IHE DELFT Institute for Water Education

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Equity Assessment for Transboundary Water Resources Management Using Remote Sensing Data and QGIS

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Delft, April 2023

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QGIS

WaPOR
The FAO portal to monitor WAter Productivity through Open access of Remotely sensed derived data

Introduction

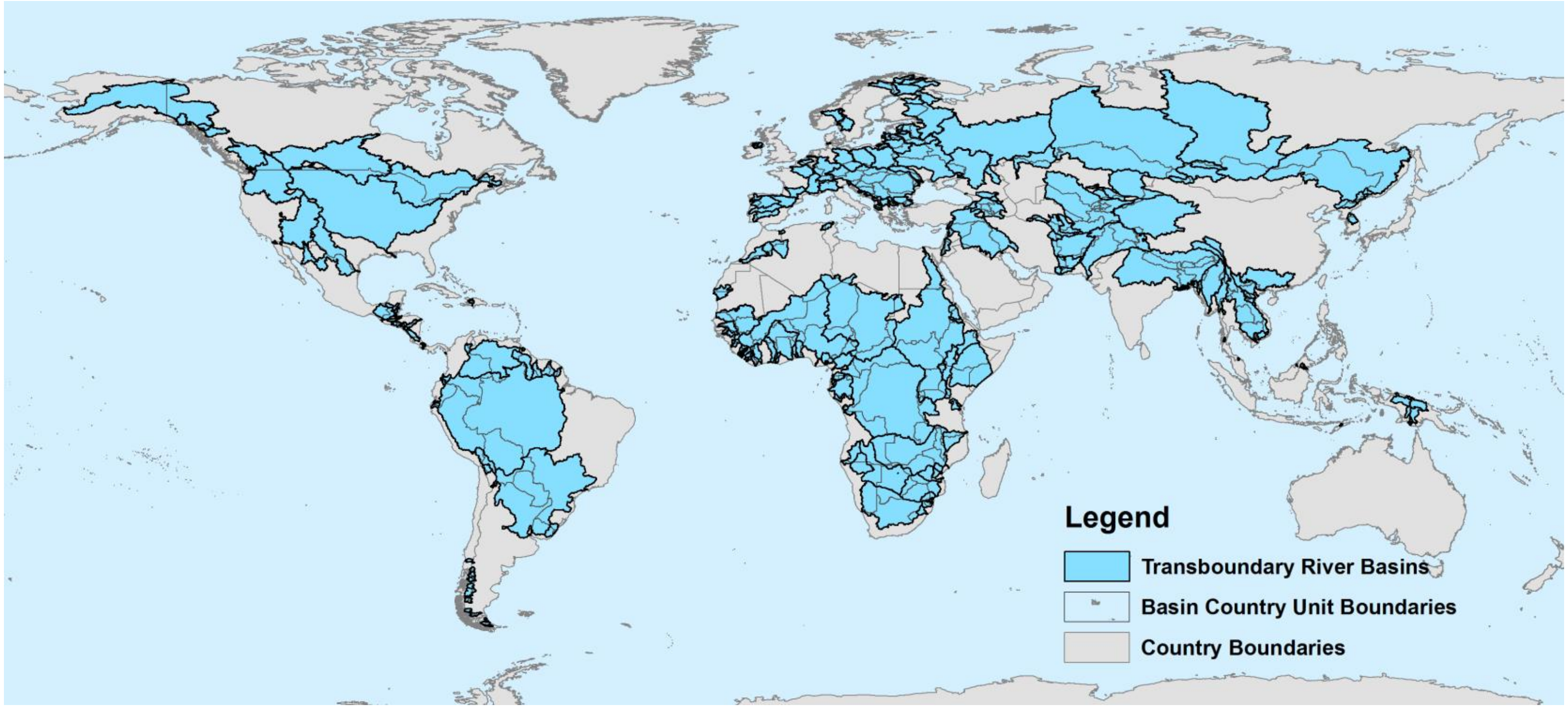
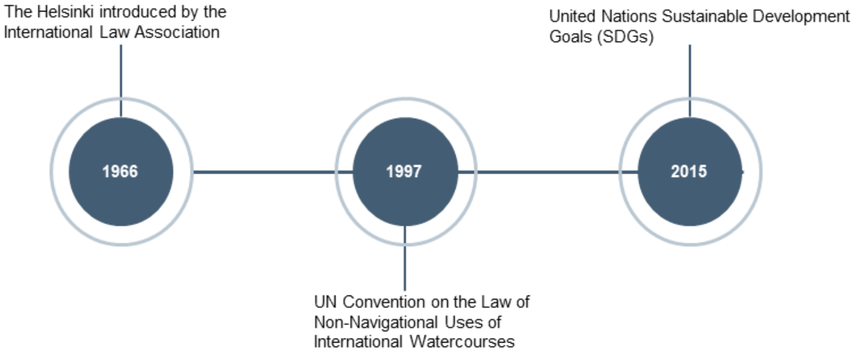


Figure 1 Transboundary river basins, Source: twap-rivers.org

Introduction

The principle of reasonable and equitable use is defined in general terms and needs clearer and more specific criteria to quantify.



Introduction

Equity assessment : the process of assessing whether the distribution of water or benefits and costs of shared water resources is fair and equitable.

- Equity in transboundary water management leads to reduced conflicts and tensions among riparian countries

Problem Statement

- The lack of materials and methods to assess equity

- The lack of data and unwillingness to share the data in transboundary basins.

Research question

How equity can be quantified and assessed in transboundary water management using remote sensing data and QGIS?

Study area

Nile River Basin

Challenges in the basin

- No agreement on water allocation that is accepted by all countries
- The downstream countries water insecurity
- Population growth
- Climate change

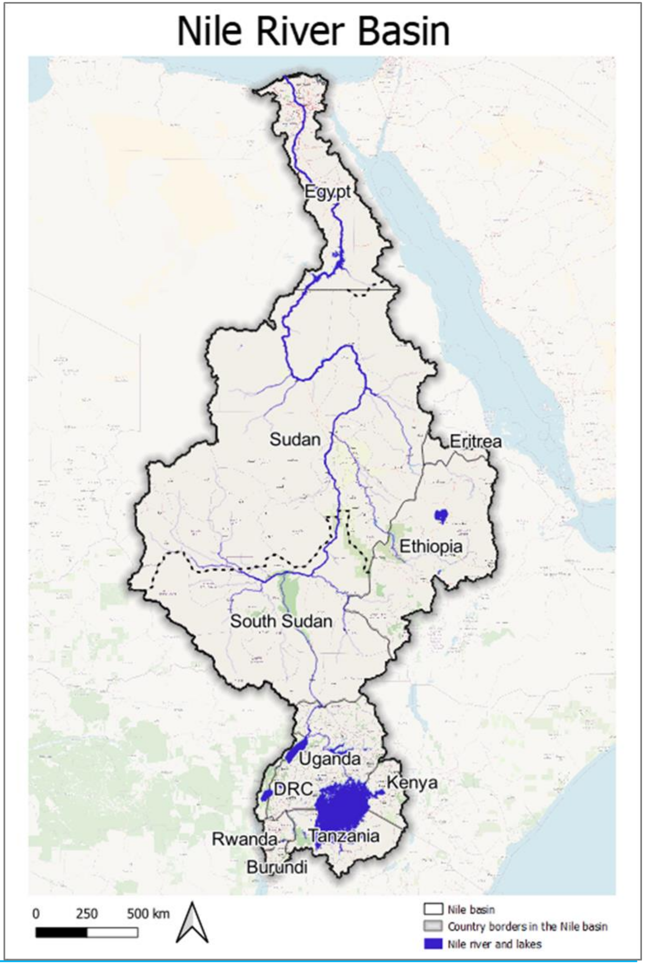


Figure 2 Location of the Nile River Basin and the eleven countries of Nile

Methodology

Remote sensing data

- Site independent
- Free and accessible
- Spatio-temporal coverage

Figure 3 Satellite in orbit around Earth capturing radar images as it revolves around the planet Source: esa.int

Conceptual framework

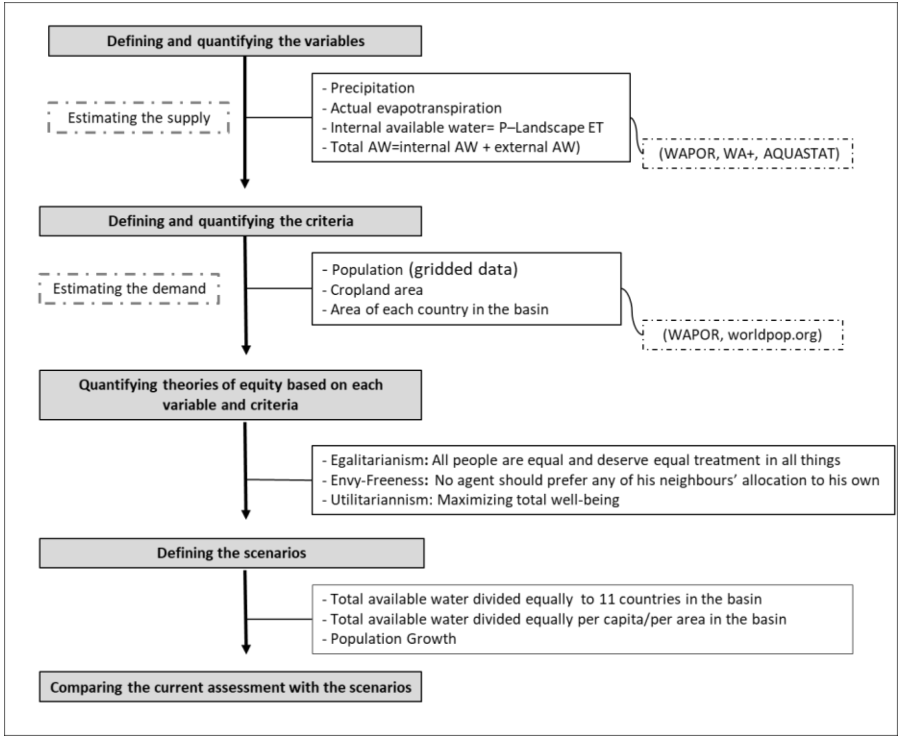
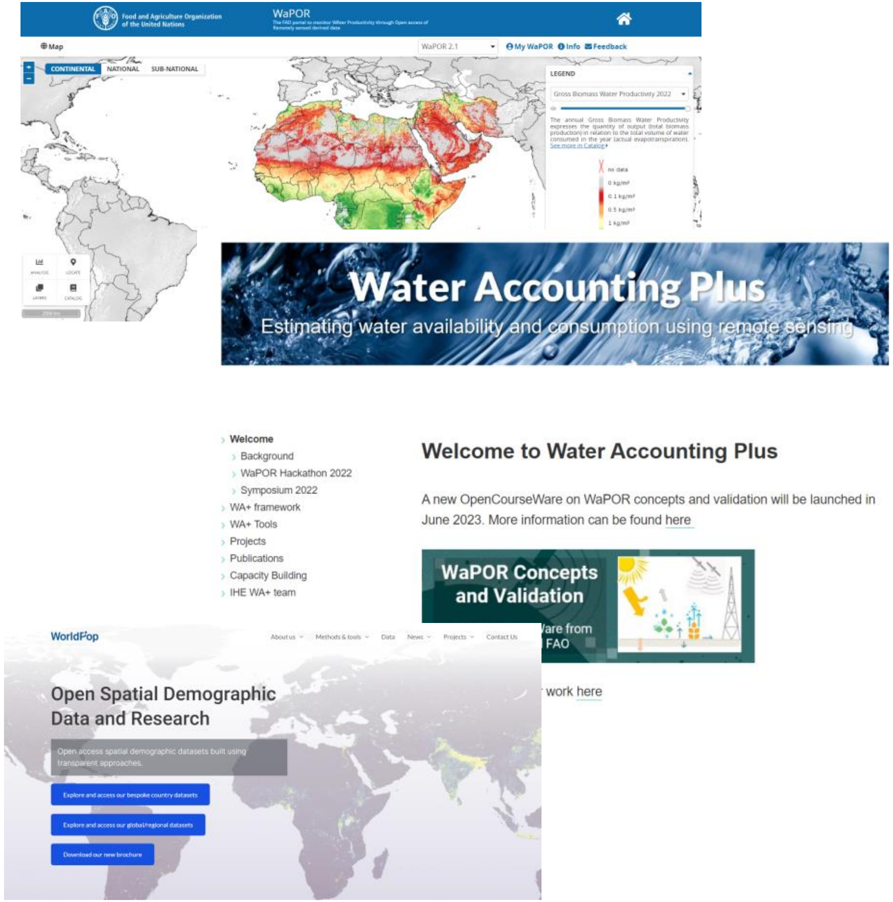


Figure 3 Flowchart of the steps for equity assessment



QGIS analysis

QGIS

Precipitation

(Eta, internal AW, total AW)

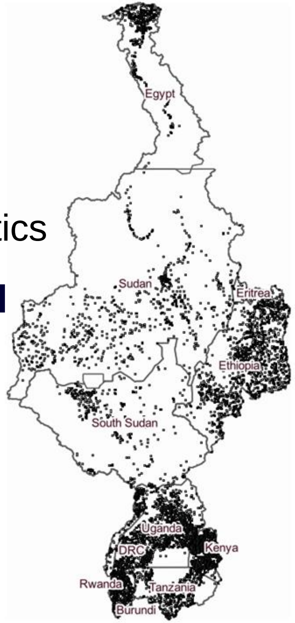
Zonal statistics

Variable

Countries	Precipitation (Billion m3/yr)
	0
Egypt	4
Eritrea	14
Burundi	20
DRC	27
Rwanda	28
Kenya	83
Tanzania	163
Uganda	331
Sudan	417
Ethiopia	449
South Sudan	647
Total	2,184

Equity Assessment

Zonal statistics



Population

(Area, cropland area)

Precipitation 2018

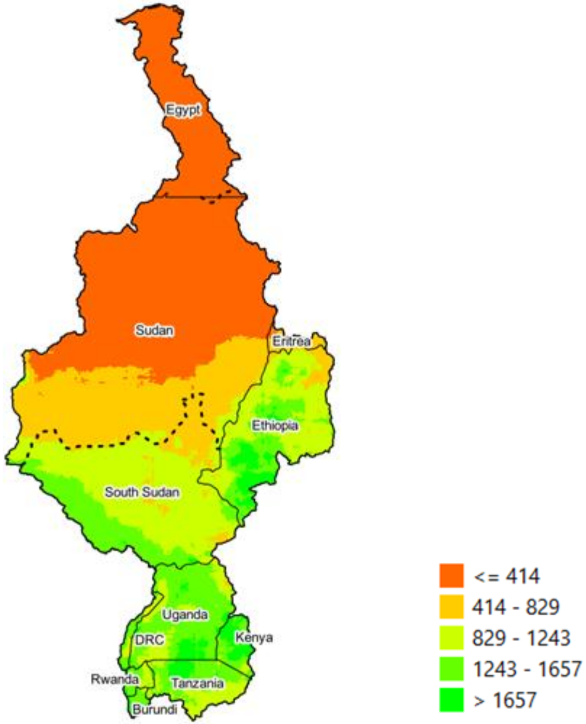


Figure 7 Annual precipitation (mm/y), 2018 (FAO and IHE Delft, 2020)

Actual-evapotranspiration 2018

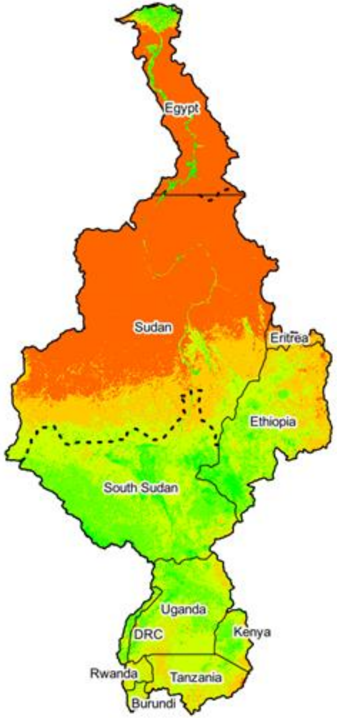


Figure 8 Annual Evapotranspiration (mm/y), 2018 (FAO and IHE Delft, 2020)

Available water 2018

AW = P – Landscape ET

Landscape ET = ETa – managed water ET

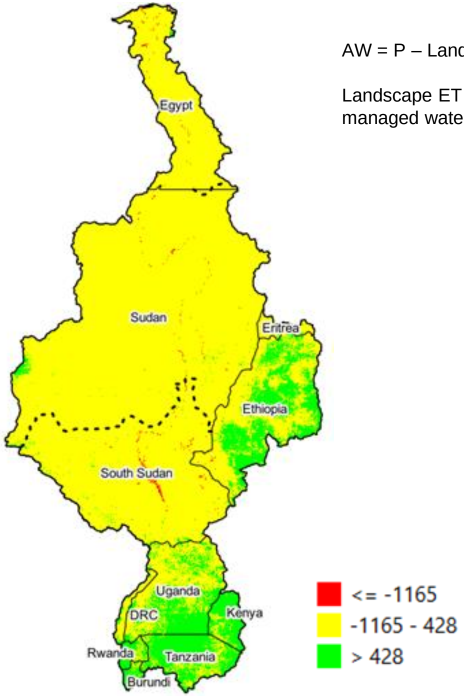


Figure 9 Available Water (mm/y), 2018 (FAO and IHE Delft, 2020)

Land cover classification map

Gridded population

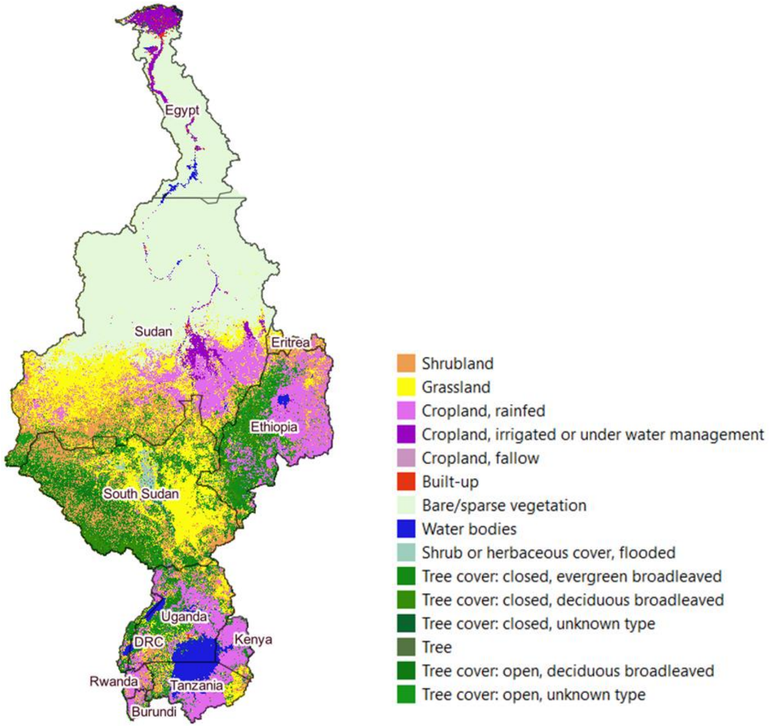


Figure 10 Land cover classification of Nile basin for the year 2018 (FAO and IHE Delft, 2020)

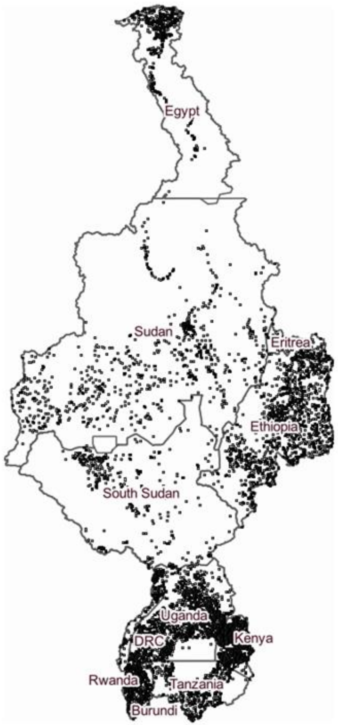


Figure 11 Population map of Nile basin countries (https://www.worldpop.org/)

(Preliminary Data)

Variables

Table 1 Equity assessment variables in Nile basin countries for the year 2018

Country	P (mm/y)	P (Billion m^3/yr)	ETa (mm/y)	ETa (Billion m^3/yr)	In. AW (mm/y)	Internal. AW (Billion m^3/yr)	External AW (Billion m^3/yr)	Total AW (Billion m^3/yr)
Burundi	1,501	20	961	13	542	7	-	7
DRC	1,332	27	1,276	26	65	1	-	1
Egypt	18	4	271	68	- 78	-	57	57
Eritrea	586	14	510	12	78	2	-	2
Ethiopia	1,234	449	1,023	372	213	77	-	77
Kenya	1,686	83	1,153	57	559	28	-	28
Rwanda	1,332	28	945	20	392	8	4	12
Sudan	311	417	357	478	- 33	-	34	34
South Sudan	1,049	647	1,263	780	- 213	-	24	24
Tanzania	1,359	163	961	115	492	59	-	59
Uganda	1,396	331	1,163	276	258	61	21	82

Criteria

Table 2 Equity assessment criteria in Nile basin countries for the year 2018

Country	Area (km^2)	Population (M)	Rainfed cropland (km^2)	Irrigated cropland (km^2)	Cropland (km^2)
Burundi	13,199	6	7,481	17	7,498
DRC	20,450	4	4,096	453	4,549
Egypt	251,430	84	36	32,733	33,738
Eritrea	24,497	1	4,572	168	4,740
Ethiopia	363,314	39	148,846	928	149,775
Kenya	49,476	20	34,382	161	34,543
Rwanda	20,836	11	12,593	116	12,709
Sudan	1,339,764	37	148,932	29,966	179,269
South Sudan	617,142	11	7,366	1,047	8,413
Tanzania	119,785	12	42,937	289	43,227
Uganda	237,021	42	67,657	1,754	69,411

RESULTS & DISCUSSION

Egalitarianism

Table 3 Gini coefficient values based on each criterion for the year 2018

	Precipitation	ETa	Internal AW	Total AW
Country area	0.11	0.06	0.68	0.35
Population	0.55	0.55	0.52	0.15
Cropland area	0.29	0.34	0.33	0.10

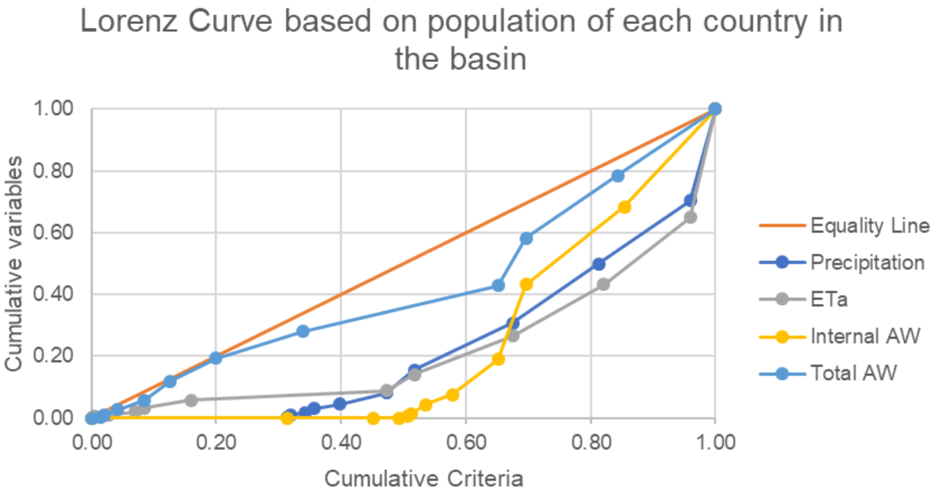


Figure 12 Distribution of water resource variables based on area of each country within the Nile basin

Envy-freeness (in terms of population)

Concerning the internally generated available Ethiopia and Uganda as well as Tanzania are envied by other countries because their available water is more than their demand. However, Sudan and South Sudan are no longer envied by other countries because their demand is higher than their available water.

Normalized Envy Freeness Calculation for D-Internal_AW in terms of population

Countries	Burundi	DRC	Egypt	Eritrea	Ethiopia	Kenya	Rwanda	S.Sudan	Sudan	Tanzania	Uganda
Burundi	0.0	0.0	0.0	0.0	0.9	0.3	0.0	0.0	0.0	0.7	0.7
DRC	0.1	0.0	0.0	0.0	1.0	0.3	0.1	0.0	0.0	0.7	0.8
Egypt	0.1	0.0	0.0	0.0	1.0	0.4	0.1	0.0	0.0	0.8	0.8
Eritrea	0.1	0.0	0.0	0.0	1.0	0.3	0.1	0.0	0.0	0.7	0.7
Ethiopia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kenya	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.4	0.4
Rwanda	0.0	0.0	0.0	0.0	0.9	0.2	0.0	0.0	0.0	0.6	0.7
Sudan	0.1	0.0	0.0	0.0	1.0	0.4	0.1	0.0	0.0	0.8	0.8
South Sudan	0.1	0.0	0.0	0.0	1.0	0.3	0.1	0.0	0.0	0.8	0.8
Tanzania	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Uganda	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0

Envy-freeness (in terms of irrigated cropland area)

- Egypt and Sudan hold the maximum irrigated cropland area in the basin
- Sudan has a higher precipitation volume than its irrigated cropland water demand. For this reason the country is envied by all the countries in terms of D-P. However, the volume of its total AW is much lower than its cropland water demand, thus it envies all other countries

Normalized Envy Freeness Calculation for D-AW in terms of Irrigated Cropland area

Countries	Burundi	DRC	Egypt	Eritrea	Ethiopia	Kenya	Rwanda	S.Sudan	Sudan	Tanzania	Uganda
Burundi	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.1
DRC	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.2	0.1
Egypt	0.8	0.8	0.0	0.8	1.0	0.9	0.8	0.1	0.8	1.0	0.9
Eritrea	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.1	0.1
Ethiopia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kenya	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0
Rwanda	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.1
Sudan	0.8	0.8	0.0	0.8	0.9	0.8	0.8	0.0	0.7	0.9	0.9
South Sudan	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.2	0.1
Tanzania	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uganda	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Conclusion

- The use of multiple equity assessment theories provided a more comprehensive understanding of equity in the Nile river basin

- Different criteria can lead to different results. Assessing equity using country area in the basin has demonstrated equal distributed results than using cropland area and population. However, the interconnection between the criteria are complex, for example, areas with high population may also have high levels of cropland use, which could exacerbate water scarcity issues in those regions

- It was noted that precipitation and actual evapotranspiration only can not demonstrate a good picture of water equity assessment. Therefore, other sources of water such as groundwater would yield much better results.

- The use of remote sensing data has several advantages, including the ability to provide a comprehensive and objective assessment of equity, even in hard-to-reach areas, and the ability to track changes over time

Limitations and Suggestions

On Remote sensing

- Various sources of errors, such as atmospheric interference, cloud cover, and sensor calibration, can affect the accuracy and reliability of the data, which, in turn, can affect the equity assessment results
- Information on the physical characteristics of water resources and their distribution, it cannot fully capture social and cultural aspects of equity, such as perceptions of fairness, cultural norms, and historical inequalities.

Of the study

- Only surface water was considered for the calculations of equity assessment, while there are other important sources such as ground water and reservoirs.
- The assessment assumed a certain amount of water demand per population or cropland, which may not accurately reflect the actual water demand.
- Lack of accurate data on the amount of transboundary water entering a country and the amount passing downstream were a big challenge to do the assessment.
- The study was limited by time constraints which may have impacted the accuracy of the assessment

Thank you!

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