e.g. number of people)
dc	Degrees Celsius (°C)
dg	Degrees
dk	Decimeters per kilometer
ha	Hectares
id	ID number
ix	Index value
kh	Kilogram per hectare (kg/ha) per year
m3	Cubic meters per second (m^3/s)
mc	Million cubic meters (mcm)
mk	Meters per square kilometer (m/km^2)
mm	Millimeters
mt	Meters *or* Meters above sea level (m.a.s.l.)
pc	Percent *or* Percent cover
pk	Per square kilometer (e.g. people per square kilometer)
tc	Thousand cubic meters
th	Tonnes per hectare
ud	US dollars

Spatial extent key:
One digit that describes the spatial extent of the attribute. See Table 3 for possible keys.

Table 3: Spatial extent keys. Note that all attributes represent average values within the spatial unit unless stated otherwise in the attribute's catalog sheet.

Key	Spatial representation
c	In reach catchment (i.e. the local catchment that drains directly into the reach)
p	At sub-basin pour point *or* At reach pour point
r	Along reach segment
s	In sub-basin
u	In total watershed upstream of sub-basin pour point *or* In total watershed upstream of reach pour point *or*

Dimension key:
Two digits that describe the dimension of the attribute in terms of its aggregation level or other type of spatio-temporal association. The dimension key can refer to a temporal dimension, a statistical aggregation, or a class or year association. See Table 4 for possible keys.

Table 4: Dimension keys.

Key	Temporal or statistical aggregation or other association
01-12	Calendar month (January to December) for monthly data
00-99	Class number (e.g. for spatial extent calculations of individual classes)
00-99	Other numbers may be used & explained as needed (e.g. to represent a specific year)
av	Average
g1-g9	Class groupings (individual groups are defined in HydroATLAS catalog)
lt	Long-term maximum
mj	Spatial majority (dominant value)
mn	Minimum *or* Annual minimum
mx	Maximum *or* Annual maximum
se	Spatial extent (%)
su	Sum
va	Value
yr	Annual average

License, disclaimer and acknowledgement

1.1.2 License agreement

1.1.3 Disclaimer of warranty

The HydroATLAS database and any related materials contained therein are provided “as is” without warranty of any kind, either express or implied, including, but not limited to, the implied warranties of merchantability, fitness for a particular purpose, noninterference, system integration, or noninfringement. The entire risk of use of the data shall be with the user. The user expressly acknowledges that the data may contain some nonconformities, defects, or errors. The authors do not warrant that the data will meet the user's needs or expectations, that the use of the data will be uninterrupted, or that all nonconformities, defects, or errors can or will be corrected. The authors are not inviting reliance on these data, and the user should always verify actual data.

###Limitation of liability

In no event shall the authors be liable for costs of procurement of substitute goods or services, lost profits, lost sales or business expenditures, investments, or commitments in connection with any business, loss of any goodwill, or for any direct, indirect, special, incidental, exemplary, or consequential damages arising out of the use of the HydroATLAS database and any related materials, however caused, on any theory of liability, and whether or not the authors have been advised of the possibility of such damage. These limitations shall apply notwithstanding any failure of essential purpose of any exclusive remedy.

1.2 Data citations and acknowledgements

When using an attribute contained in HydroATLAS, citations and acknowledgements should be made to both the original data source and the HydroATLAS compendium. For example, the following template illustrates a reference to precipitation data sourced from HydroATLAS: > *"Precipitation data from the WorldClim v1.4 database (Hijmans et al. 2005) have been used in the spatial format as provided by HydroATLAS v1.0 (Linke et al. 2019)."*

Information regarding the reference(s) for each hydro-environmental attribute is provided on the individual attribute sheets in the BasinATLAS and RiverATLAS catalogs. In addition, every data source may have individual requests for acknowledgements, and users of HydroATLAS are asked to honor those requests when using the respective attributes.

General citations and acknowledgements of HydroATLAS should be made as follows: > Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M., Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., Thieme, M. (2019). Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Scientific Data 6: 283. DOI: 10.1038/s41597-019-0300-6.<

We kindly ask users to cite both source data and HydroATLAS in any published material produced using the data. If possible, online links to the HydroATLAS website should be provided .

1.2.1 References

Lehner, B., Grill G. (2013). Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrological Processes 27(15): 2171- 2186. Lehner, B., Verdin, K., Jarvis, A. (2008). New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU 89(10): 93-94. Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M., Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., Thieme, M. (2019). Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Scientific Data 6: 283. DOI:%5B10.1038/s41597-019-0300-6](https://doi.org/10.1038/s41597-019-0300-6)

```
library(readxl)
library(flextable)
att<-read_excel("attributes.xlsx", sheet = 'attr_appendix')

t1<-flextable(att,col_keys = names(att),
  cwidth = 3,
  cheight = 0.005,
  defaults = list(),
   theme_booktabs())
t1<-fontsize(t1,part = 'all', size = 8)
t1<-border_outer(t1,part = 'all', border = NULL)
t1<-border_inner(t1,part = 'all', border = NULL)
t1<-bold(t1, part = 'header')
t1
```

ID	**Category**	**Variable**
H01	Hydrology	Natural Discharg
H02	Hydrology	Land Surface Ru
H03	Hydrology	Inundation Exten
H04	Hydrology	Limnicity (Percen
H05	Hydrology	Lake Volume
H06	Hydrology	Reservoir Volume
H07	Hydrology	Degree of Regula
H08	Hydrology	River Area
H09	Hydrology	River Volume
H10	Hydrology	Groundwater Tab

ID	**Category**	**Va**
P01	Physiography	El
P02	Physiography	Te
P03	Physiography	St
C01	Climate	Cl
C02	Climate	Cl
C03	Climate	Ai
C04	Climate	Pr
C05	Climate	Po
C06	Climate	Ac
C07	Climate	G
C08	Climate	Cl
C09	Climate	Sn
L01	Landcover	La
L02	Landcover	La
L03	Landcover	Po
L04	Landcover	Po
L05	Landcover	W
L06	Landcover	W
L07	Landcover	Fo
L08	Landcover	Cr
L09	Landcover	Pa
L10	Landcover	Irr
L11	Landcover	G
L12	Landcover	Po
L13	Landcover	Pr
L14	Landcover	Te
L15	Landcover	Te
L16	Landcover	Fr

ID	Category	Variable
L17	Landcover	Freshwater Ecore
S01	Soils & Geology	Clay Fraction in S
S02	Soils & Geology	Silt Fraction in So
S03	Soils & Geology	Sand Fraction in
S04	Soils & Geology	Organic Carbon C
S05	Soils & Geology	Soil Water Conte
S06	Soils & Geology	Lithological Class
S07	Soils & Geology	Karst Area Exten
S08	Soils & Geology	Soil Erosion
A01	Anthropogenic	Population Count
A02	Anthropogenic	Population Densi
A03	Anthropogenic	Urban Extent
A04	Anthropogenic	Nighttime Lights
A05	Anthropogenic	Road Density
A06	Anthropogenic	Human Footprint
A07	Anthropogenic	Global Administra
A08	Anthropogenic	Gross Domestic I
A09	Anthropogenic	Human Developn

Chapter 2

Datasets

```
FALSE Reading layer `admin0_aoi' from data source
FALSE   `C:\Users\Makabe\opennaps\HydroAtlas\o_nap_countries\admin0_aoi.shp'
FALSE   using driver `ESRI Shapefile'
FALSE Simple feature collection with 10 features and 1 field
FALSE Geometry type: MULTIPOLYGON
FALSE Dimension:     XY
FALSE Bounding box:  xmin: 11.66847 ymin: -34.83514 xmax: 40.83931 ymax: -4.372591
FALSE Geodetic CRS:  WGS 84

FALSE Reading layer `towns_aoi' from data source
FALSE   `C:\Users\Makabe\opennaps\HydroAtlas\o_nap_countries\towns_aoi.shp'
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FALSE Simple feature collection with 290 features and 31 fields
FALSE Geometry type: POINT
FALSE Dimension:     XY
FALSE Bounding box:  xmin: 11.85999 ymin: -34.52953 xmax: 40.71502 ymax: -5.559623
FALSE Geodetic CRS:  WGS 84

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FALSE   `C:\Users\Makabe\opennaps\HydroAtlas\o_nap_countries\basins1_aoi.shp'
FALSE   using driver `ESRI Shapefile'
FALSE Simple feature collection with 1 feature and 294 fields
FALSE Geometry type: MULTIPOLYGON
FALSE Dimension:     XY
FALSE Bounding box:  xmin: 11.66847 ymin: -34.83514 xmax: 40.83931 ymax: -4.372591
FALSE Geodetic CRS:  WGS 84

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```

```
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FALSE Simple feature collection with 3 features and 294 fields
FALSE Geometry type: MULTIPOLYGON
FALSE Dimension:     XY
FALSE Bounding box:  xmin: 11.66847 ymin: -34.83514 xmax: 40.83931 ymax: -4.372591
FALSE Geodetic CRS:  WGS 84

FALSE Reading layer `basins3_aoi' from data source
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FALSE Geometry type: MULTIPOLYGON
FALSE Dimension:     XY
FALSE Bounding box:  xmin: 11.66847 ymin: -34.83514 xmax: 40.83931 ymax: -4.372591
FALSE Geodetic CRS:  WGS 84

FALSE Reading layer `basins5_aoi' from data source
FALSE   `C:\Users\Makabe\opennaps\HydroAtlas\o_nap_countries\basins5_aoi.shp'
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FALSE Geometry type: MULTIPOLYGON
FALSE Dimension:     XY
FALSE Bounding box:  xmin: 11.66847 ymin: -34.83514 xmax: 40.83931 ymax: -4.372591
FALSE Geodetic CRS:  WGS 84

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FALSE Geometry type: MULTIPOLYGON
FALSE Dimension:     XY
FALSE Bounding box:  xmin: 11.66847 ymin: -34.83514 xmax: 40.83931 ymax: -4.372591
FALSE Geodetic CRS:  WGS 84

FALSE Reading layer `rivers_aoi' from data source
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FALSE   using driver `ESRI Shapefile'
FALSE Simple feature collection with 282639 features and 295 fields
FALSE Geometry type: MULTILINESTRING
FALSE Dimension:     XY
FALSE Bounding box:  xmin: 11.6875 ymin: -34.79375 xmax: 40.82625 ymax: -4.40992
FALSE Geodetic CRS:  WGS 84
```
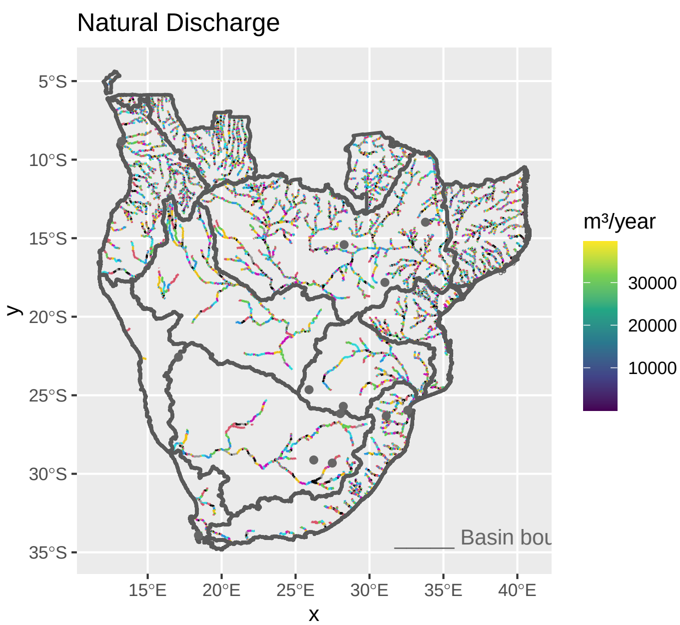

Natural Discharge

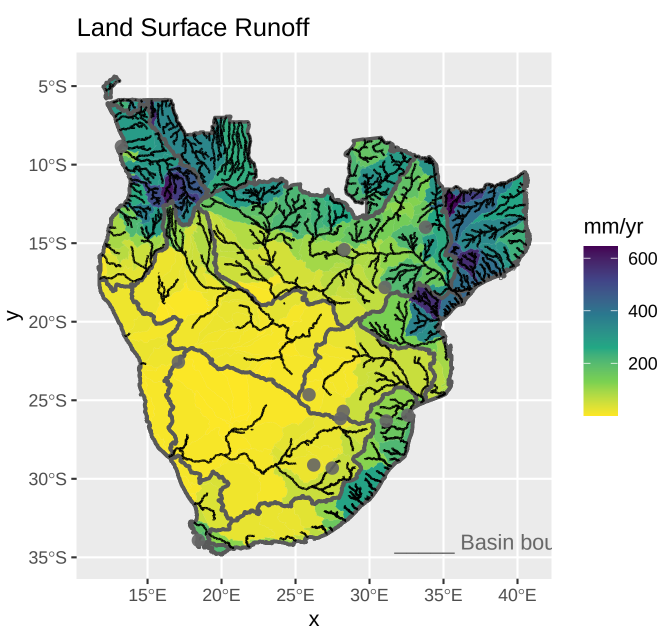
Table 2.1: Natural Discharge

ID	H01
Category	Hydrology
Attribute	**Natural Discharge**
Source Data	WaterGAP v2.2
Description	Discharge and runoff estimates for HydroATLAS are based on long-term (1971–2000) avera equator) to the 15 arc-second (5̃00 m) resolution of the HydroSHEDS river network using ge statistics, for areas that are dominated by snow, glaciers, wetlands, and (semi-)arid conditior
Reference	Döll, P., Kaspar, F., Lehner, B. (2003). A global hydrological model for deriving water availab
Website	http://www.watergap.de/
Licence	Creative Commons CC-BY 4.0
Additional Information	Annual minimum and maximum discharges were derived from the 12 long-term average mor represent the flow of the lowest or highest month within the average year. Additional reading hydrography and network routing: baseline data and new approaches to study the world's la 27(15), 2171-2186. doi: 10.1002/hyp.9740.



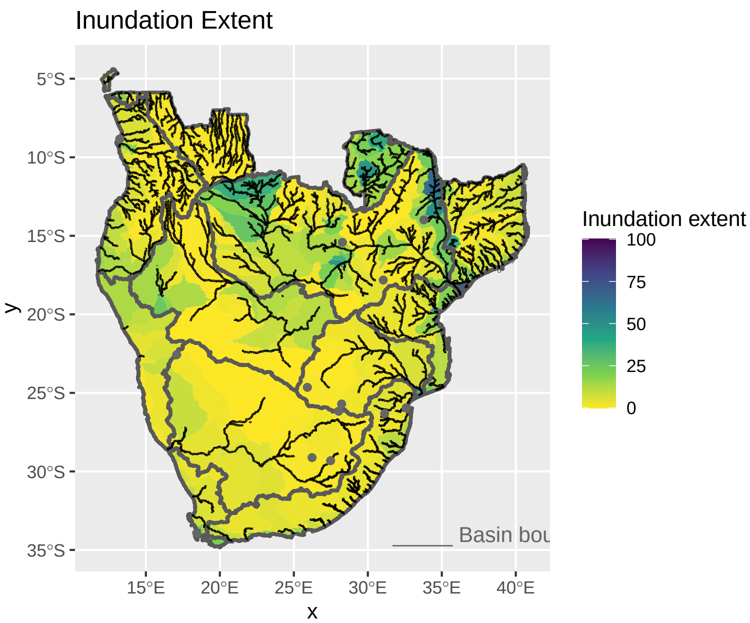
Land Surface Runoff

ID	H02
Category	Hydrology
Attribute	**Land Surface Runoff**
Source Data	WaterGAP v2.2
Description	Discharge and runoff estimates for HydroATLAS are based on long-term (1971–2 equator) to the 15 arc-second (5̃00 m) resolution of the HydroSHEDS river netwo Preliminary tests against approximately 3000 global gauging stations indicate a g
Reference	Döll, P., Kaspar, F., Lehner, B. (2003). A global hydrological model for deriving wa
Website	http://www.watergap.de/
Licence	Creative Commons CC-BY 4.0
Additional Information	Annual minimum and maximum discharges were derived from the 12 long-term a represent the flow of the lowest or highest month within the average year. Additio hydrography and network routing: baseline data and new approaches to study the 27(15), 2171-2186. doi: 10.1002/hyp.9740.



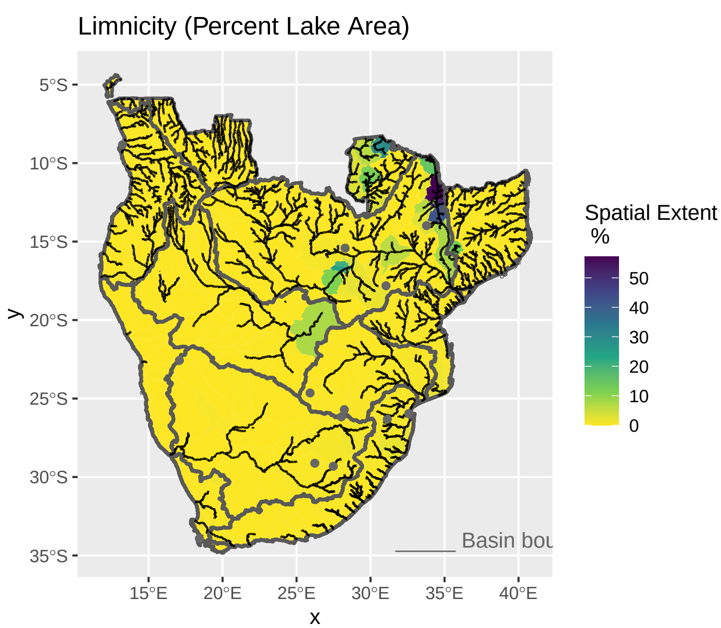
Inundation Extent

ID	H03
Category	Hydrology
Attribute	**Inundation Extent**
Source Data	GIEMS-D15
Description	GIEMS-D15 is a high-resolution global inundation map at a pixel size of 15 arc-seconds (app and Wetlands Database (GLWD, Lehner andDöll 2004). GIEMS-D15 represents three states
Reference	Fluet-Chouinard, E., Lehner, B., Rebelo, L. M., Papa, F., & Hamilton, S. K. (2015). Developm
Website	http://www.estellus.fr/index.php?static13/giems-d15
Licence	Creative Commons CC-BY 4.0
Additional Information	Further readings: Prigent, C., Papa, F., Aires, F., Rossow, W.B., Matthews, E. (2007). Global satellite observations, 1993-2000. Journal of Geophysical Research, 112(D12107), 1-13. Le validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology, 296(



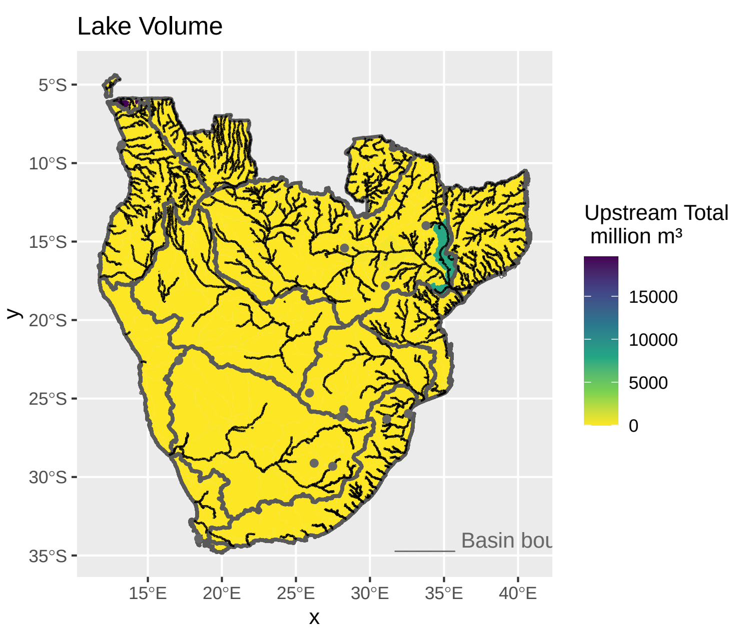
Limnicity (Percent Lake Area)

ID	H04
Category	Hydrology
Attribute	**Limnicity (Percent Lake Area)**
Source Data	HydroLAKES
Description	HydroLAKES is a database aiming to provide the shoreline polygons of all global pour points. The volume of most lakes is estimated based on the surrounding ter
Reference	Messager, M.L., Lehner, B., Grill, G., Nedeva, I., Schmitt, O. (2016). Estimating th
Website	http://www.hydrosheds.org/page/hydrolakes
Licence	Creative Commons CC-BY 4.0
Additional Information	In the stored data, percent values are multiplied by 10 (i.e. value 10 means 1%).



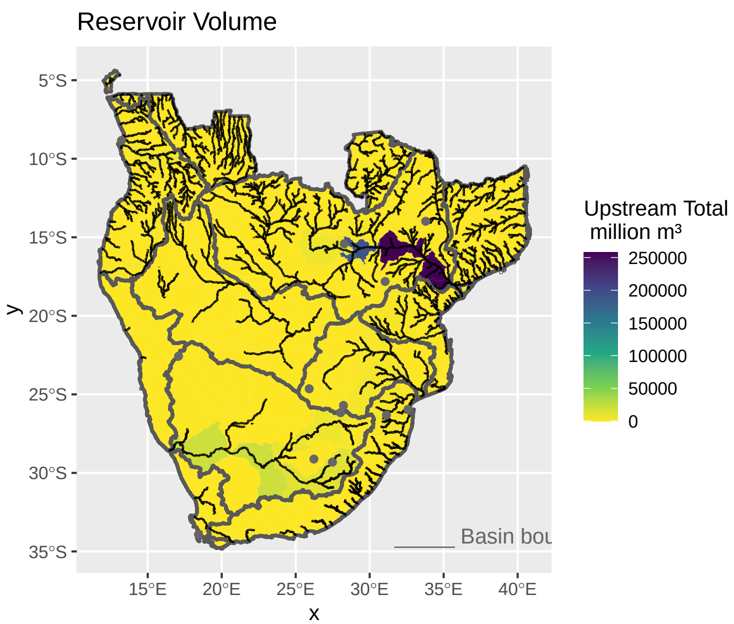
Lake Volume

ID	H05
Category	Hydrology
Attribute	**Lake Volume**
Source Data	HydroLAKES
Description	HydroLAKES is a database aiming to provide the shoreline polygons of all global lakes and r pour points. The volume of most lakes is estimated based on the surrounding terrain informa
Reference	Messager, M.L., Lehner, B., Grill, G., Nedeva, I., Schmitt, O. (2016). Estimating the volume a
Website	http://www.hydrosheds.org/page/hydrolakes
Licence	Creative Commons CC-BY 4.0
Additional Information	



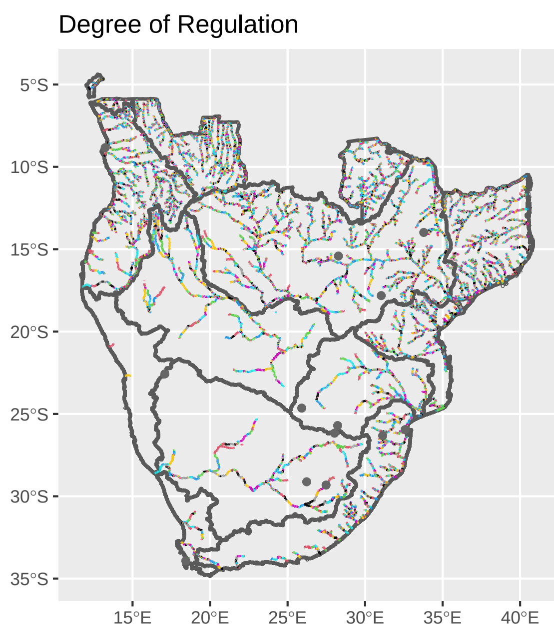
Reservoir Volume

ID	H06
Category	Hydrology
Attribute	**Reservoir Volume**
Source Data	GRanD v1.1
Description	The Global Reservoir and Dam (GranD) database, version 1.1, contains 6,862 re the main focus was to include all dams associated with reservoirs that have a sto
Reference	Lehner, B., Reidy Liermann, C., Revenga, C., Vörösmarty, C., Fekete, B., Crouze
Website	https://sedac.ciesin.columbia.edu/data/collection/grand-v
Licence	Original: Free for non-commercial use – HydroATLAS: Creative Commons CC-BY
Additional Information	The calculations used all dams from GRanD v1.1 except those attributed as ”unk construction” yet with unknown year of completion, and ”unreliable quality”. Also, structure that is not operated at full capacity. This left 6,778 out of all 6,862 origin



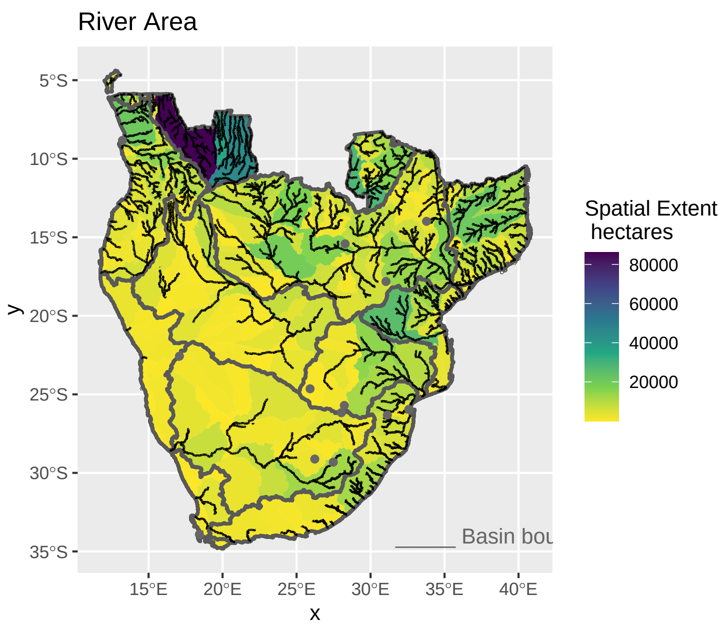
Degree of Regulation

ID	H07
Category	Hydrology
Attribute	**Degree of Regulation**
Source Data	HydroSHEDS & GRanD
Description	The Degree of Regulation (DOR) provides an index of how strongly a dam or set of dams ca H01 and H06). A high DOR value indicates an increased probability that substantial flow volu assuming that higher estimates are likely outliers or errors.
Reference	Lehner, B., Reidy Liermann, C., Revenga, C., Vörösmarty, C., Fekete, B., Crouzet, P., ... & W
Website	https://sedac.ciesin.columbia.edu/data/collection/grand-v1
Licence	Creative Commons CC-BY 4.0
Additional Information	In the stored data, percent values are multiplied by 10 (i.e. value 10 means 1%). The calcula full capacity. This left 6,778 out of all 6,862 original GRanD reservoirs.



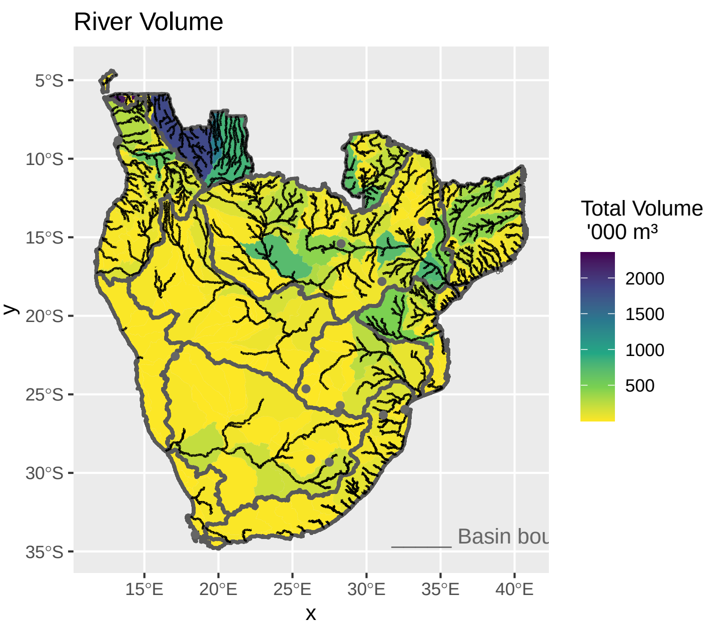
River Area

ID	H08
Category	Hydrology
Attribute	**River Area**
Source Data	HydroSHEDS & WaterGAP
Description	River area was calculated using the the HydroSHEDS database at 15 arc-second approximation of the dimensions of channel width was derived for every river rea
Reference	Lehner, B., Grill G. (2013). Global river hydrography and network routing: baselin
Website	http://www.hydrosheds.org/
Licence	Creative Commons CC-BY 4.0
Additional Information	urther reading: Allen, P.M., Arnold, J.C., Byars, B.W. (1994). Downstream channe



River Volume

ID	H09
Category	Hydrology
Attribute	**River Volume**
Source Data	HydroSHEDS & WaterGAP
Description	River volume was calculated using the the HydroSHEDS database at 15 arc-second resoluti approximation of the dimensions of channel width and depth was derived for every river reac
Reference	Lehner, B., Grill G. (2013). Global river hydrography and network routing: baseline data and
Website	http://www.hydrosheds.org/
Licence	Creative Commons CC-BY 4.0
Additional Information	urther reading: Allen, P.M., Arnold, J.C., Byars, B.W. (1994). Downstream channel geometry



Groundwater Table Depth