

Congrès:

Téledétection: applications pour l'hydrologie et la limnologie

Water Accounting Plus (WA+):
une nouvelle méthode pour la quantification des
ressources en eau depuis l'espace
Le cas du bassin de la Volta

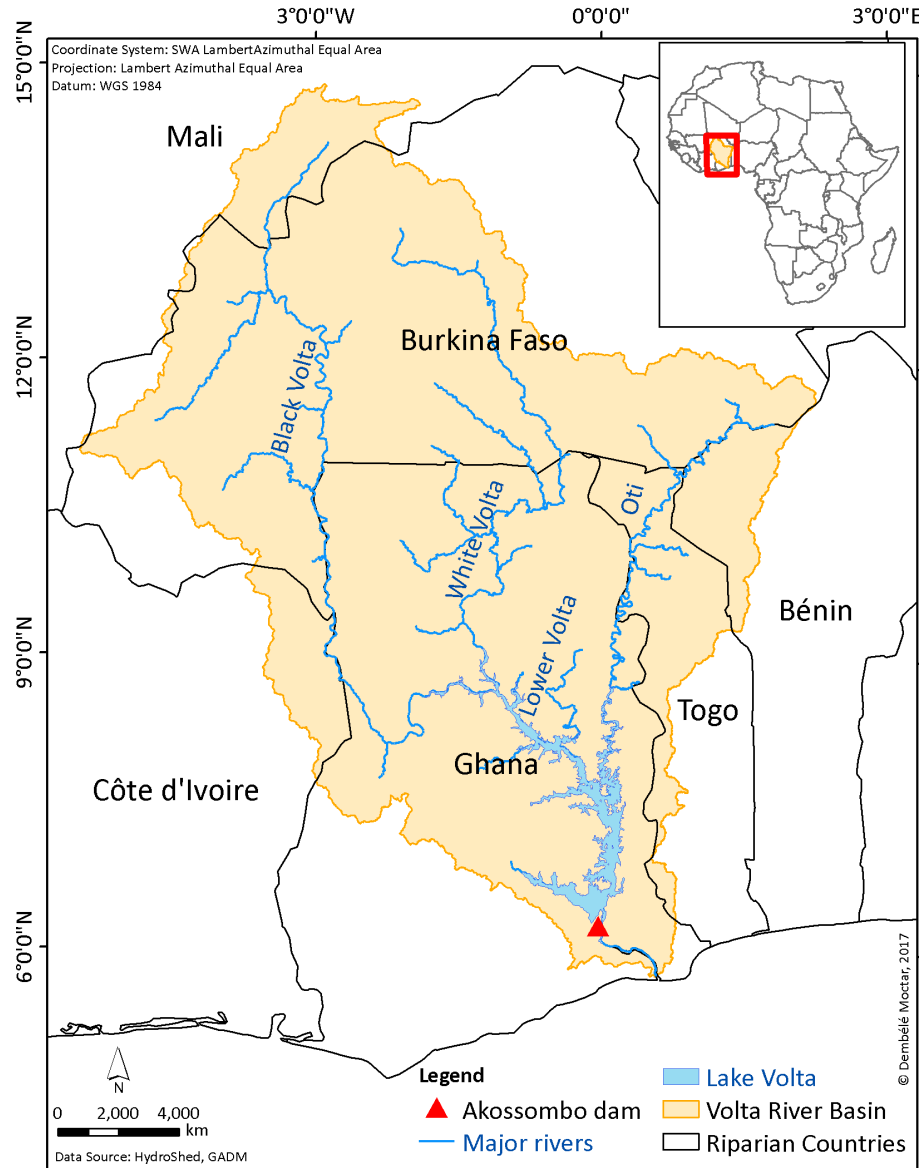
Bienne, 13 Septembre 2017

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The Volta River Basin – Overview



Latitudes: 5°45' N and 14°10' N
Longitudes: 2°17' E and 5°20' W

Area $\approx 410,000 \text{ km}^2$

2010: 23.8 million inhabitants

2030: 38.4 million (Williams et al., 2016).

70% of rural population

Growth rate: 2.4% per year (van de Giesen et al., 2001)

**Mean annual
Temperature**

27°C in the south
36°C in the north

**Mean annual
Rainfall**

500 - 1,500 mm

ET = 88% of rainfall

Source: Williams, et al. (2016)

Economic development

- Electricity production
- Irrigation
- Aquaculture
- Livestock watering
- Domestic water supply
- Livelihood for rural populations

Constraints

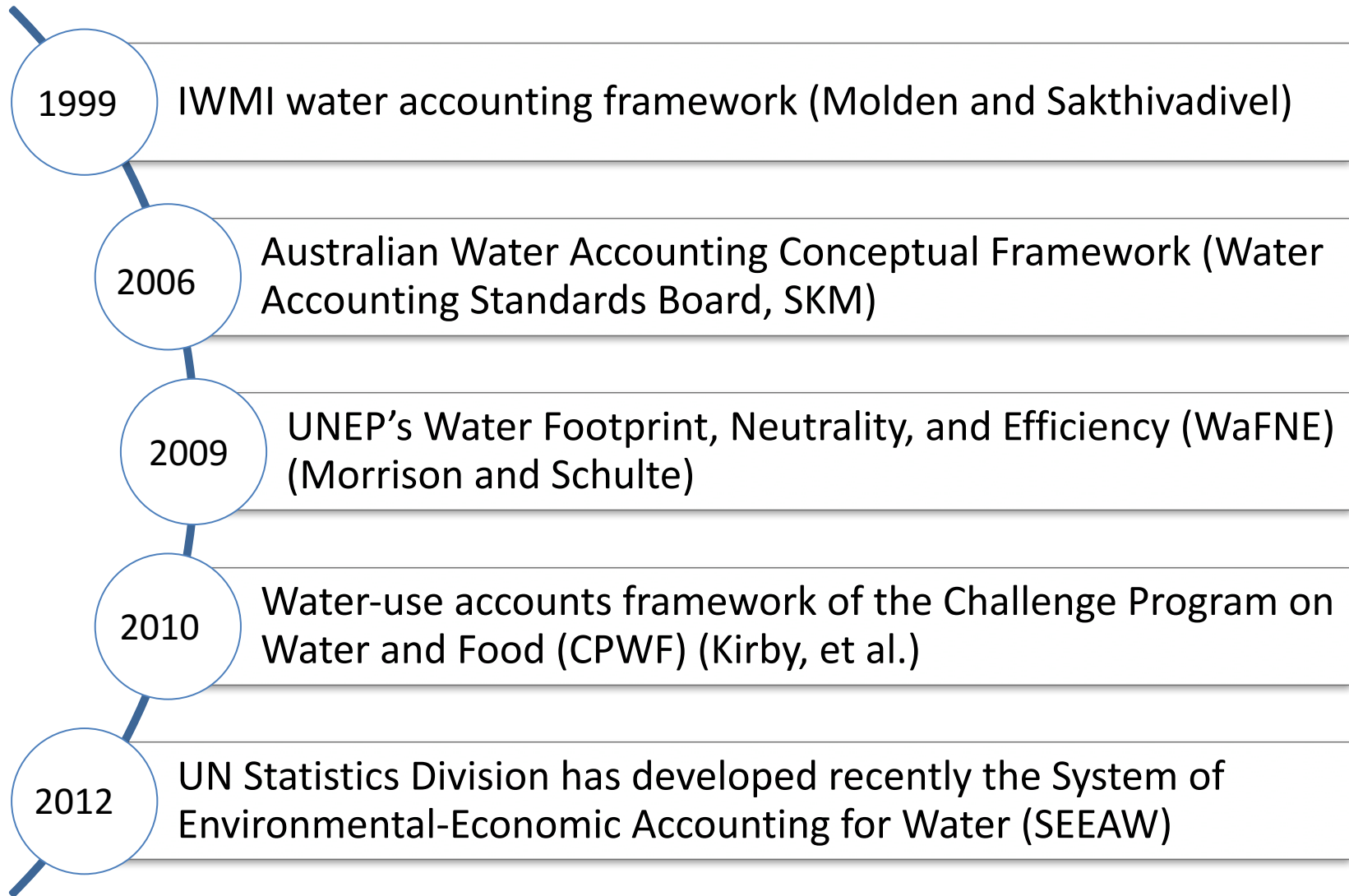
- Urbanization
- Rapid population growth
- Economic development
- Climate Change



Water scarcity

Water demand is projected to increase by more than 1000% between 2000 and 2025 (Biney, 2010).

Existing Water Accounting Frameworks



Shortcomings in Major Water Accounting Frameworks

- Complex results and difficult to understand
- High requirement of input data $\Rightarrow$ Not suitable for data scarce regions
- Consider abstracted water but not consumptive use and return flows
- No link between land use and water flows
- Land use impact on water is unknown

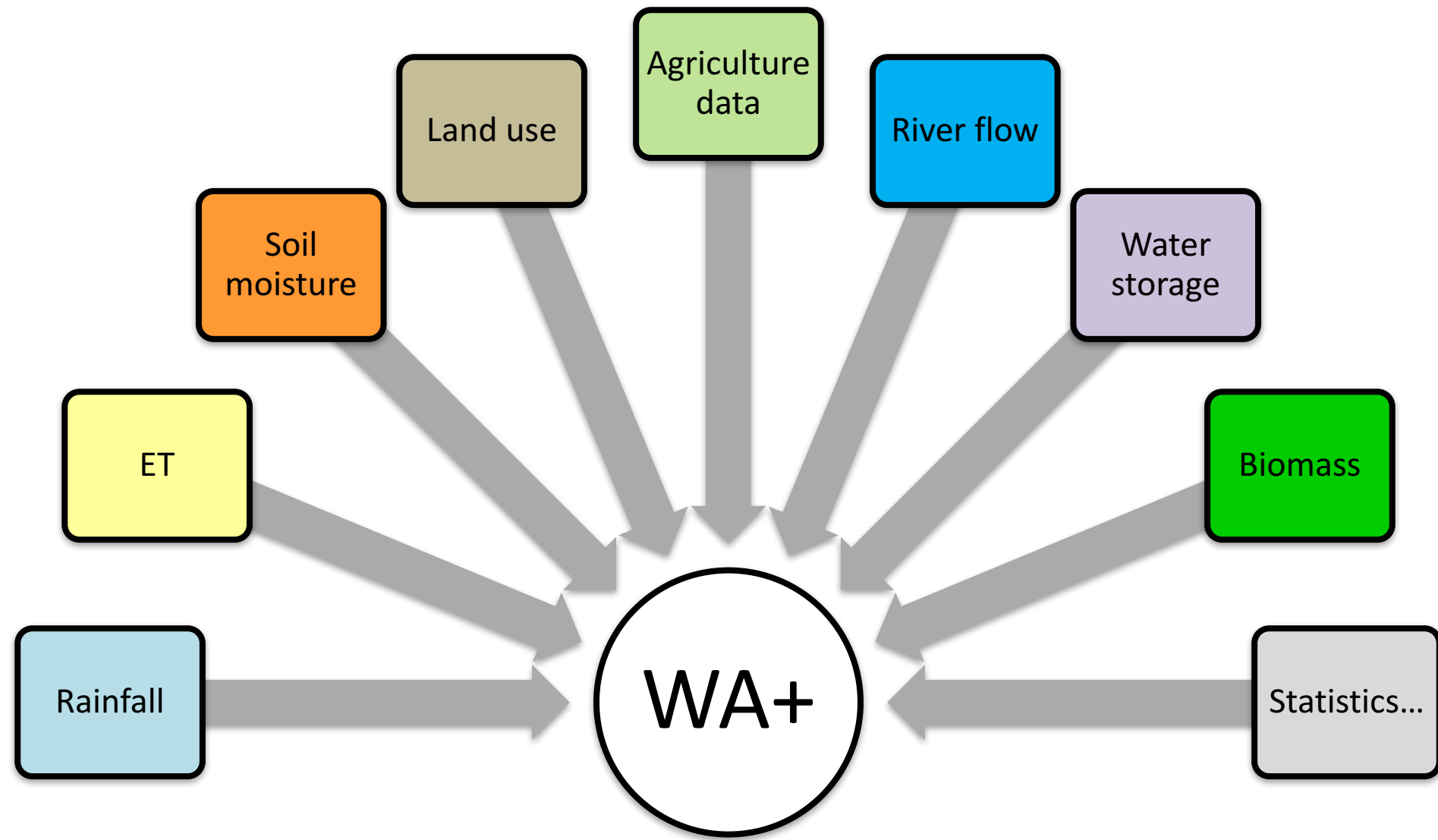
WA+ framework has been developed to address most of these shortcomings

Water Accounting Plus (WA+)

A new framework that summarizes complex hydrological processes and water management issues using public domain data



Input data to WA+



8 sheets for results with key indicators

Sheet 1 **Resource Base**

Water allocation

Sheet 2 **Evapotranspiration (ET)**

Water consumption

Sheet 3 **Agricultural Services**

Water productivity in agriculture

Sheet 4 **Utilized Flow**

Manmade and natural withdrawals

Sheet 5 - **Surface Water**

Water availability and river flow

Sheet 6 **Groundwater**

Availability and withdrawals

Sheet 7 **Ecosystem Services**

Land and atmosphere interactions

Sheet 8 **Sustainability**

Reliability, resilience and vulnerability

Protected Land Use (PLU)

- tropical rainforests
- wetlands
- mountainous vegetation
- national parks
- RAMSAR sites
- etc.

Utilized Land Use (ULU)

- forests
- natural pastures
- savannas and deserts
- woodlands
- lakes
- shrublands
- grasslands
- etc.

Modified Land Use (MLU)

- urban encroachment
- built-up areas
- rainfed croplands
- bio-fuel crops
- timber plantations
- etc.

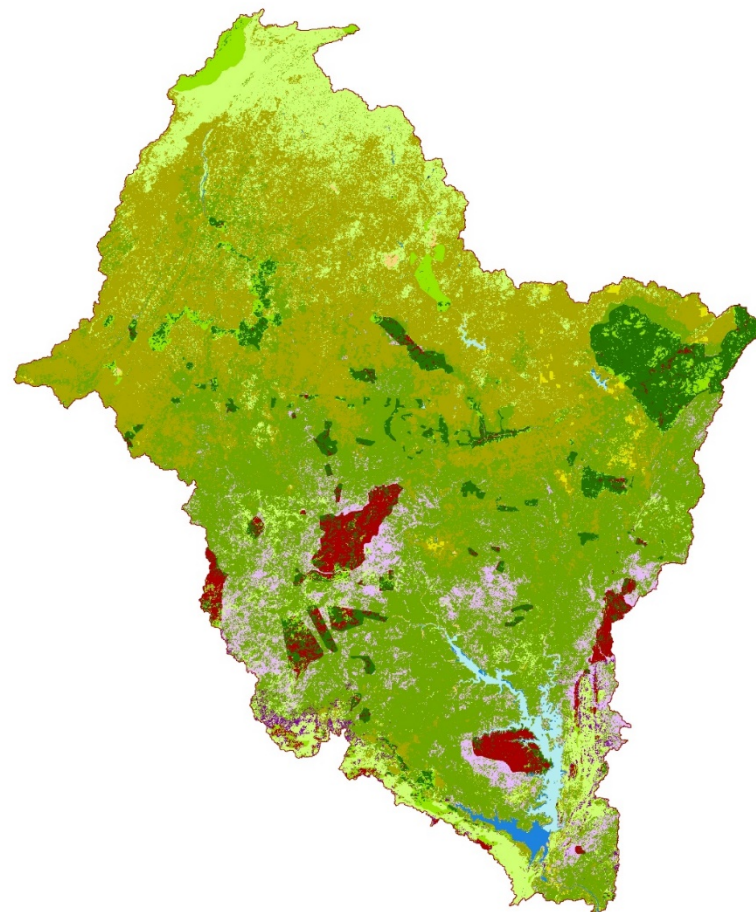
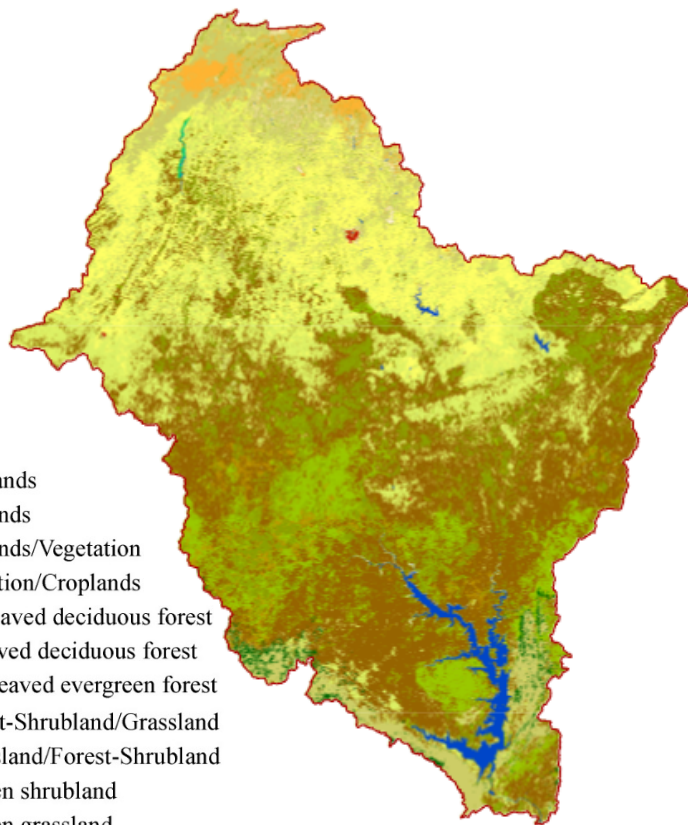
Managed Water Use (MWU)

- irrigation
- urban water supply
- industrial extractions
- diversion dams
- canals, ditches, gates, weirs, pipes
- etc.

Source: adapted from Karimi et al. (2013), Bastiaanssen et al. (2015)

WA+ Land Use Land Cover Map

Globcover
2009



Land cover type

- 11 - Irrigated croplands
- 14 - Rainfed croplands
- 20 - Mosaic Croplands/Vegetation
- 30 - Mosaic Vegetation/Croplands
- 50 - Closed broadleaved deciduous forest
- 60 - Open broadleaved deciduous forest
- 70 - Closed needleleaved evergreen forest
- 110 - Mosaic Forest-Shrubland/Grassland
- 120 - Mosaic Grassland/Forest-Shrubland
- 130 - Closed to open shrubland
- 140 - Closed to open grassland
- 150 - Sparse vegetation
- 90 - Open needleleaved deciduous or evergreen forest
- 100 - Closed to open mixed broadleaved and needleleaved forest
- 40 - Closed to open broadleaved evergreen or semi-deciduous forest
- 160 - Closed to open broadleaved forest regularly flooded (fresh-brackish water)
- 170 - Closed broadleaved forest permanently flooded (saline-brackish water)
- 180 - Closed to open vegetation regularly flooded
- 190 - Artificial areas
- 200 - Bare areas
- 210 - Water bodies

LULC classes for WA+

- | Bare Areas | Croplands | Forest | Grasslands | Shrublands | Urban Areas |
|------------|-----------|-----------|------------|------------|---------------------|
| Protected | Rainfed | Protected | Protected | Protected | Managed |
| Utilized | Irrigated | Utilized | Utilized | Utilized | Water Bodies |
| | | Managed | | | Protected |
| | | | | | Utilized |
| | | | | | Managed |

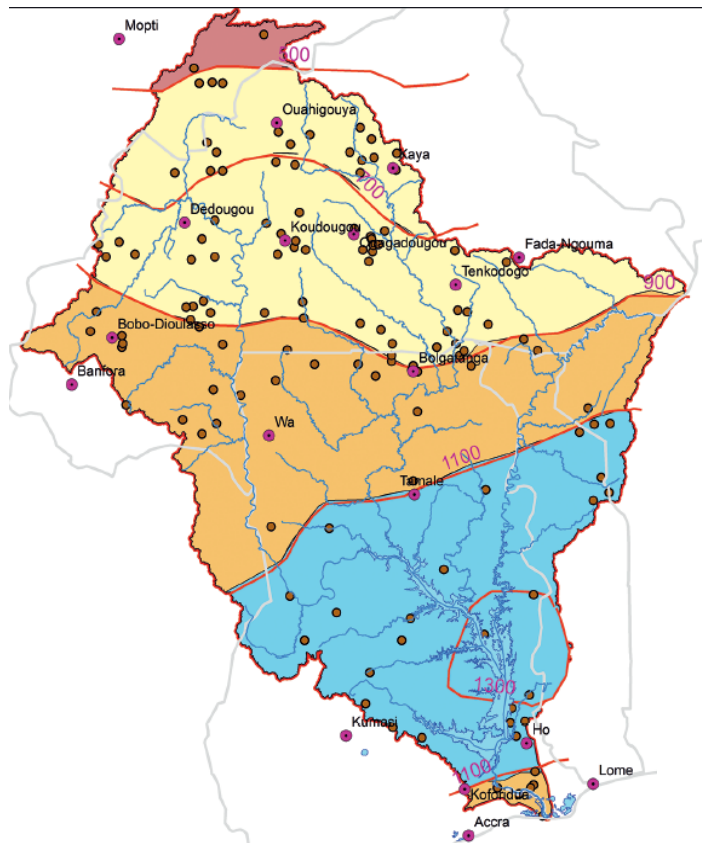
Evapotranspiration Sheet

Year: 2008

		ET	T		ET	T			Units : [km3/year]	
Total Evapotranspiration	Non-Manageable	38.0	32.3	Bare Areas	0.02	0.01	57.9	Interception	Non-Beneficial	41.4
				Forest	10.38	8.92				
				Grasslands	8.69	7.15				
				Shrublands	18.84	16.16				
				Water Bodies	0.02	0.01				
	Manageable	161.5	131.5	Bare Areas	0.72	0.41	Evaporation	37.7	Beneficial	264.7
				Forest	2.71	2.34				
				Grasslands	36.02	28.19				
				Shrublands	119.33	99.36				
				Water Bodies	2.70	1.21				
	Managed	106.7	82.2	Forest Woodland	22.10	18.68	Transpiration	248.3	Agriculture	106.9
				Rainfed Croplands	77.43	63.45				
				Urban Areas	0.10	0.07				
				Irrigated Croplands	1.38	1.11				
				Water Bodies	5.69	1.17				
	Managed	106.7	2.3	Water Bodies	5.69	1.17	Transpiration	248.3	Environment	128.2
	Managed	106.7	2.3				Transpiration	248.3	Economy	11.2
	Managed	106.7	2.3				Transpiration	248.3	Energy	6.1
	Managed	106.7	2.3				Transpiration	248.3	Leisure	12.3

Input Data Validation - Rainfall

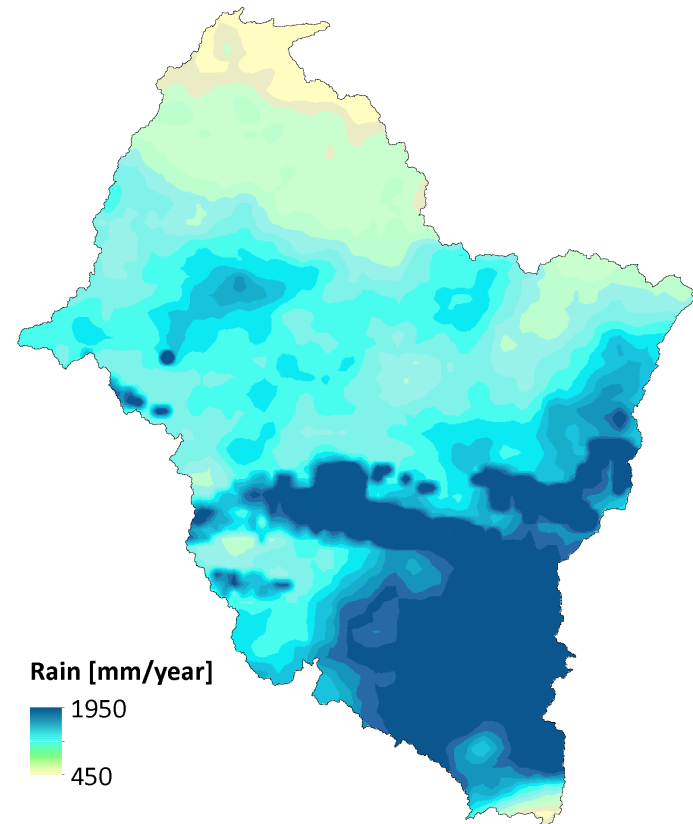
Climate zones



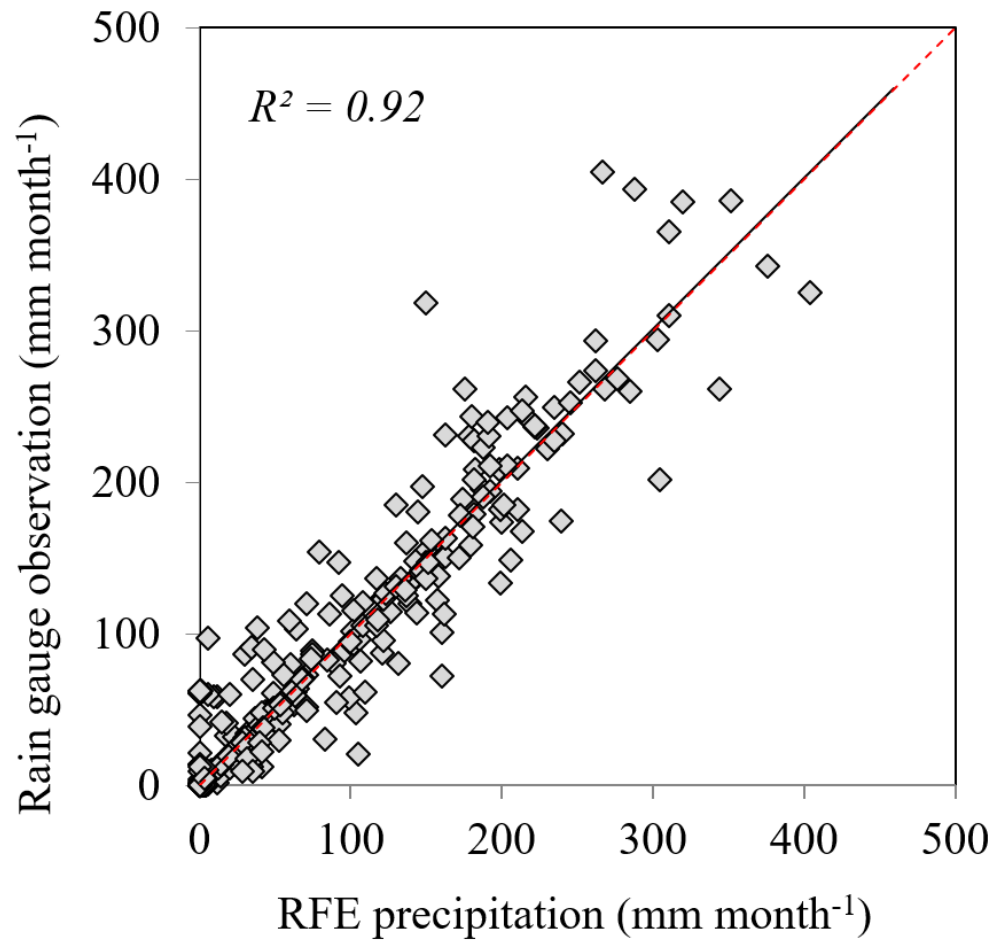
Climate zones



RFE



Input Data Validation - Rainfall



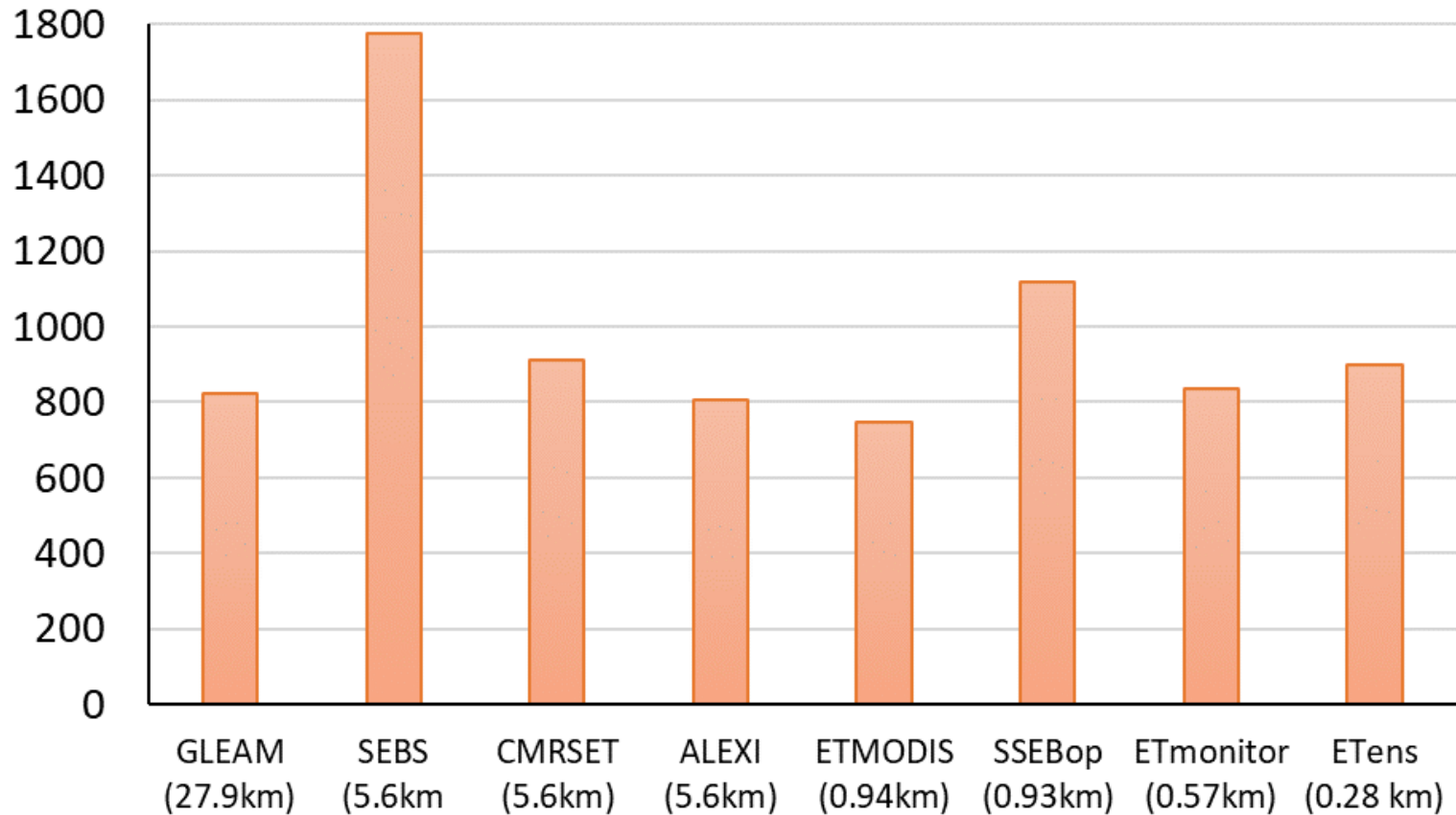
2001–2014

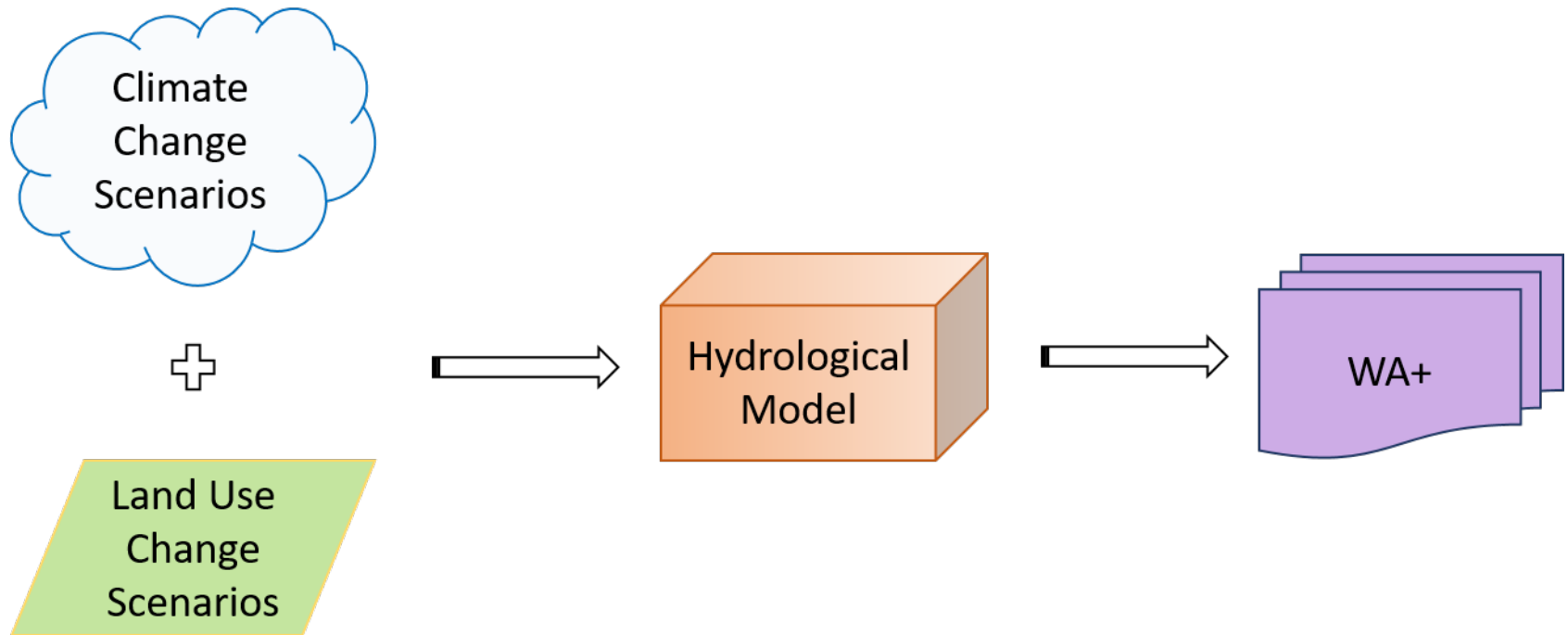
r	ME	$RMSE$	$Bias$	Eff	POD	FAR
0.96	-2.25	23.60	0.96	0.62	0.95	0.10

Source: Dembélé & Zwart (2016)

Satellite-derived ET products and ETens in the VRB in 2008

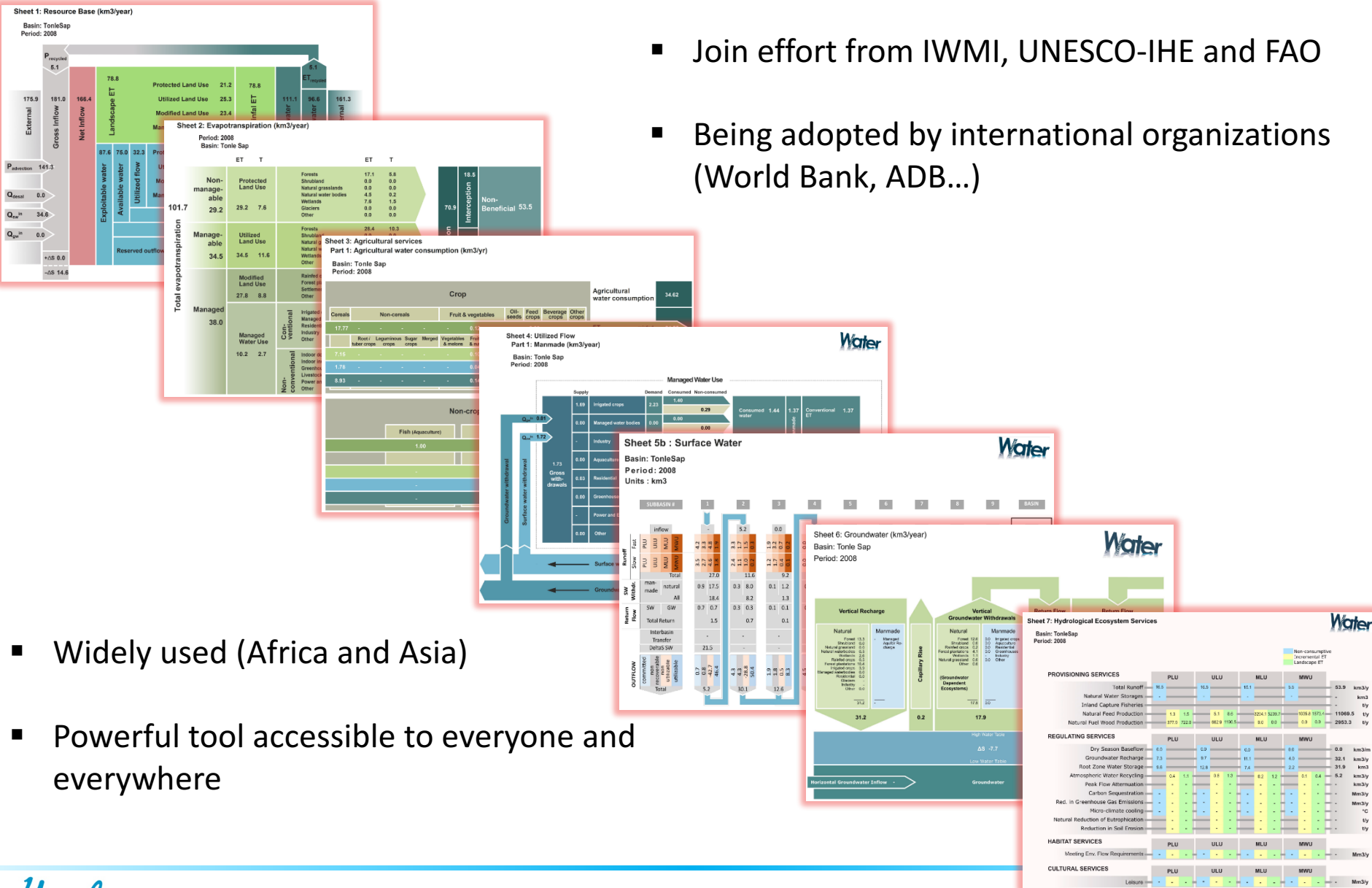
Evapotranspiration data





Summary and conclusion

- Join effort from IWMI, UNESCO-IHE and FAO
- Being adopted by international organizations (World Bank, ADB...)

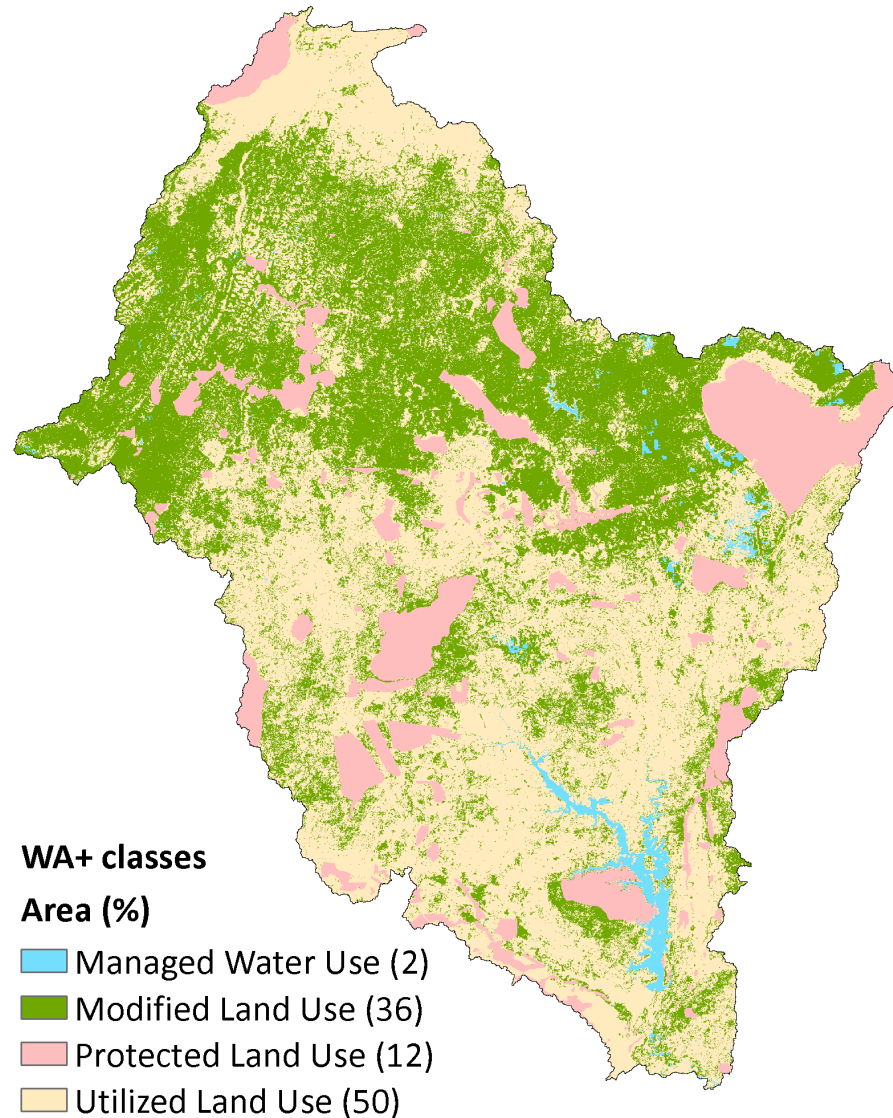


- Widely used (Africa and Asia)
- Powerful tool accessible to everyone and everywhere

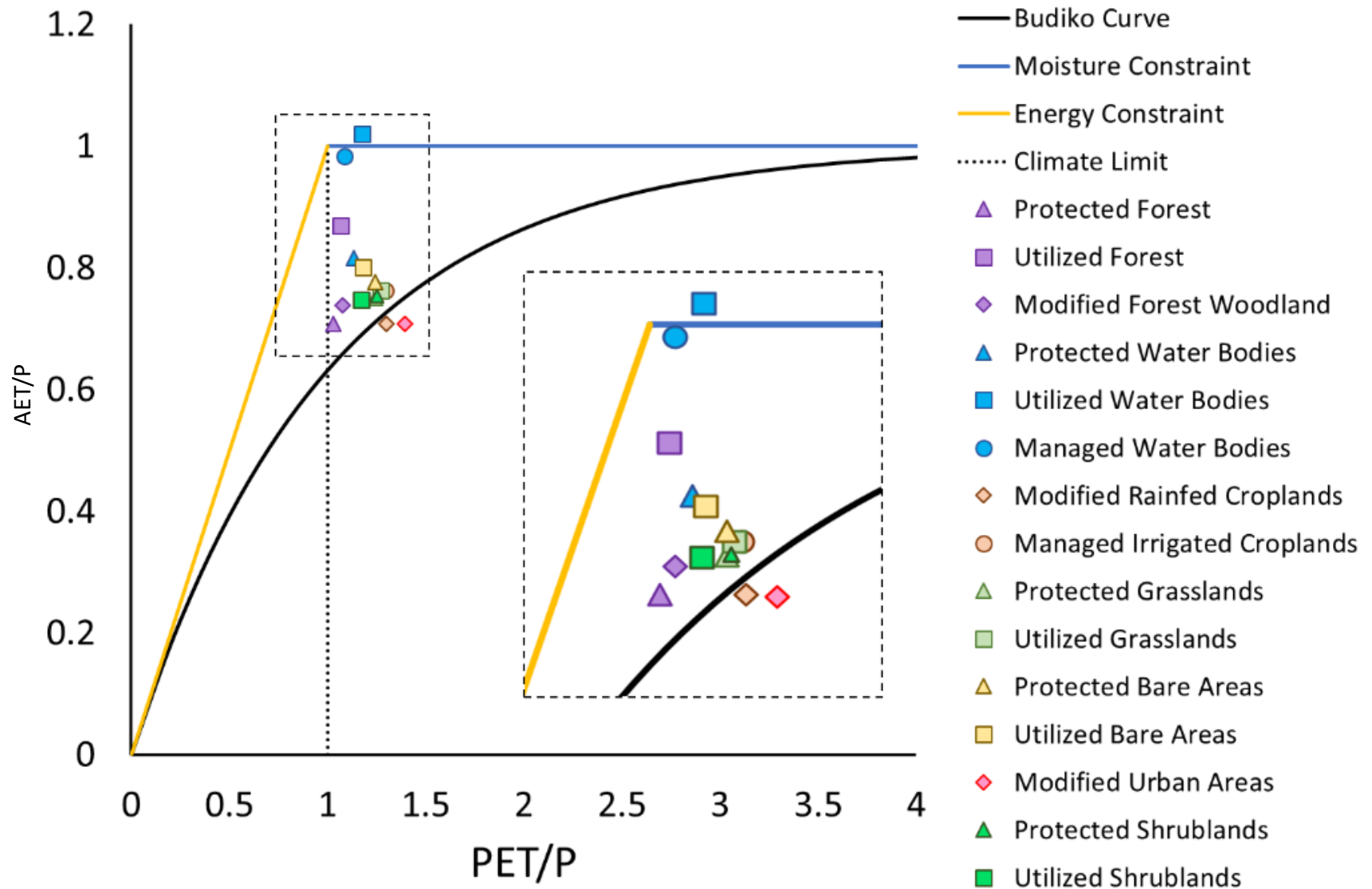
Danke!
Merci

www.wateraccounting.org

WA+ Land Use Land Cover Map



Budyko Framework Analysis – Results



Input	Source(s)
Rainfall	TRMM, GSMaP, GPCP, FEWSNET, PERSIANN, CMORPH, APHRODITE, CRU, ECMWF
Evapotranspiration	MOD16, GLEAM, CMRSET, ALEXI, ETens
Soil moisture	SMAP, ASCAT
Land use	Globcover, AfriCover, Corine, MIRCA, GIAM, GMIA
Lake levels	Global Reservoir and Lake Monitoring (GRLM), River Lake Hydrology (RLH), Hydroweb, Global Land Surface Altimetry data (ICESat-GLAS)
WaterStat database	AquaStat, Waterfootprint.org, Worldwater.org, World water assessment program, Aqueduct

Comparison between SEEAW and WA+

Process	Low end performance description	High end performance description	WA+	SEEAW
	*	*****		
Field measurements involved	Few	Intensive	*	*****
Remote sensing measurements	No remote sensing	Intensive remote sensing	*****	**
Land use classes	Minimum attention	Maximum attention	*****	*
Economy	No attention	Maximum attention	*	***
Water quality	Not accounted for	Included	*	***
Temporal scale	Annual	Weekly	***	*
Consumptive use	Maximum attention	Minimum attention	*****	**
Hydrological cycle	A few terms only	All terms	*****	*
Natural vegetation	No attention	Fully explored	*****	*
Withdrawals general	Minimum attention	Maximum attention	****	*
Withdrawals domestic & industry	Minimum attention	Maximum attention	**	*****
Local reuse of water	No attention	Measured	*	*****
Return flow	Minimum attention	Maximum attention	****	**
Surface water	Not accounted for	Measured	***	*****
Groundwater	Not accounted for	Estimated	***	**
Crop production	Detailed estimates	Not accounted for	*****	*
Crop water productivity	Not accounted for	Estimated	*****	*
Greenhouse gas emissions	Not accounted for	Estimated	****	*
Carbon sequestration	Not accounted for	Estimated	****	*
Ecosystem services	Detailed estimates	Not accounted for	*	*****
Stocks (i.e. assets)	Not accounted for	Measured	***	*****
Data consistency	Agency dependent	Single source	****	*
Access to results	Not accessible	Website with data	*****	**
Understanding	Complex	Simple	*****	**
Implementation	High efforts	Little efforts	*****	*
Communication tool	No	Yes	****	**

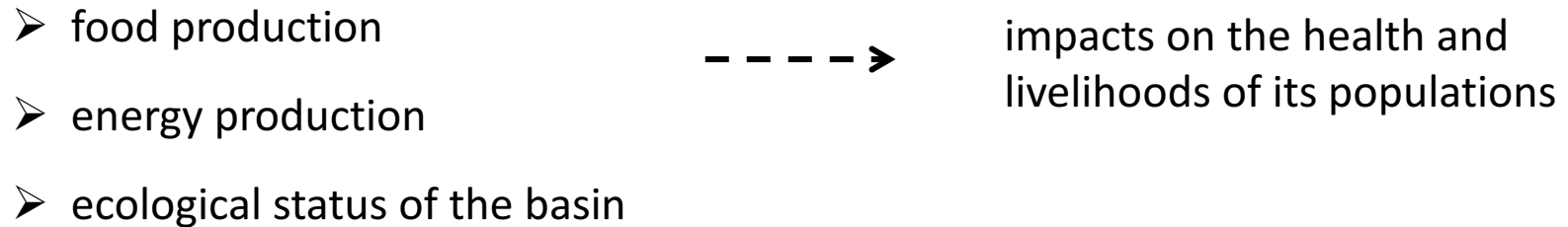
Input Data Validation - Evapotranspiration

Satellite-derived ET products and ETens in the VRB in 2008

ET products (mm/year) / WA+ LULC	GLEAM (27.9 km)	SEBS (5.6 km)	CMRSET (5.6 km)	ALEXI (5.6 km)	ETMODIS (0.94 km)	SSEBop (0.93 km)	ETmonitor (0.57 km)	ETens (0.28 km)
Protected Water Bodies	905	1900	1031	835	843	1250	827	1015
Utilized Water Bodies	1184	2034	1617	672	889	1277	1198	1312
Managed Water Bodies	1255	2109	1775	753	929	1322	1348	1441
Protected Bare Areas	710	1588	892	763	581	1181	490	701
Utilized Bare Areas	808	1769	852	808	676	1060	714	817
Modified Urban Areas	565	1516	337	685	270	589	508	453
Modified Rainfed Croplands	619	1619	564	794	464	980	675	643
Managed Irrigated Croplands	677	1647	627	836	614	1036	741	726
Protected Grasslands	708	1629	679	783	624	1010	725	736
Utilized Grasslands	682	1538	567	736	523	828	668	643
Protected Shrublands	702	1796	743	768	718	1135	771	790
Utilized Shrublands	783	1789	814	817	827	1149	849	889
Protected Forest	858	1889	1023	881	981	1283	959	1035
Utilized Forest	1038	1919	1164	1112	1258	1381	1111	1229
Modified Forest Woodland	865	1883	973	868	985	1275	962	1026
VRB	824	1775	911	807	745	1117	836	897

Many river basins experience issues of water stress and populations live with an inadequate level of water security.

Water stress affects :



Climate change as well as other global and regional changes are expected to exacerbate water issues.

There is an increasing uncertainty in water availability in declining rainfall areas such as the Volta basin.