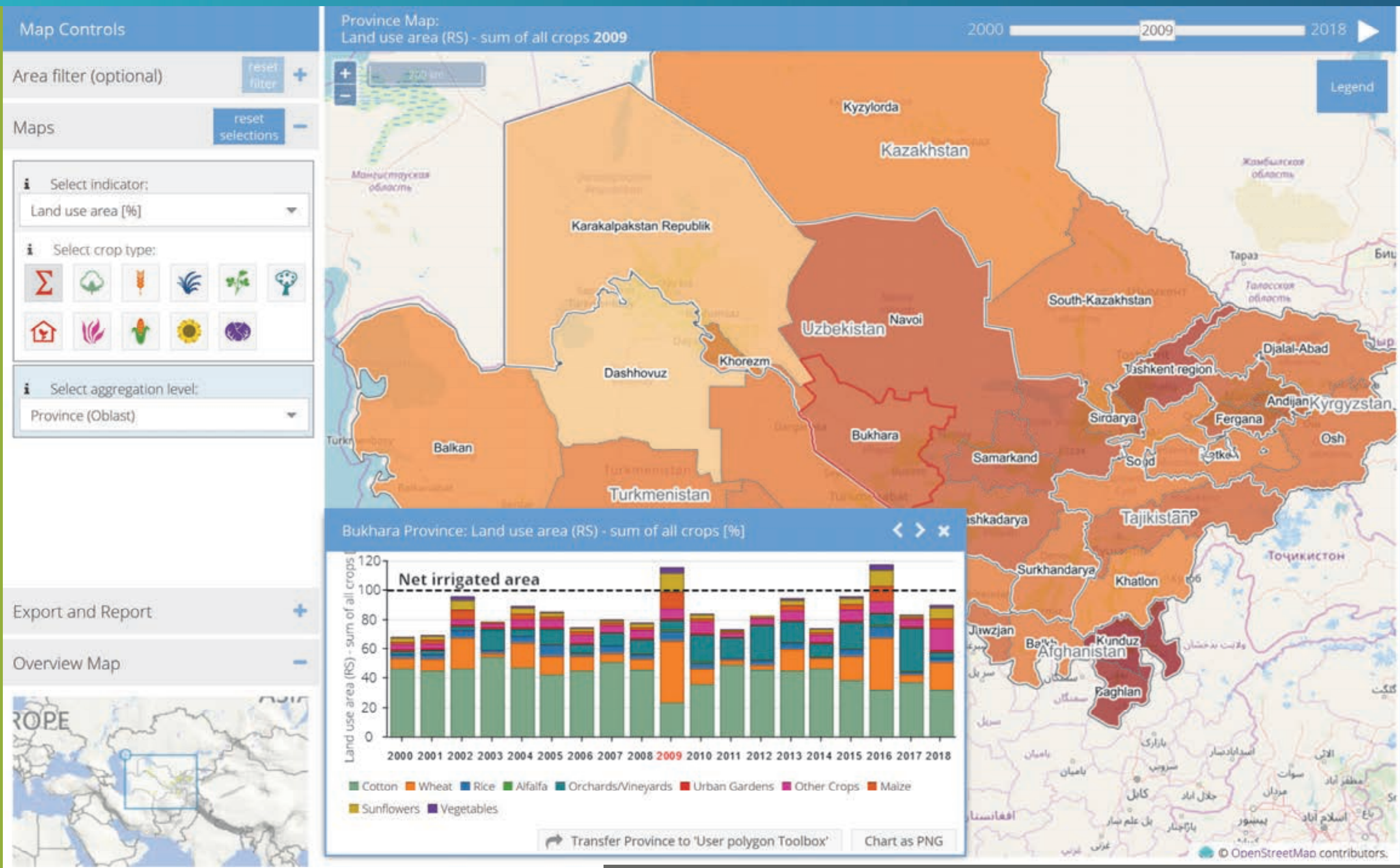
WUEMoCA

Water Use Efficiency Monitor in Central Asia

CAWa

Informed Decision-Making in Land and Water Resources Management



Land use intensity in all provinces in the Aral Sea Basin, 2009

Introduction

WUEMoCA is an operational scientific web-mapping tool for the regional monitoring of land and water use efficiency in the irrigated croplands of the transboundary Aral Sea Basin that is shared by Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, and Afghanistan. Satellite data on land use, crop production and water consumption is integrated with hydrological and economic information to provide of a set indicators. The tool is useful for large-scale decisions on water distribution or land use, and may be seen as demonstrator for numerous applications in practice, that require independent area-wide spatial information.

WUEMOCA at a glance

≈ Online accessible for everyone

≈ Overview of spatial and temporal trends in the Aral Sea Basin: “Big picture”

≈ Identification of irrigated areas with need for action

≈ Compliance with UN Sustainability indicators (SDGs 2 & 6)

≈ Options to include user-defined areas and statistics to calculate additional water indicators

≈ Privacy: Sensitive statistics and additional calculation results remain with the user

≈ Open-source code for further tool development, e.g. in water related institutions and universities

WUEMoCA

Water Use Efficiency Monitor in Central Asia

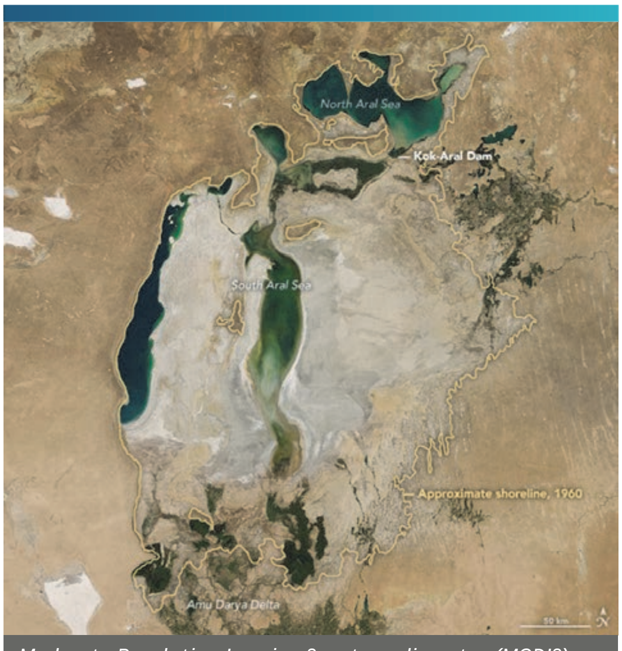
Informed Decision-Making in Land and Water Resources Management

Cooperation between Central Asia & Germany

The selected indicators were approved by the regional water management institutions of Central Asia. The remote sensing tools and data integration was implemented by the German partners.

The web platform with user interaction is a common development.

Brochure Contents



Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite, shows the Aral Sea in Central Asia on August 22, 2017

Regional Research Network "Water in Central Asia" (CAWa), http://www.cawa-project.net/

Central Asia faces big water-related challenges, among them water scarcity, degrading water quality and inefficient water use.
Climate change may even aggravate the situation.
These challenges can be met only in a joint effort of all Central Asian states.
The CAWa project intends to contribute to a sound scientific and a reliable regional data basis for the development of sustainable water management strategies in Central Asia.
CAWa is part of the German Water Initiative for Central Asia (2008 – 2019) and is funded by the Federal Foreign Office of Germany.

WUEMoCA analysis results are spatially aggregated to all irrigated provinces and districts of the Aral Sea Basin.
For selected regions aggregations are shown also for Water User Associations, supply zones of (Basin) Irrigation System Authorities, and channel command areas.

WUEMoCA Overview Purpose and Content

WUEMoCA is an acronym for the **Water Use Efficiency Monitor in Central Asia**. The online tool is based on remote sensing analysis for the regional assessments of the irrigation water use efficiency in the Aral Sea Basin.

For land and water management. The decision-support tool allows for identification of areas with need for action, such as marginal lands with low productivity, inefficient water use or exposure to droughts.

Indicator-based. Decisions can be derived from indicators for economic performance and sustainability, grouped into **land use, productivity and water use efficiency** (see table below).

Geodata integration. The tool integrates **satellite** data (MODIS, calibrated with in-situ data), **climate** data and area-wide available **statistics.**

Operational monitoring. Information is provided for the period from 2000 onwards. The automated processing chain includes continuous download and processing (land use classification, evapotranspiration and crop yield estimation, and aggregation to administrative boundaries).

Flexible choice of information. Users define the content of the output (maps, diagrams and tables) by the selection of area, time, indicators, and crop types for their specific application.

User Polygon Toolbox. Users are enabled to interact with the tool by defining own areas (user polygons > 30 ha) and adding statistical data to calculate further indicators on **productivity** and **irrigation efficiency**. Sensitive data remains with the user. In addition, compensation of uncertainties of remote sensing models becomes possible by manual data correction.

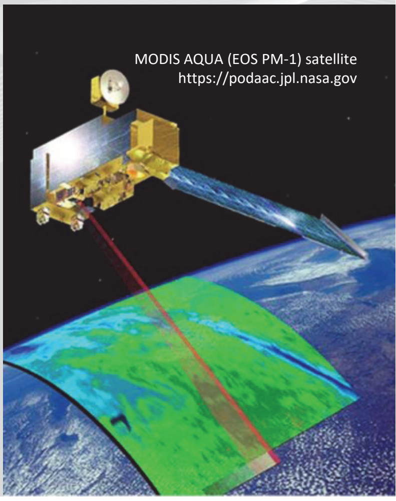
Combination of Satellite Information with Ground Observations – Generation of a new Data Basis of Indicators

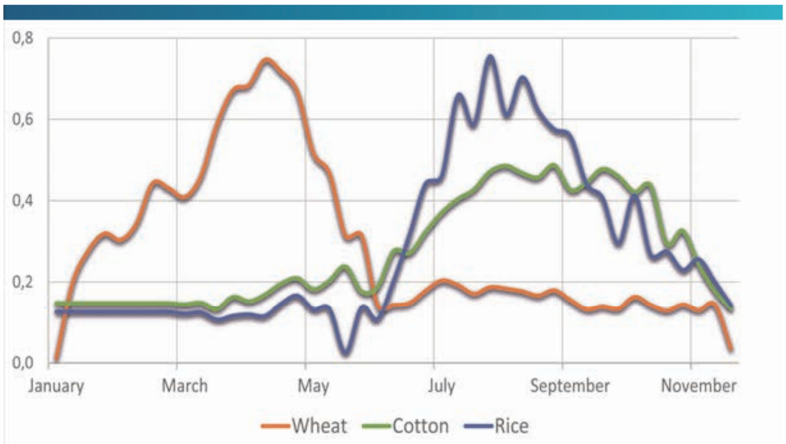
Indicator [unit]	**Short description**	**Crop specific**	**Data sources**
	Land use indicators		
Net irrigated area [ha]	Area equipped with irrigation infrastructure, incl. fallow land	-	🔵⚪⚪
Crop acreage [ha]	Crop area under irrigation (double usage is counted twice)	**yes**	🔵⚪⚪
Land use area [%]	Area share of crop acreage in net irrigated area	**yes**	🔵⚪⚪
Temporarily unused irrigable land [%]	Area share of fallow land in net irrigated area	-	🔵⚪⚪
Crop type diversity [-]	Variety of different crop types (spatially)	-	🔵⚪⚪
	Multi-annual Land use indicators		
Fallow land frequency [-]	Average number of years in which land was not cultivated	-	🔵⚪⚪
Land use rotation [-]	Average number of land use alternations, incl. fallow land	-	🔵⚪⚪
Major land use [-]	Predominant crop type based on average frequency	-	🔵⚪⚪
	Productivity indicators		
Farm crop output [t]	Estimated crop harvest (crop yield * crop acreage)	**yes**	🔵🟡⚪
Crop yield [t ha^{-1}]	Estimated crop harvest per ha crop acreage	**yes**	🔵🟡⚪
Total productivity [$]	Crop-specific economic revenue (crop harvest * crop price)	**yes**	🔵🟡🔴
Productivity per hectare [$ ha^{-1}]	Crop-specific economic revenue per ha crop acreage	**yes**	🔵🟡🔴
Quantity per water consumed [kg m^{-3}]	Crop-specific harvest per m³ surface water consumed	**yes**	🔵🟡🔴
Productivity per water cons. [$ m^{-3}]	Crop-specific economic revenue per m³ surface water cons.	**yes**	🔵🟡🔴
Specific water supply [m³ ha^{-1}]	Water intake (+ groundwater, rainfall) per ha net irr. area	-	⚪⚪🔴
	Water use efficiency indicators		
Actual evapotranspiration [mm] = **ET_{act}**	Quantity of water released to atmosphere by evaporation and transpiration (stands for actual water consumption)	**yes**	🔵🟡⚪
Water availability (ET) [-]	Index of appropriate water supply (ET_{act} per water demand)	**yes**	🔵🟡⚪
Water productivity (ET) [kg m^{-3}]	Crop-specific harvest per m³ of water consumed (in ET_{act})	**yes**	🔵🟡⚪
Irrigation efficiency [-]	Index of efficiency in delivering water to the plants and minimizing water losses (ET_{act} per water intake)	-	🔵🟡🔴

Data sources of indicators

- 🔵 **= RS-based** (based on remote sensing data from MODIS; Moderate Resolution Imaging Spectroradiometer)
- 🟡 **= climate data** (radiation, temperature, precipitation, humidity)
- 🔴 **= user input/statistics** (crop prices, water intake, groundwater, rainfall)
- **= "on-the-fly"** calculation possible with user input (**User Polygon Toolbox**)

Utilizing Satellite Information





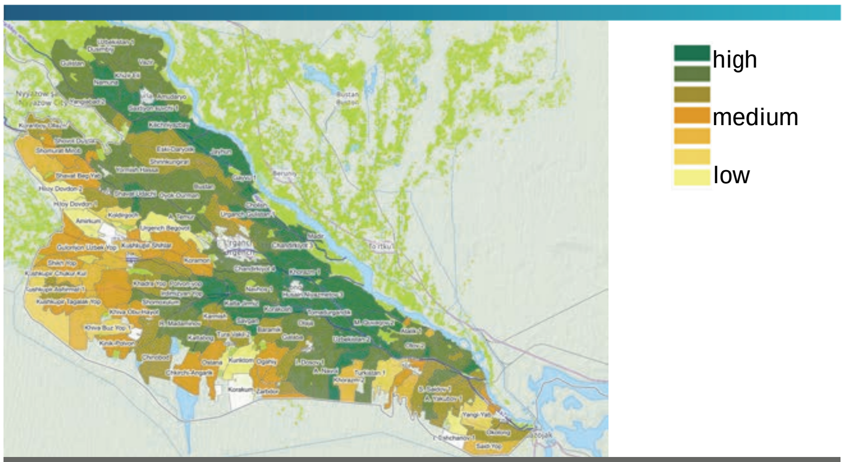
Vegetation index (NDVI) from satellite data analysis: annual crop curves show typical growth cycles of wheat, cotton, and rice

Land use maps. The MODIS sensor records the earth day by day and is thus the preferred instrument for crop monitoring in WUEMoCA. It provides daily information on vegetation conditions (index: **NDVI**) for pixels with a size of 250 m * 250 m (~6.25 ha). Different crop classes are derived from phenological curves. These are regular time series of NDVI. Every crop has its typical curve.

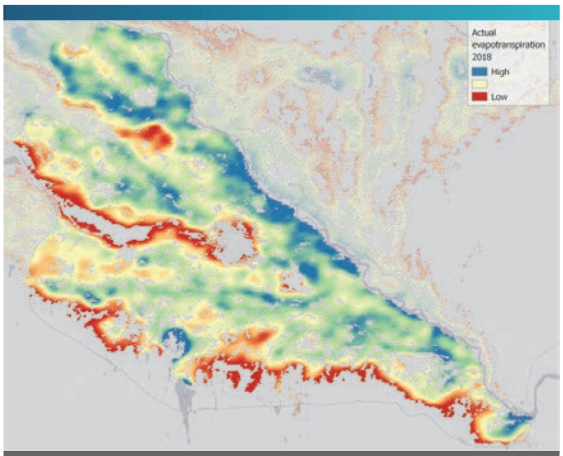
Crop yields. WUEMoCA uses a Light Use Efficiency (**LUE**) model for cotton, wheat, and rice that is well-known for accurate results. The model calculates daily **biomass** growth from the amount of energy that is used by the crop for photosynthesis. Input parameters are satellite data on vegetation condition (index: **EVI**) and meteorological data on radiation. Daily actual **evapotranspiration** values serve for the implementation of a crop specific water stress factor. The model also considers temperature stress.

Regional crop parameters reflect environmental variations (e.g. altitude and climate) of the Aral Sea Basin in the crop yield model. Crop growth stages are considered using the growing-degree-days approach. Harvest indices available in literature convert the end-of-season biomass to crop yields.

Cotton yield in Uzbekistan



Cotton yield from satellite and climate data analysis, aggregated to boundaries of Water User Associations in the Khorezm province, as shown in WUEMoCA



Actual evapotranspiration (water consumption) 2018 in Khorezm, modeled with S-SEBI

Modeling evapotranspiration. The simplified surface-energy-balance index (**S-SEBI**) allows for area-wide, daily estimations of potential actual evapotranspiration (ET) for all irrigation systems in the Aral Sea Basin. The algorithm is optimal for constant atmospheric conditions over the area and sufficient hydrological variability (moisture conditions).

The model solely operates on remote sensing and meteorological data. WUEMoCA utilizes MODIS satellite data, i.e. thermal information and data on reflection of solar radiation (albedo). Meteorological parameters include radiation, temperature, precipitation, relative humidity, and atmospheric transmissivity. The third input is the land use classifications (irrigated land, and crop specific areas). The difference between potential and actual ET indicates crop water stress in the crop yield model of WUEMoCA.

Statistics - Quality Management and Data Enhancement

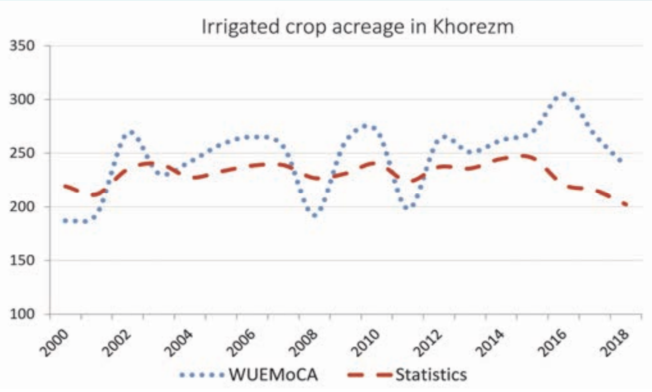
Comparison

To get information about the quality of the remote sensing results in WUEMoCA, a comparison with statistical information is intended. Two indicators were selected for validation:

Net irrigated area. "Area equipped with irrigation infrastructure" incl. fallow land, i.e. temporarily unused irrigable land; this indicator is (almost) constant over time.

Crop acreage. "Crop-specific area under irrigation", i.e. used for crop cultivation, not incl. fallow land. Areas used in both, winter and summer season, are counted twice; a dynamic indicator that shows annual fluctuations.

WUEMoCA shows remote sensing-based analysis results, here aggregated to province boundaries (from national sources).



Comparison of Irrigated crop acreage (in thous. ha) in Khorezm province from 2000 to 2018.

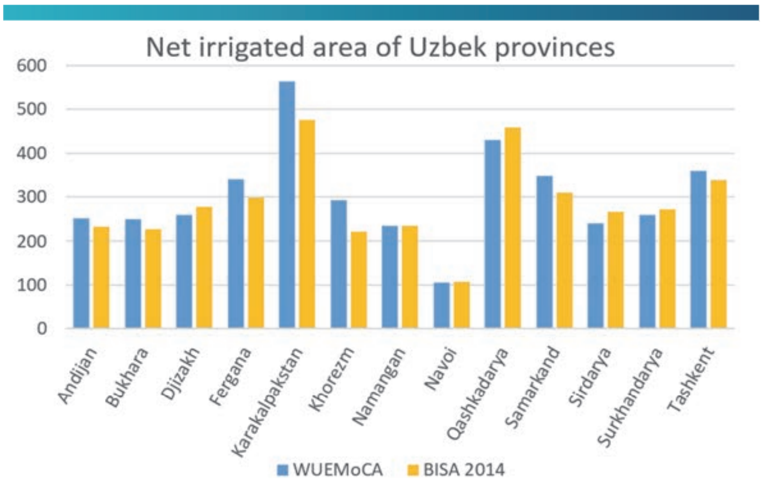
- ≈ *Remote sensing results (WUEMoCA)*
- ≈ *Official province statistics from State Committee of the Republic of Uzbekistan (Statistics)*

The comparison shows varying fluctuations of the land use intensity. These fluctuations are caused by changing annual shares of single used (e.g. cotton) and double used (e.g. wheat followed by rice) fields, and uncropped areas (fallow land).

Take advantage of both data sources!

The comparison of satellite information with official statistics can help to identify hot spots with noticeable deviations and inaccuracies. These are caused by methodical weaknesses and data gaps in both, remote sensing & manual data collection.

Possible improvements: High resolution satellite data and harmonized data collection can support to solve such discrepancies in future.



Comparison of the Net irrigated area (in thous. ha) in all Uzbek provinces

- ≈ *Remote sensing results (WUEMoCA)*
- ≈ *Official statistics from Basin Irrigation System Authority (BISA)*

The comparison shows some small over- and under-estimations.

Uncertainties Assessment

Both data sources, satellite information and official statistics, comprise numerous uncertainties:

WUEMoCA information is calculated from **MODIS** satellite images. For the large area of the Aral Sea Basin this is a very pragmatic mapping solution. But there are few possible sources of uncertainty, because the MODIS pixel size of about 6.25 ha does not depict the local field scale or cadastre information - it is **regional information**! In addition, **mix-up** of agriculture with wetlands or **misclassifications** of urban structures can cause distortion of **net irrigated area**. Also, spectral similarity of crops, e.g. rice and cotton, may result in confusion in **crop acreage** calculations.

Official statistics on the other hand, are based on not reviewable, qualitatively different **collection** methods of several data **providers** (national water organizations, farm reports, land cadastre, state committee, BISA/ISA data collections). Also **definitions**, such as "net irrigated area", are varying. This can impede the calculation of the indicators using official statistics and leads to inconsistencies in the official reporting system.

Further statistics are integrated directly into the indicator calculations of WUEMoCA:

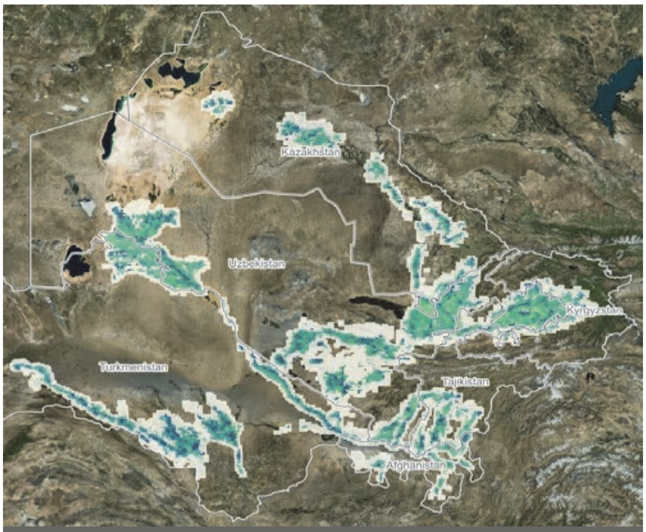
- ≈ Water data extend the indicator system significantly. (e.g. water productivity, irrigation efficiency)
- ≈ Crop distributions are used to extend the variety of second season crops, which are not detectable from space.

Example: Assessments of Water Use Efficiency in Uzbekistan

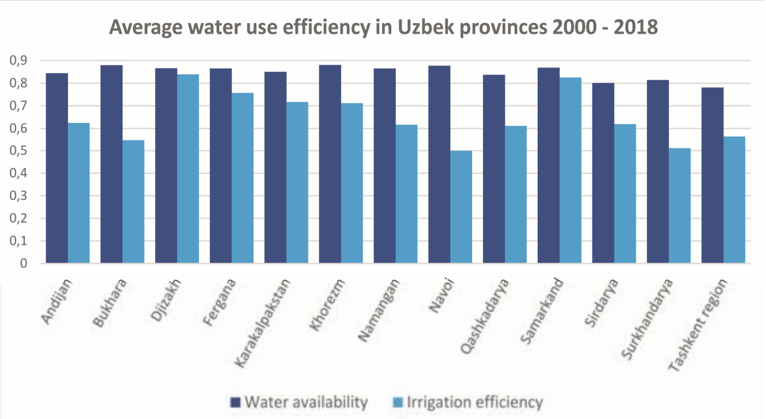
Avoid water losses. One of the tasks of water management is to optimize the performance of irrigation systems by avoiding water losses as much as possible. Two WUEMoCA indicators can be used to monitor the change of water use efficiency over time – even in line with the UN Sustainable Development Goals:

Water availability. "Index of appropriate water supply for crop cultivation". The ratio of water used for growing crops (actual evapotranspiration ET_{act}) to crop water requirements (ET_{crop}) indicates a deficit (< 1) or situations, in which more water is applied to plants than needed (> 1).

Irrigation efficiency. "Index of efficiency in delivering water to the plants and minimizing water losses". The ratio of the amount of water consumed (ET_{act}) to the amount of water delivered (statistical water intake) characterizes water losses.

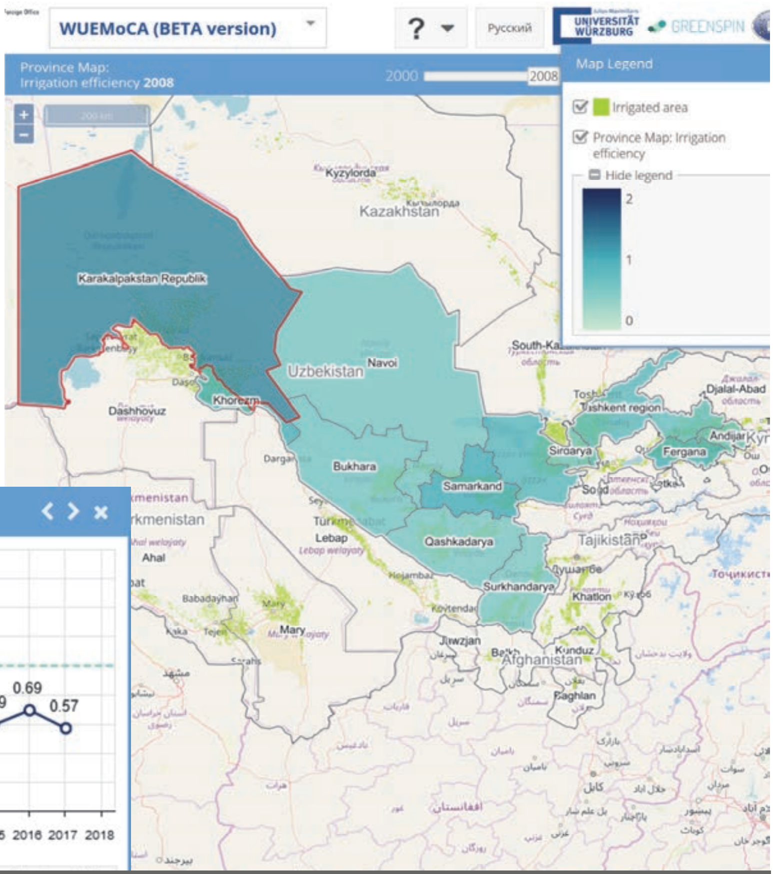


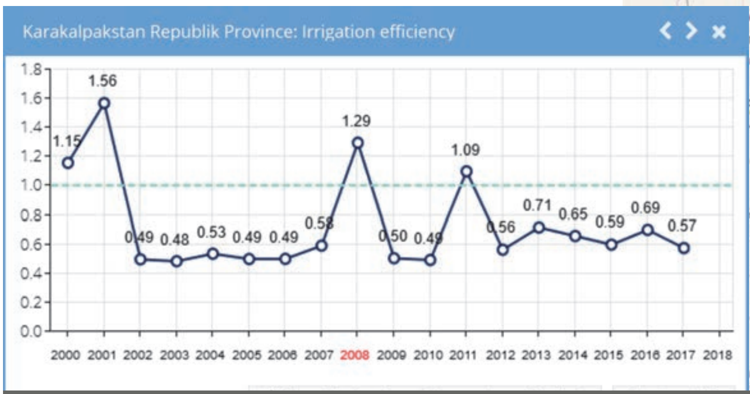
Water availability in the Aral Sea Basin, 2013
*Aggregated to 5km * 5km regular grids, as shown in WUEMoCA*



Water availability compared with irrigation efficiency. These two indicators are aggregated to the provinces of Uzbekistan and averaged over time. To achieve that, WUEMoCA province data is exported to a table calculation program such as Excel and being further analyzed.

Large differences highlight provinces with increased water losses.





Irrigation efficiency map of Uzbek provinces, as shown in WUEMoCA. The line chart shows the multi-annual development in Karakalpakstan. High irrigation efficiency values indicate dry years (e.g. 2001, 2008, 2011)

Further Examples
WUEMoCA Highlights

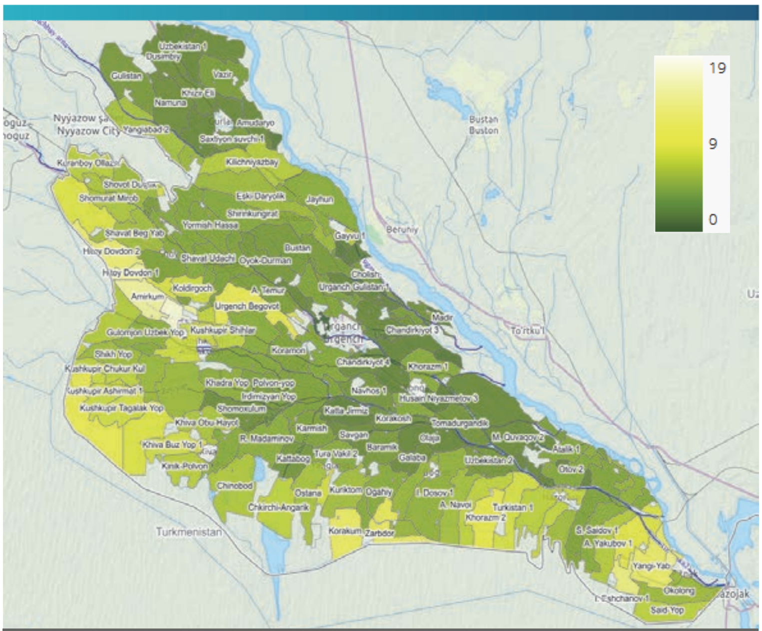
Example 1

Fallow Land Frequency

WUEMoCA allows to detect and analyze parts of the cropland in the large-scale irrigation systems of the Aral Sea Basin that show very irregular usage. Reasons can be manifold. Very likely are problems in water management, infrastructure, and consequences such as soil salinity or land abandonment. Especially downstream parts of the irrigation systems and areas far from main channels are affected.

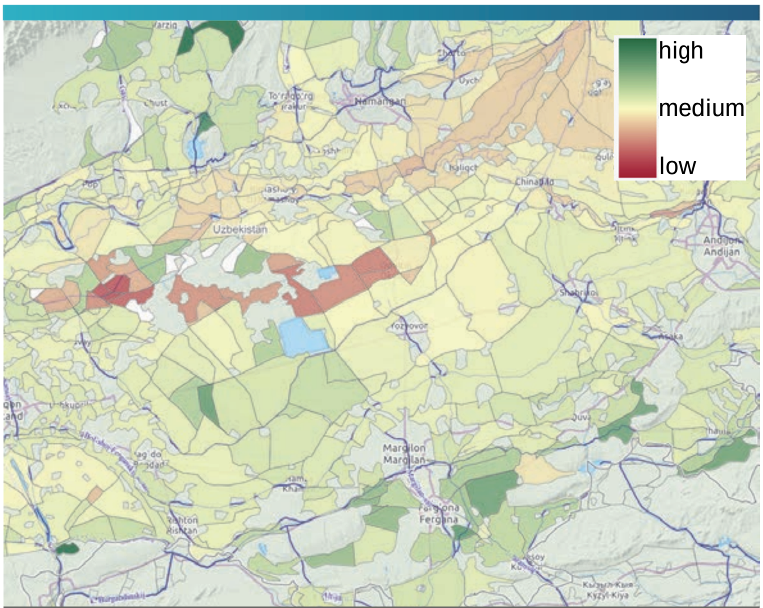
The indicator fallow land frequency is calculated as average number of years, in which net irrigated land was not cultivated within the WUEMoCA period of observation (2000 – 2018). The indicator is available for regular grids of 5km * 5km over the entire Aral Sea Basin and Water User Associations in two pilot areas (the map shows one pilot area – the Khorezm province).

Maps showing these multi-annual distributions can help to localize land that is at risk to be abandoned. Such identified areas might require investments in irrigation and drainage infrastructure, or the implementation of alternative land use options (e.g. agroforestry).



Example 1: Multi-annual fallow land frequency (number of unused years), aggregated to Water User Associations (WUAs) in the Khorezm province.

WUAs, which are supplied by main channels show a intensive land use. In contrast, WUAs far from river lay fallow in many years. WUEMoCA helps to identify these areas and potential reasons for unsustainable crop production.



Example 2: Water productivity of cotton (kg/m³) in the year 2008, aggregated to Channel command areas in the Fergana valley.

Red areas indicate low water productivity, green areas show high water productivity (“more crop per drop”) and higher sustainability of crop production with regard to the Aral Sea Basin.

Example 2

Water Productivity

is defined as the yield over the amount of total water applied. In WUEMoCA, water productivity is crop-specific harvest in kg/m³ of water consumed (measured in actual evapotranspiration). The WUEMoCA information can be translated into a contribution to the indicator „Change in water use efficiency over time” in the UN Sustainable Development Goal 6.

Water productivity information can be applied to assess and to compare the water use for crop production in different irrigation systems in the Aral Sea Basin. For instance, water managers can assess the success of crop production for their channel command areas, i.e. the result of water supply from different sources including groundwater and precipitation.

Maps showing different water productivity levels in irrigation can help to localize areas with need for action, e.g. for reducing risks of yield loss and for water saving.

Analyzing Own Data in WUEMoCA

The User Polygon Toolbox is a common development of German and Uzbek project partners to enhance the usability of WUEMoCA in the region of Central Asia and Afghanistan

What is the User Polygon Toolbox for?

- ≈ Fill data gaps with own boundaries and additional statistics
- ≈ Analyze sensitive (water) data without sharing to the public
- ≈ Monitor the irrigation performance within the ongoing season
- ≈ Do further analyses on the basis of detailed temporal results
- ≈ Propose future extensions such as new indicators, updated calculation formulas, additional parameters etc.

User Polygon Toolbox features

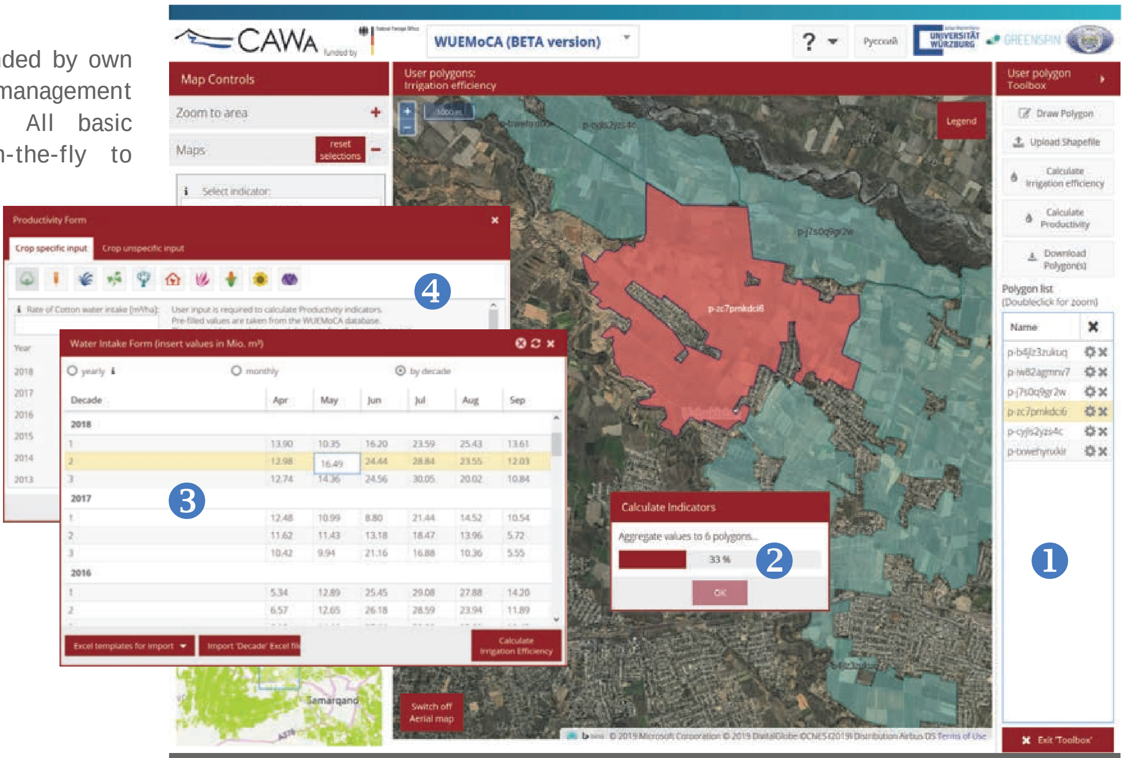
1. Polygon and Tool management panel
2. On-the-fly processing of all indicators for user polygons (= any area of interest)
3. Irrigation efficiency calculation tool (data input form for additional water statistics)
4. Productivity calculation tool (using additional statistics on crops, water, prices, and harvest)

Add own areas of interest

Firstly, WUEMoCA can be extended by own aggregation areas, e.g. water management or irrigation planning zones. All basic indicators are aggregated on-the-fly to these user-defined polygons.

Calculate additional indicators

Secondly, WUEMoCA can be extended by indicators of crop productivity and water use efficiency. For all available units in WUEMoCA as well as for any user-defined boundary, further indicators can be calculated by adding statistics that are valuable for the respective area.
All remote sensing based input parameters are adjustable where not plausible.



WUEMoCA with activated User Polygon Toolbox

Example 3

Irrigation efficiency

is expressed as the water consumption by crops (measured in actual evapotranspiration, ET_{act}) in relation to statistical irrigation water intake (added by the user).

In order to monitor the irrigation performance of any area of interest, users can enter water intake values even for decades of the ongoing season (by the input form ③). Decadal ET_{act} is available in the WUEMoCA database and is aggregated on-the-fly to the respective user polygon.

After the calculation, all input parameters and results can be downloaded as an Excel table. At the moment, only annual results are shown as diagrams within WUEMoCA.

	A	C	L	M	N	O	P	Q
1	name	year	etf_m4_1	vir_m4_1	wf_m4_1	etf_m4_2	vir_m4_2	wf_m4_2
2	Kattakurgan District	2000	26.852	1.03	9.14	31.416	1.05	10.51
3	Kattakurgan District	2001	26.56	1.11	8.38	24.86	0.91	9.64
4	Kattakurgan District	2002	28.269	0.68	14.52	25.454	0.54	16.7
5	Kattakurgan District	2003	28.419	0.7	14.31	19.868	0.42	16.46
6	Kattakurgan District	2004	22.887	0.53	15.28	39.814	0.8	17.58
7	Kattakurgan District	2005	34.328	0.8	15.12	37.653	0.76	17.4
8	Kattakurgan District	2006	28.502	0.74	13.45	35.629	0.81	15.47
9	Kattakurgan District	2007	33.673	0.81	14.56	35.137	0.74	16.76
10	Kattakurgan District	2008	22.549	0.75	10.53	31.09	0.9	12.12
11	Kattakurgan District	2009	22.382	0.54	14.53	27.105	0.57	16.72
12	Kattakurgan District	2010	27.782	0.67	14.55	34.105	0.72	16.73
13	Kattakurgan District	2011	27.887	0.88	11.12	30.584	0.84	12.8
14	Kattakurgan District	2012	33.333	0.67	17.43	40.71	0.71	20.05
15	Kattakurgan District	2013	36.909	0.95	13.7	36.391	0.81	15.81
16	Kattakurgan District	2014	27.973	0.79	12.48	32.794	0.99	11.62
17	Kattakurgan District	2015	30.222	0.76	13.9	33.288	0.9	12.98
18	Kattakurgan District	2016	22.181	1.46	5.34	32.621	1.75	6.57
19	Kattakurgan District	2017	30.362	0.86	12.48	40.966	1.24	11.62
20	Kattakurgan District	2018	31.812	0.83	13.9	30.028	0.84	12.98

Irrigation efficiency calculation downloaded as Excel table

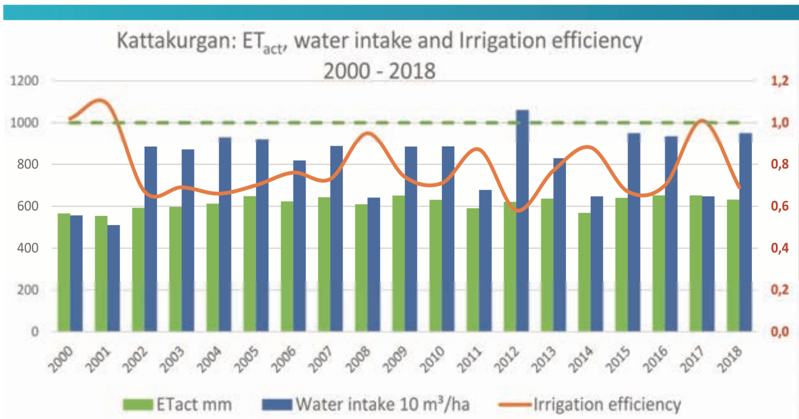
Export Data for Further Analysis and Integration into Other Tools

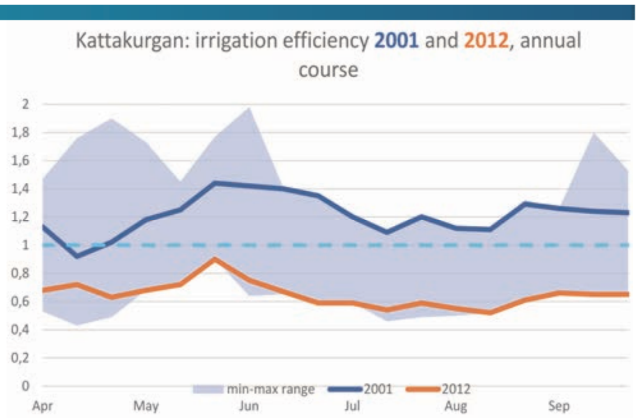
Exemplary irrigation efficiency analyses

Multi-annual and decadal irrigation efficiency data is analyzed for Kattakurgan district (Uzbek Samarkand province). The calculation results from WUEMoCA are exported and further prepared using Excel chart functions.

Future improvements

For more robust results, additional input parameters such as groundwater contribution and actual rainfall can be integrated into the calculation formula.

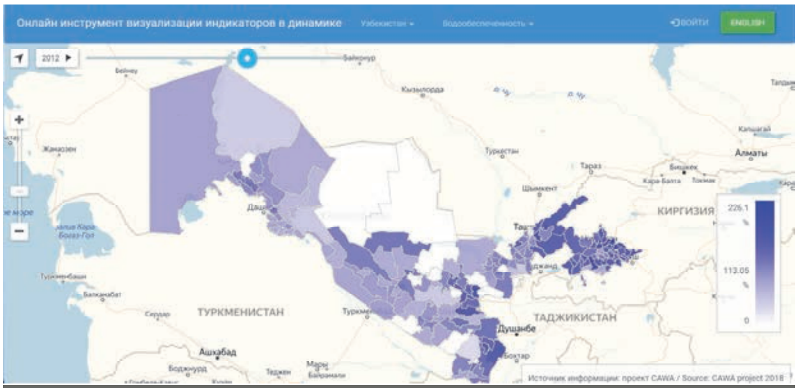




Left diagram: *Multi-annual representation of ET_{act}, water intake and the resulting Irrigation efficiency in Kattakurgan from 2000 to 2018. In drought years (e.g., 2001, 2008, 2017), low water intake increases the Irrigation efficiency.*

Right diagram: *Decadal development of Irrigation efficiency in the yearly course with overall min-max-range and a dry year in blue (2001) and a wet year in orange (2012) highlighted. Apparently droughts are associated with better use of limited resources.*

Data integration and Future Developments



Online-information tool by SIC-ICWC that uses WUEMoCA data.

Using WUEMoCA data for tools from the region

For additional interpretation of WUEMoCA indicators via maps, a simplified online tool (http://cawater-info.net/data), inspired by WUEMoCA, was developed by SIC-ICWC. This tool visualizes annual efficiency indicators on color graded maps, which are created by the underlying data range, and are aggregated to administrative district boundaries. This CaWaterInfo-tool utilizes WUEMoCA data as input for a refined calculation method.

Perspectives of Usage. WUEMoCA is developed at regional scale. High level water management organizations of all countries of the Aral Sea Basin (Central Asia and Afghanistan) can make use of it, i.e. compare the underlying data and calculations with own management systems. Data can be extracted and implemented in “own” tools.

From scientific perspective, WUEMoCA data and indicators can be implemented in models, e.g. the regional scenario model (ASBmm) provided by the Scientific Information Center - Interstate Coordination Water Commission (SIC-ICWC).

Solely open-source software was selected for the development of WUEMoCA. The code is freely available. Everybody can access it, e.g. research institutions and universities from the region. Motivated and talented students could further develop the use of remote sensing and web mapping technologies based on this open code. First insights can be gained at the CAWa summer schools that are given year by year at the German-Kazakh-University in Almaty (Kazakhstan).

Field Sampling Framework Workflow for Optimized Crop Mapping

WUEMoCA is a regional information system. At the local scale, no field information but objective approximations of the current crop distribution are possible.

Validation & local adjustments. To improve the quality of these approximations and for better operation of WUEMoCA at the local scale, a field sampling framework has been developed. It aims at the generation of field information for single agricultural parcels which in turn improves the WUEMoCA classifications and validate the results. It consists of three components:

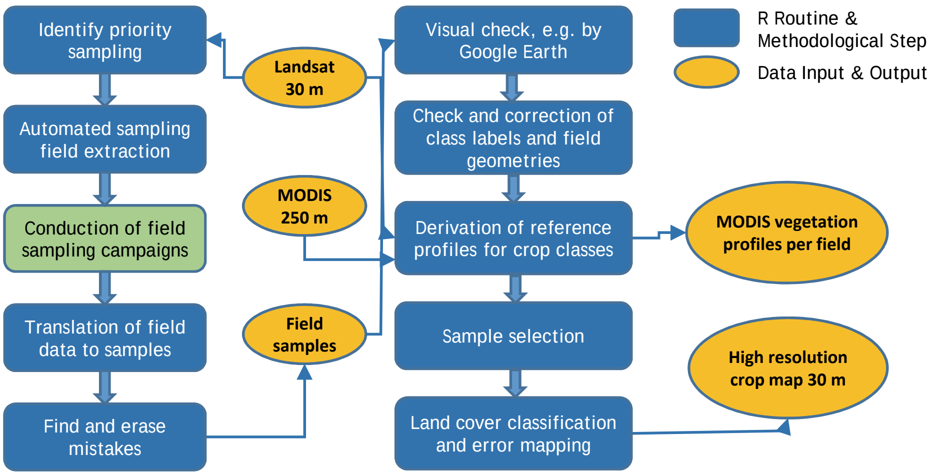
A Documented field sampling strategy
B Usage of Landsat 30m satellite data
C Digital analysis workflow based on open source R code

This sampling strategy is ready to use in all irrigation systems of the Aral Sea Basin and requires cooperation by the colleagues in the region.

Cooperation & Training. Field campaigns have been operated in Fergana Valley, in Khorezm, and in areas in Central Uzbekistan as well as in Southern Kazakhstan by CAWa partners for which technical trainings were conducted at the University of Würzburg, Germany.

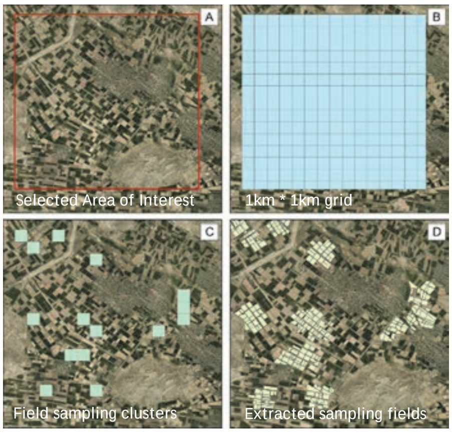
Call to collect and integrate local information in WUEMoCA using the new workflow!

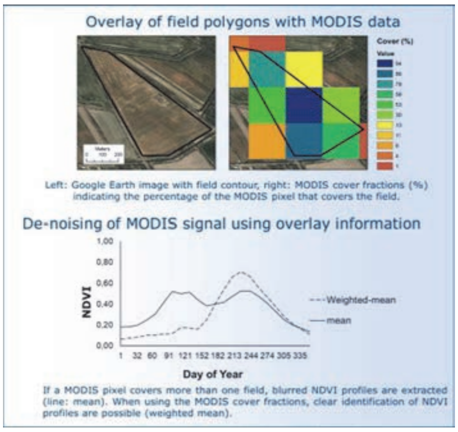
The proposed framework can be implemented in all irrigation systems of the Aral Sea Basin. You need a local university partner with basic GIS knowledge and practitioners from the region. Trainings can be provided.

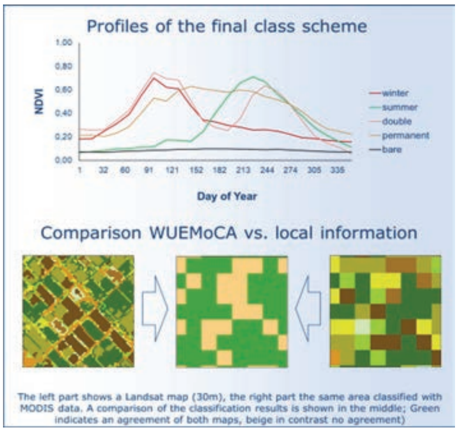


"fieldRS". This open source R-package has been developed to avoid mapping errors before and after **field data collection.** It is based on a Landsat pre-stratification of the study area, standardized mapping procedure and a series of geostatistical tools for checking samples and labels.

"CAWaR". Only homogenous information is useful as input information for the mapping routines in WUEMoCA. This R package integrates field data with Landsat and MODIS information to provide ideal NDVI profiles for classification and a high resolution map for validation.







Left: Selection of optimal field sampling clusters using the R library fieldRS. The clusters should be located in the vicinity of roads, and should suggest diverse sampling sites (online source: https://cran.r-project.org/web/packages/fieldRS).
Middle: De-noising of MODIS signal for the extraction of reference profiles (online source: https://cran.r-project.org/web/packages/CAWaR).
Right: Resulting high resolution crop maps provide validation information and help erasing errors from MODIS classification.

Irrigated fields - Photo by Jeff Vanuga, USDA

From Remote Sensing Data to Decision Support

Water scarcity in the Aral Sea Basin together with the persistent dependency from agricultural production as well as with the effects of population growth and climate change is supposed to imply future conflicts in all water use sectors. An efficient irrigation agriculture will essentially contribute to sustainable regional development. Optical satellite remote sensing data such as MODIS provides necessary information for monitoring irrigated cropland use on the regional, respectively landscape scale.

In this context, the WUEMoCA tool intends to provide agriculturally relevant, spatio-temporal geoinformation to support planning in the water resources management sector. Potential groups of end-users comprise policy makers and advisors from national governments but also regional and transboundary decision makers and specialists dealing with geoinformation technology and remote sensing based analysis for sustainable land and water resources management.

WUEMoCA - application fields

≈ A geoinformation tool for land and water experts to understand where river water flows to, to use water more efficiently and to save water

≈ Useful for political dialogue and public awareness in the fields of climate and environment, e.g.
  - ≈ assessing climate change risks and development of climate adaptation strategies and
  - ≈ environmental protections and rehabilitation

≈ A supporting tool for informed decision making and management support

≈ A system for the collection, analysis, and dissemination of environmental data for the entire Aral Sea Basin

Federal Foreign Office

CAWa

Imprint

WUEMoCA consortium:

- Department of Remote Sensing, University of Würzburg (Germany)
- Department of Geoecology, University of Halle-Wittenberg (Germany)
- green spin GmbH, Würzburg (Germany)
- Scientific Information Center - Interstate Coordination Water Commission of Central Asia (SIC-ICWC), Tashkent (Uzbekistan)

The WUEMoCA tool is a common development of

- Prof. Dr. Christopher Conrad, University of Halle-Wittenberg
- Prof. Dr. Viktor A. Dukhovny, SIC-ICWC Tashkent
- Gunther Schorcht, green spin GmbH, Würzburg

and their teams:

- Dr. Ikrom Ergashev, SIC-ICWC Tashkent
- Steven Hill, University of Würzburg
- Ronja Hünecke, University of Halle-Wittenberg
- Dr. Shavkat Kenjabaev, SIC-ICWC Tashkent
- Klara Kurbanova, SIC-ICWC Tashkent
- Dr. Markus Möller, University of Würzburg
- Lucia Morper-Busch, University of Würzburg
- Sherzod Muminov, SIC-ICWC Tashkent
- Dr. Maik Netzband, University of Würzburg
- Ruben Remelgado, University of Würzburg
- Islom Ruziev, SIC-ICWC Tashkent
- Dr. Sarah Schoenbrodt-Stitt, University of Würzburg
- Georgy F. Solodky, SIC-ICWC Tashkent
- Dr. Anatoly G. Sorokin, SIC-ICWC Tashkent
- Denis Sorokin, SIC-ICWC Tashkent
- Dr. Galina V. Stulina, SIC-ICWC Tashkent
- Rustam Toshpulatov, SIC-ICWC Tashkent
- Oygul Usmanova, SIC-ICWC Tashkent
- Sherzod Zaitov, SIC-ICWC Tashkent

This WUEMoCA Brochure was prepared by

Prof. Dr. Christopher Conrad, University of Halle-Wittenberg
Lucia Morper-Busch, University of Würzburg
Dr. Maik Netzband, University of Würzburg
Dr. Mike Teucher, University of Halle-Wittenberg
Dr. Sarah Schönbrodt-Stitt, University of Würzburg
Gunther Schorcht, green spin GmbH, Würzburg
Prof. Dr. Viktor Dukhovny, SIC-ICWC, Tashkent

This brochure is based on research conducted by the WUEMoCA consortium in the frame of the "Water in Central Asia" project (CAWa). The views expressed in this document are those of the authors and do not necessarily reflect the views of the governments.

Please cite this brochure as:
Conrad, C., Morper-Busch, L., Netzband, M., Teucher, M., Schoenbrodt-Stitt, S., Schorcht, G., Dukhovny, V., 2019. WUEMoCA – Water Use Efficiency Monitor in Central Asia: Informed Decision-Making in Land and Water Resources Management. Information Brochure of the CAWa project. 10.25972/OPUS-19193

You can find the WUEMoCA tool and information material in Russian and English languages at
http://wuemoca.net
http://wuemoca.geographie.uni-wuerzburg.de

Acknowledgements
The German Federal Foreign Office has provided support for the described project activities and the preparation of this brochure in the frame of the "German Water Initiative for Central Asia" (the so-called "Berlin Process").

Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

GFZ
Helmholtz Centre
POTSDAM

MARTIN-LUTHER
UNIVERSITÄT
HALLE-WITTENBERG

МКВК ICWC
KAZAKHSTAN KYRGHIZSTAN TADJIKISTAN TURKMENISTAN UZBEKISTAN

Federal Foreign Office

GREENSPIN