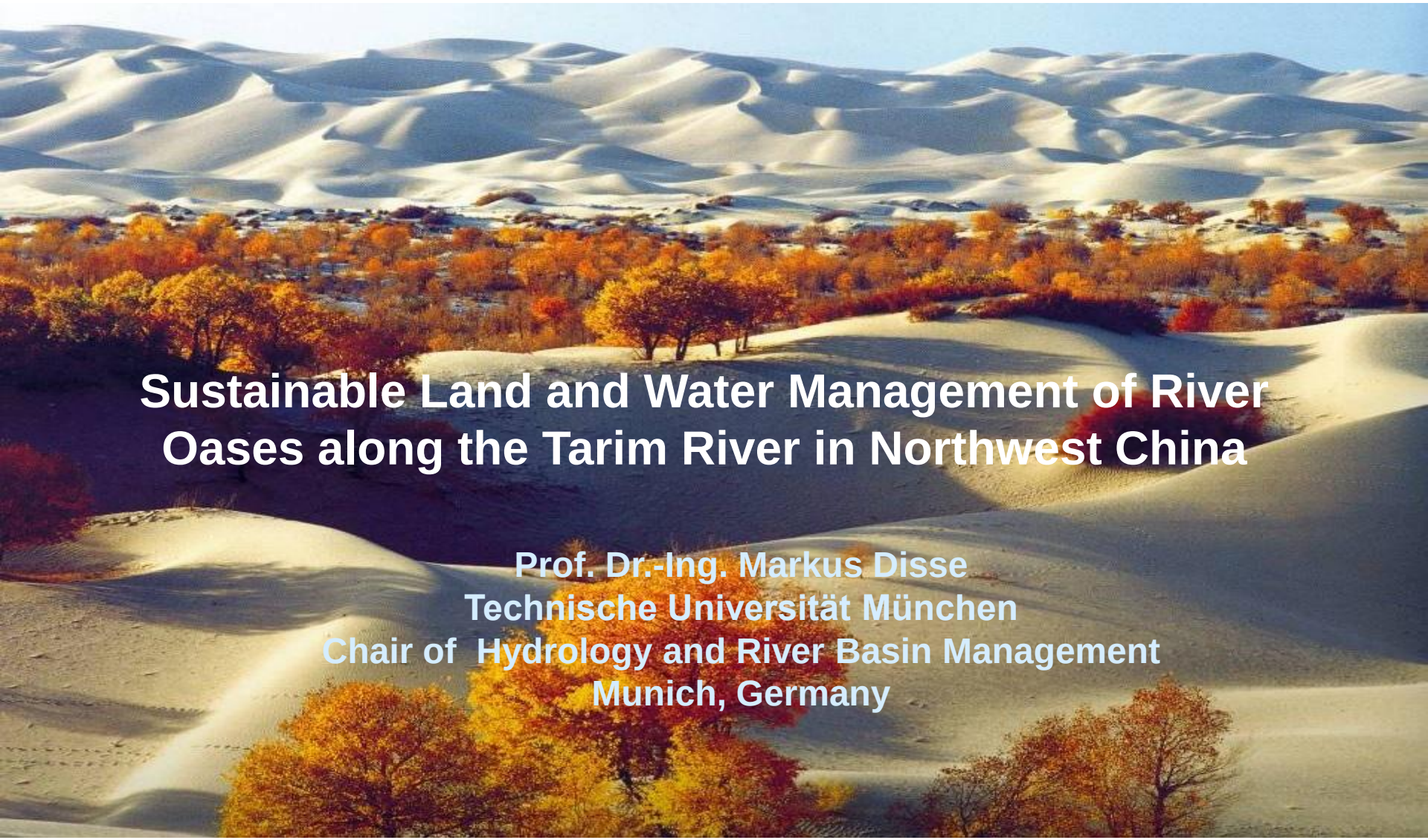


Sustainable Land and Water Management of River Oases along the Tarim River in Northwest China

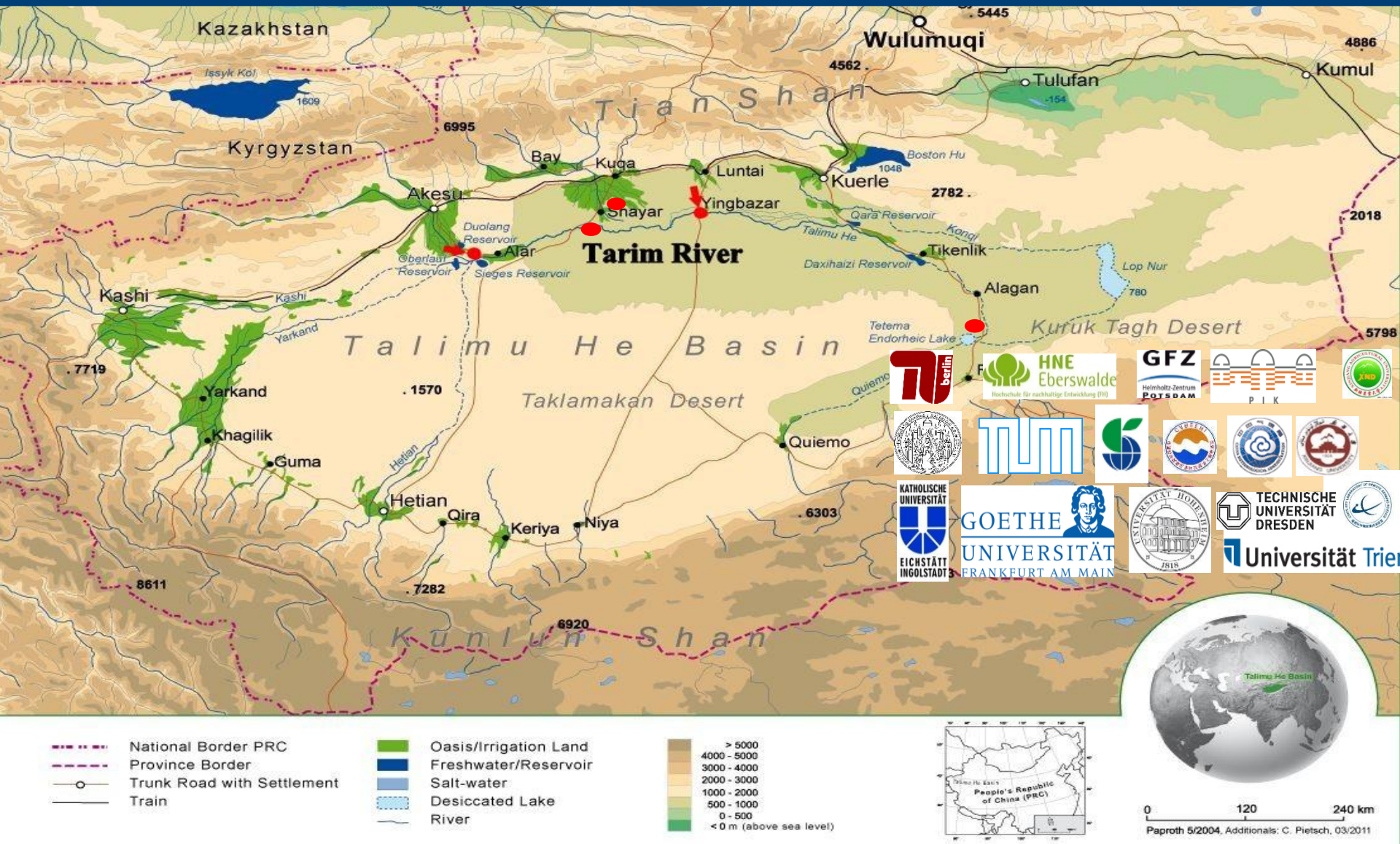
Prof. Dr.-Ing. Markus Disse
Technische Universität München
Chair of Hydrology and River Basin Management
Munich, Germany

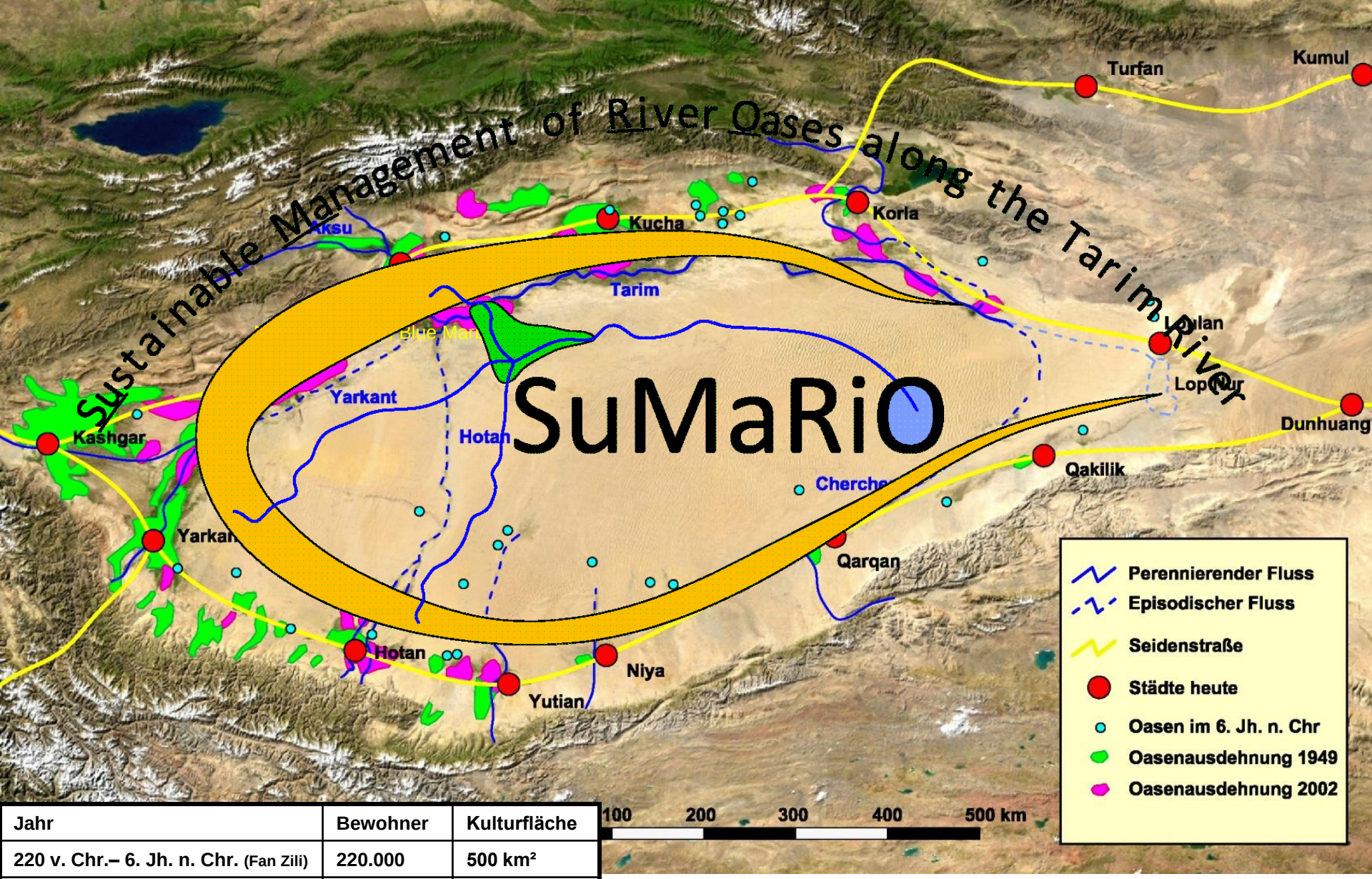
Sponsered by: Federal Ministry of Education and Research

markus.disse@tum.de

SuMaRiO Sustainable Management of River Oasis (Tarim River)

Research Area and Institutions





Jahr	Bewohner	Kulturfläche
220 v. Chr.– 6. Jh. n. Chr. (Fan Zili)	220.000	500 km²
1909 (Sven Hedin)	1.780.000	6020 km²
1949 (Fan Zili)	3.040.000	7060 km²
1980 (Niels Thevs)	6.090.000	13.300 km²
1990 (Fan Zili)	7.060.000	14.120 km²

The Sino-German project **SuMaRiO** is funded by the Federal Ministry of Education and Research in the Funding-Measure „Sustainable Land Management - GLUES“.

Funding objective:

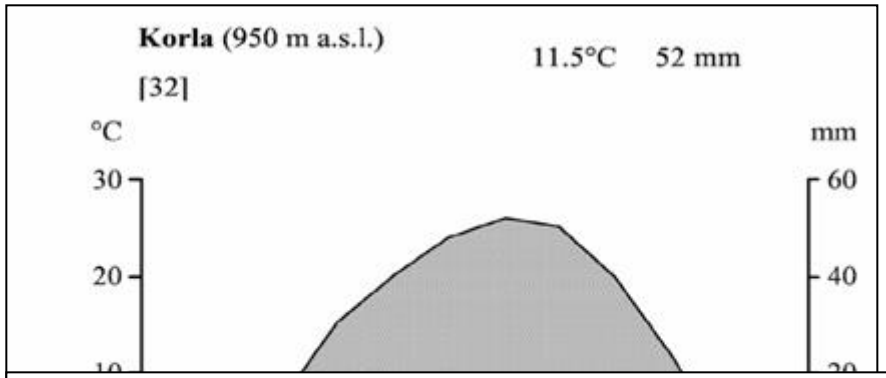
“All of the research projects work on an **inter- and transdisciplinary basis** in order to overcome barriers between disciplines, to include regional and local stakeholders and to **elaborate action-oriented concepts and strategies**.”

The project consortium comprises **eleven German** and **nine Chinese** Universities and Research Institutions and various **Chinese Stakeholders**

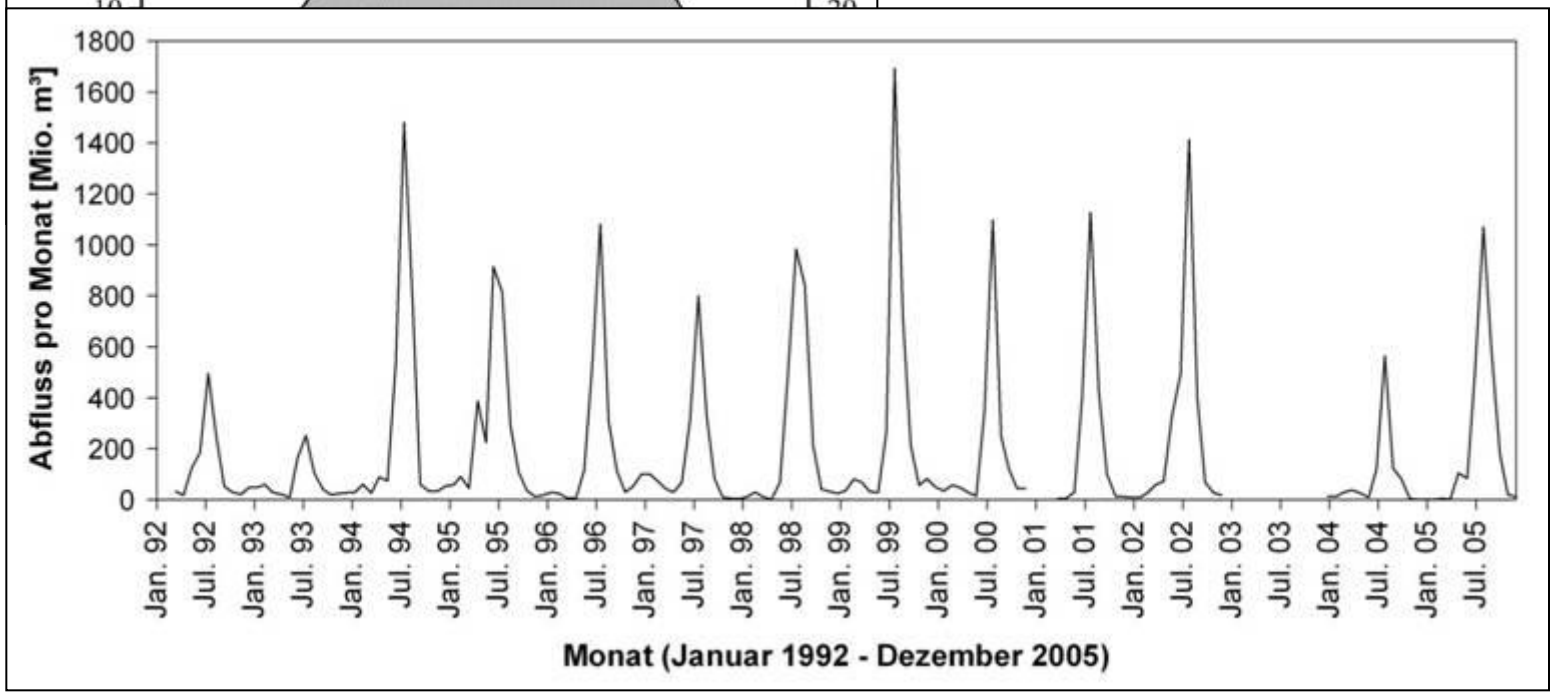
The SuMaRiO-project started in March **2011** and will end in February **2016**

Climate und Hydrology

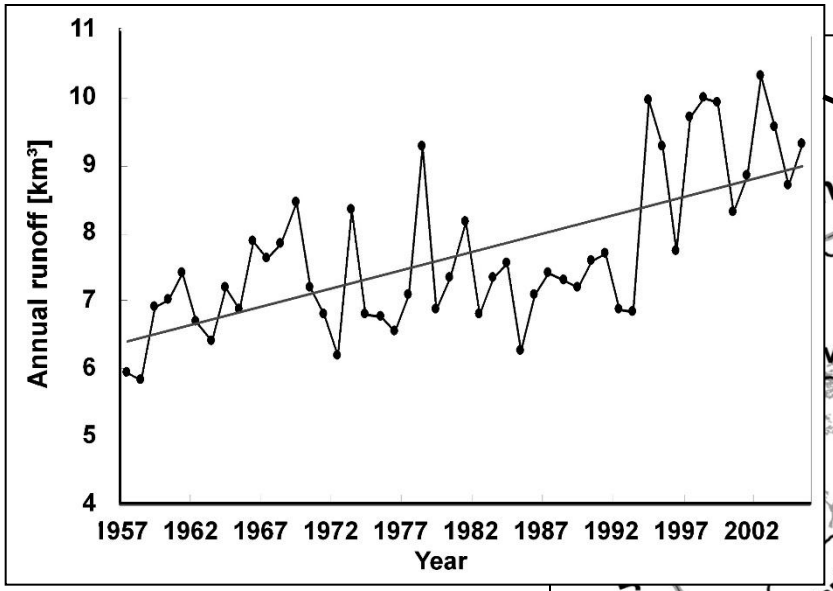
Extreme arid climate (P_{Year} = 50mm)



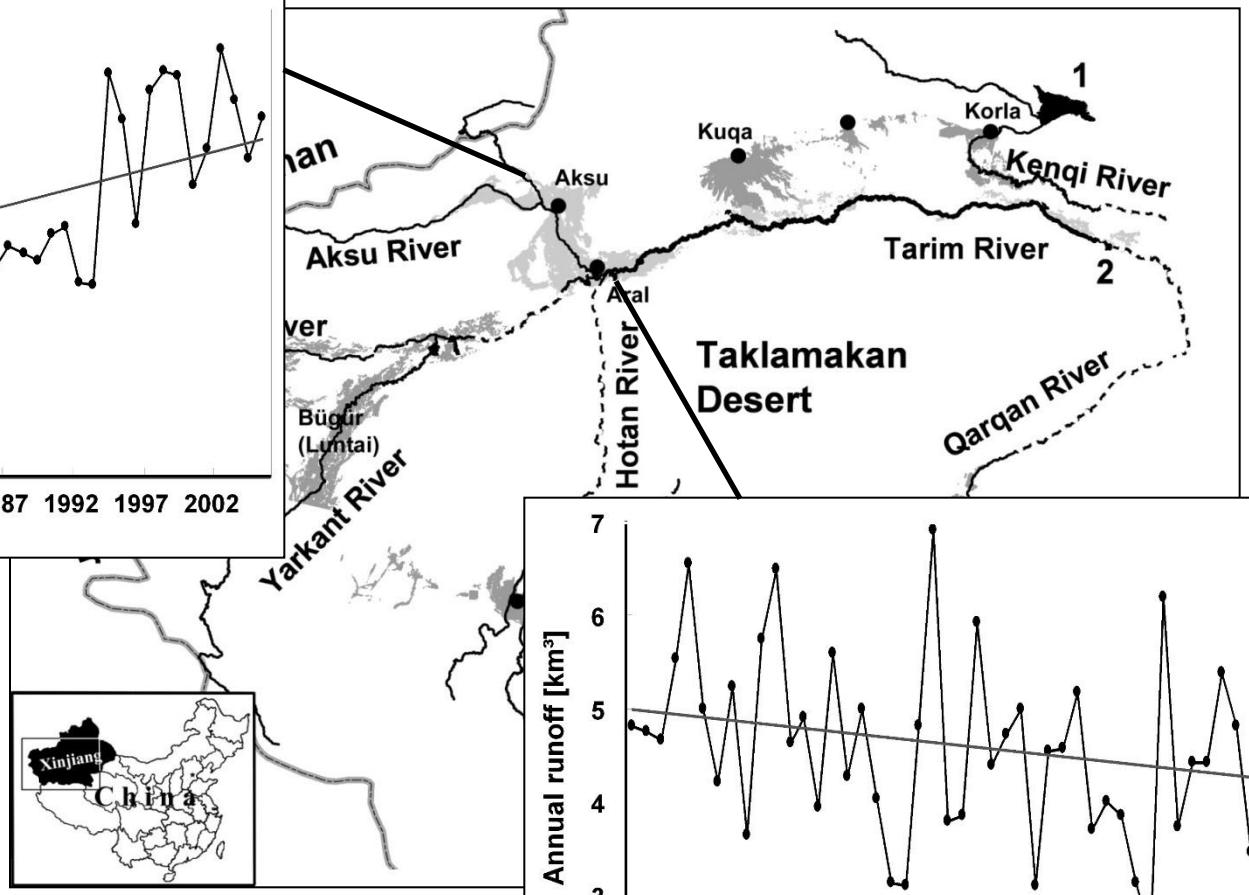
Only water resource:
River water that originates from the surrounding mountains



Gauge Yengi Bazar (Tarim Watershed Administration)



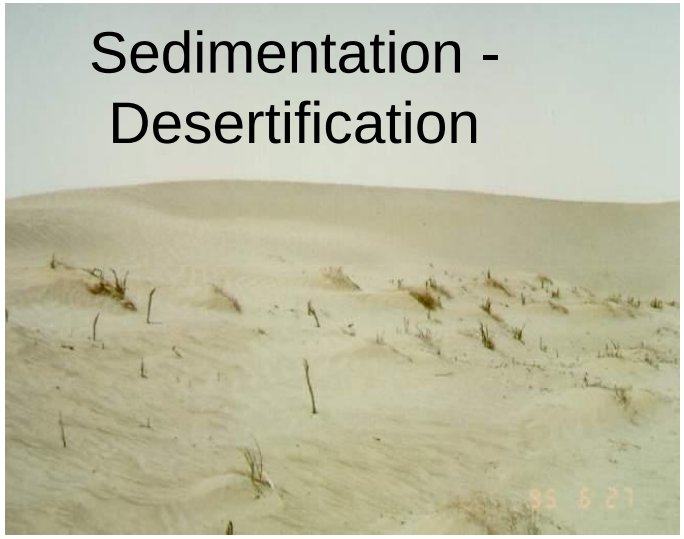
Annual runoff of Aksu River upstream of Aksu City



Annual runoff of Tarim River at Alar

Source: Tang, D. S.; Deng, M.J. (2010), On the Management of Water Rights in the Tarim River Basin, Beijing: Zhongguo Shili Shuidian Chubanshe

Ecological Consequences



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markus.disse@tum.de

Chinese Measures

- Upper reaches: water saving irrigation technologies
- Middle reaches: Channelizing of the Tarim River

  → Avoiding seepage losses

  → Decrease of evaporation

Overall goal of SuMaRiO　　SuMaRiO 的目标

- **To support sustainable oasis management along the Tarim River under conditions of climatic and social changes;**

  在气候变化和可能出现的社会变化的前提下支持对塔里木河河流绿洲的治理

- **To develop tools with Chinese partners that show the ecological and socio-economic consequences of their decisions in a changing world;**

  共同研发方法(德国合作伙伴同中国项目相关者一起)，以指出在变化了的世界，

  人们的行为所带来的生态的以及社会经济的后果

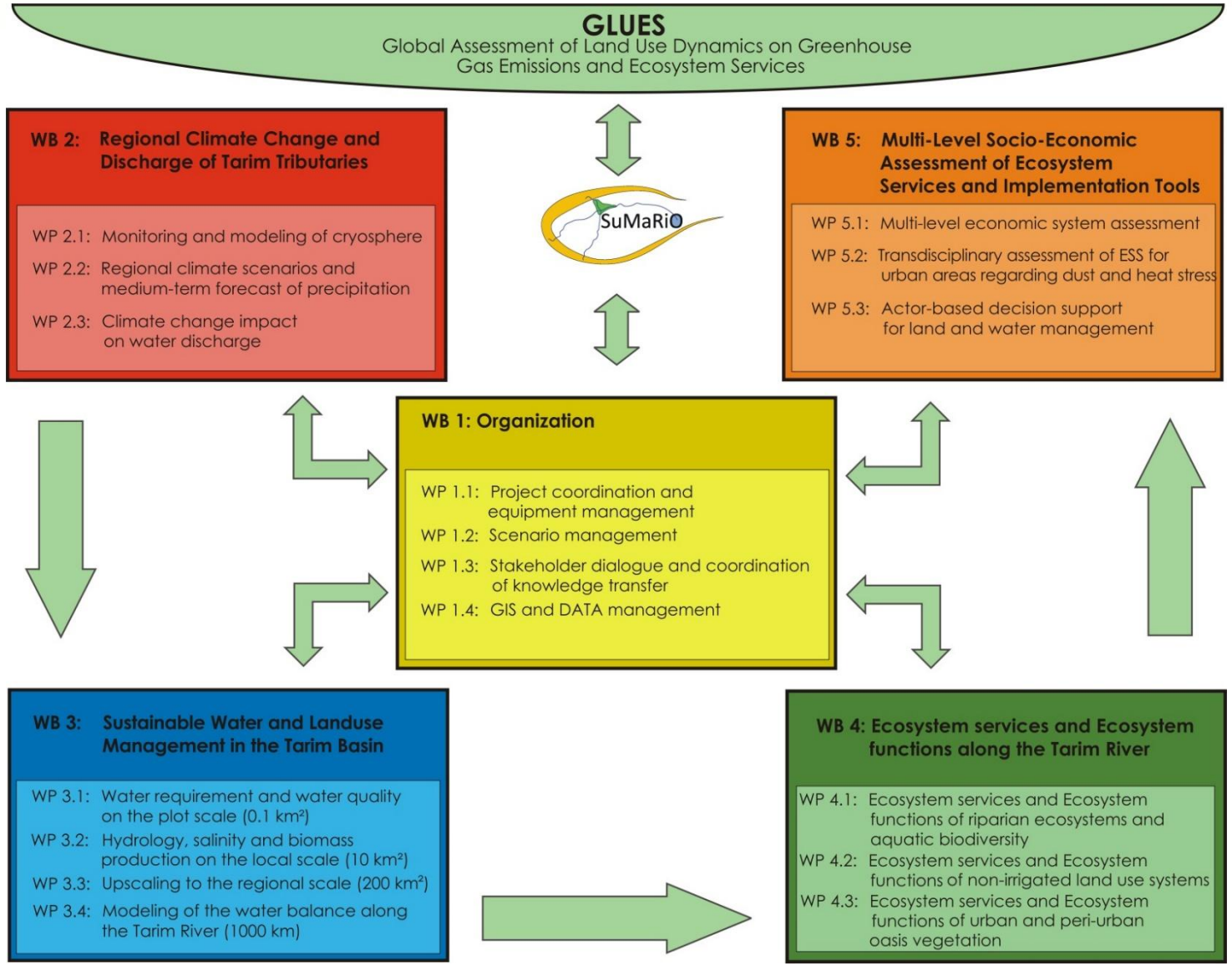
- **To identify options for optimizing economic, ecological, and social utilities;**

  共同确认并优化经济、生态和社会的可利用性。

- **To implement sustainable land management strategies.**

  实现可持续国土治理的战略

Project structure



Main Product: SuMaRiO DSS

GLUES
Global Assessment of Land Use Dynamics on Greenhouse Gas Emissions and Ecosystem Services

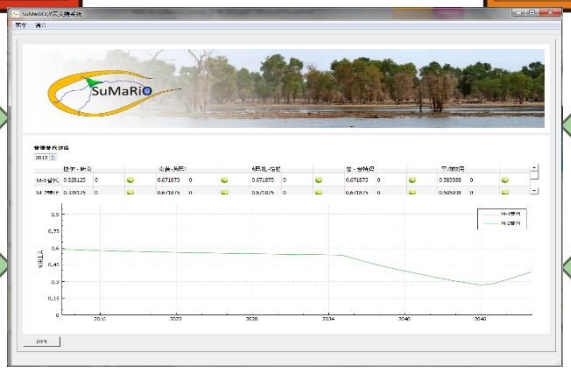
WB 2: Regional Climate Change and Discharge of Tarim Tributaries

- WP 2.1: Monitoring and modeling of cryosphere
- WP 2.2: Regional climate scenarios and medium-term forecast of precipitation
- WP 2.3: Climate change impact on water discharge

SuMaRiO

WB 5: Multi-Level Socio-Economic Assessment of Ecosystem Services and Implementation Tools

- WP 5.1: Multi-level economic system assessment
- WP 5.2: Transdisciplinary assessment of ESS for urban areas regarding dust and heat stress
- WP 5.3: Actor-based decision support for land and water management



WB 3: Sustainable Water and Landuse Management in the Tarim Basin

- WP 3.1: Water requirement and water quality on the plot scale (0.1 km²)
- WP 3.2: Hydrology, salinity and biomass production on the local scale (10 km²)
- WP 3.3: Upscaling to the regional scale (200 km²)
- WP 3.4: Modeling of the water balance along the Tarim River (1000 km)

WB 4: Ecosystem services and Ecosystem functions along the Tarim River

- WP 4.1: Ecosystem services and Ecosystem functions of riparian ecosystems and aquatic biodiversity
- WP 4.2: Ecosystem services and Ecosystem functions of non-irrigated land use systems
- WP 4.3: Ecosystem services and Ecosystem functions of urban and peri-urban oasis vegetation

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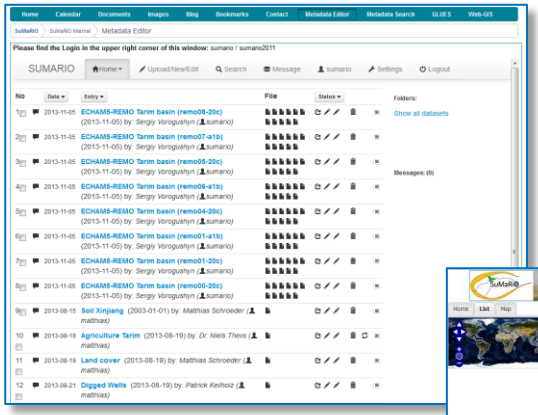
markus.disse@tum.de

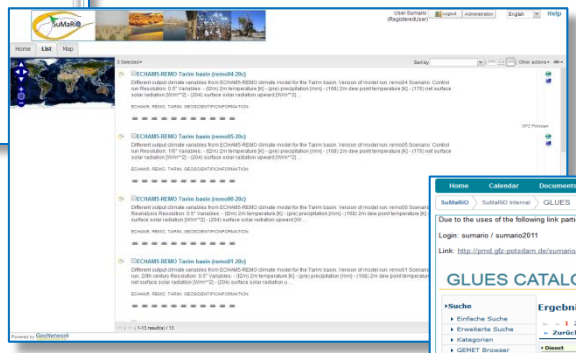
SuMaRiO Web-Applications

Metadata editor via panMetaDocs



Web-GIS solution

Metadata Search (GeoNetwork)



Metadata search via GLUES

WB 1: Organization

- WP 1.1: Project coordination and equipment management
- WP 1.2: Scenario management
- WP 1.3: Stakeholder dialogue and coordination of knowledge transfer
- WP 1.4: GIS and DATA management

Matthias Schroeder, GFZ

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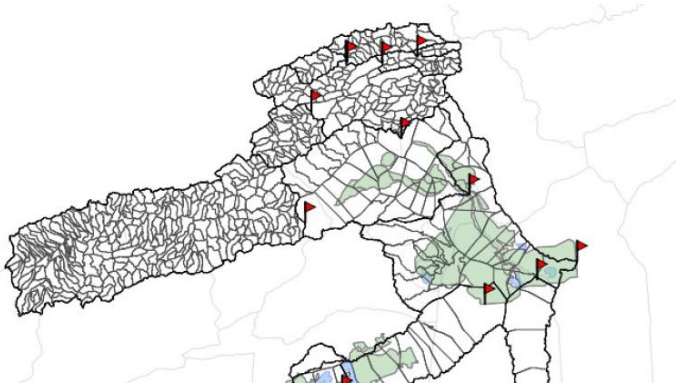
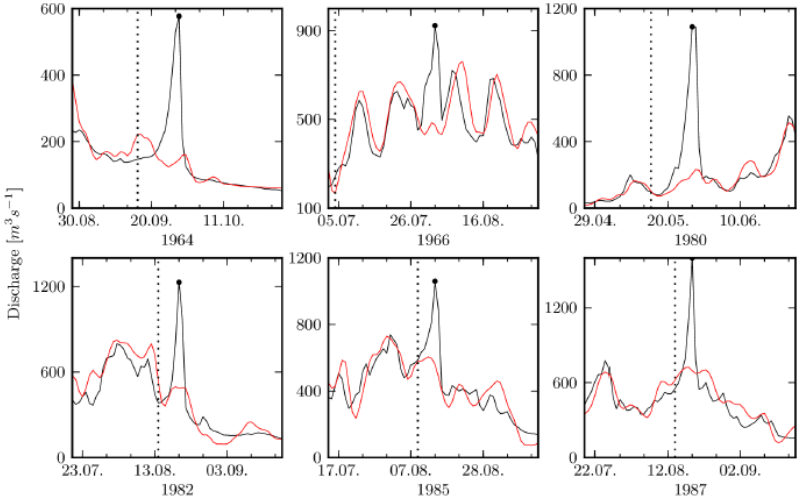
WB 2: Regional Climate Change and Discharge of Tarim Tributaries
WP 2.1: Monitoring and modeling of cryosphere
WP 2.2: Regional climate scenarios and medium-term forecast of precipitation
WP 2.3: Climate change impact on water discharge
M.W. Aug 2012

The upper Tarim SWIM model

- Catchment and model domain terminate at Arla station (S11), the 'interface' to the main stream Tarim
- Drainage area excluding desert depression and Kashgar R.: ca.184'567km^2
- 6 headwaters, 4 separate oasis zones with downstream stations (upper/lower Aksu, Hotan, Yarkant)
- Catchment divided into 1489 subbasins (river sectors in the desert)
- Unique combinations of subbasins, landuse, soils and elevation zones form 109'969 hydrotopes



Unrepresented summer peaks (GLOFs)



(Wortmann et al., 2013; Glazirin, 2010)

Michel Wortmann et al. 2013 07/12/13 Page 16

Michel Wortmann, PIK

Characterization of the soils in the region

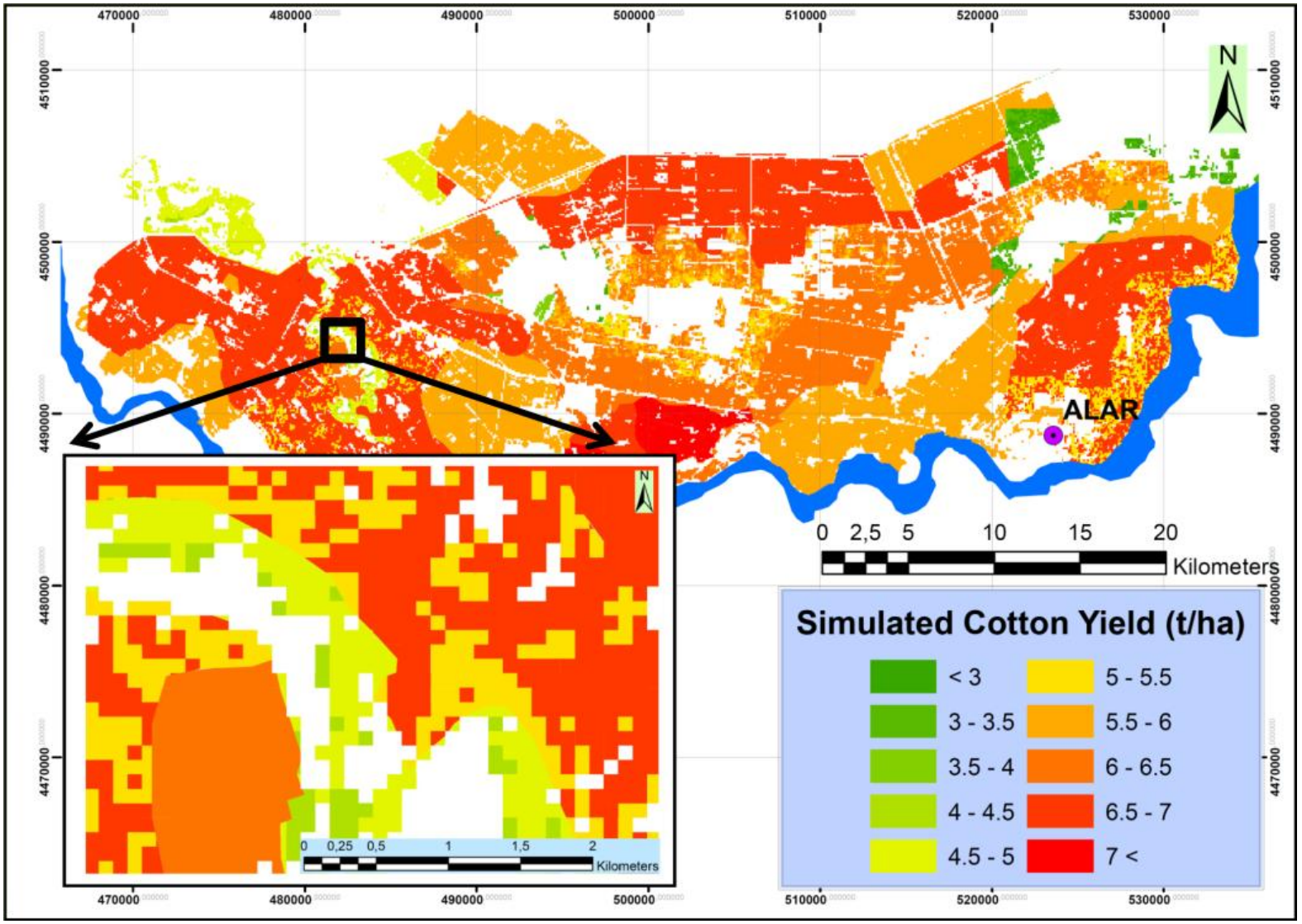
- In situ description according to FAO guidelines (2006)
- Assessment & analysis of the chemical and physical soil properties

WB 3: Sustainable Water and Landuse Management in the Tarim Basin

- WP 3.1: Water requirement and water quality on the plot scale (0.1 km²)
- WP 3.2: Hydrology, salinity and biomass production on the local scale (10 km²)
- WP 3.3: Upscaling to the regional scale (200 km²)
- WP 3.4: Modeling of the water balance along the Tarim River (1000 km)

Karl Stahr, Univ. Hohenheim

Cotton yield estimation using EPIC model



Karl Stahr, Univ. Hohen-heim

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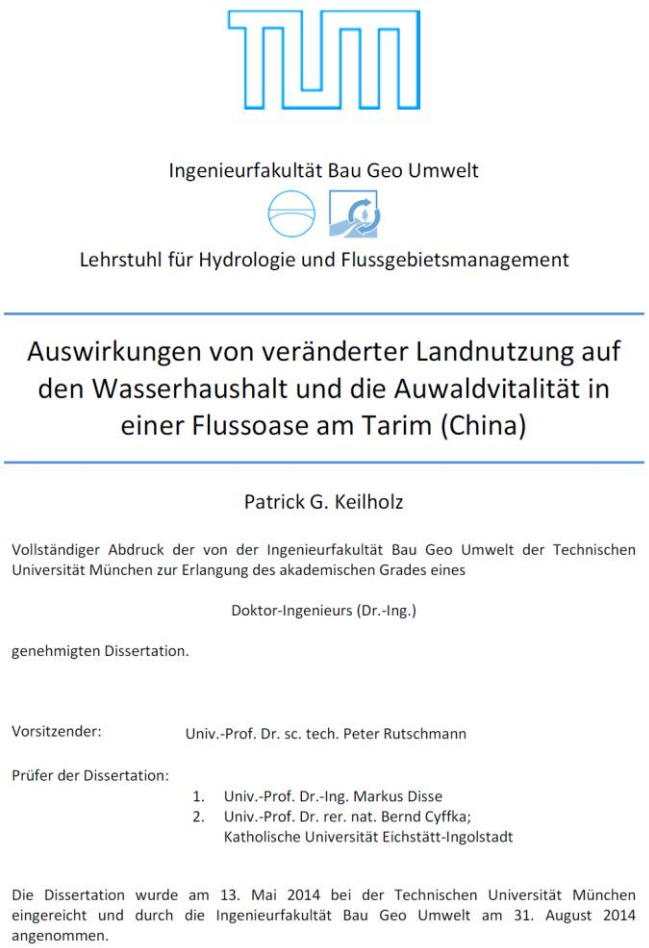
Spatial distributed modeling of groundwater recharge and impact of land use and climate change at Yengibazar (Tarim River middle reach)



Ingenieurfakultät Bau Geo Umwelt

Lehrstuhl für Hydrologie und Flussgebietsmanagement

Auswirkungen von veränderter Landnutzung auf den Wasserhaushalt und die Auwaldvitalität in einer Flussoase am Tarim (China)

Patrick G. Keilholz

Vollständiger Abdruck der von der Ingenieurfakultät Bau Geo Umwelt der Technischen Universität München zur Erlangung des akademischen Grades eines

Doktor-Ingenieurs (Dr.-Ing.)

genehmigten Dissertation.

Vorsitzender: Univ.-Prof. Dr. sc. tech. Peter Rutschmann

Prüfer der Dissertation:

1. Univ.-Prof. Dr.-Ing. Markus Disse
2. Univ.-Prof. Dr. rer. nat. Bernd Cyffka; Katholische Universität Eichstätt-Ingolstadt

Die Dissertation wurde am 13. Mai 2014 bei der Technischen Universität München eingereicht und durch die Ingenieurfakultät Bau Geo Umwelt am 31. August 2014 angenommen.

Dissertation of Patrick Keilholz, TUM (in German)

Download:
http://www.hydrologie.bgu.tum.de/index.php?id=88

Research questions

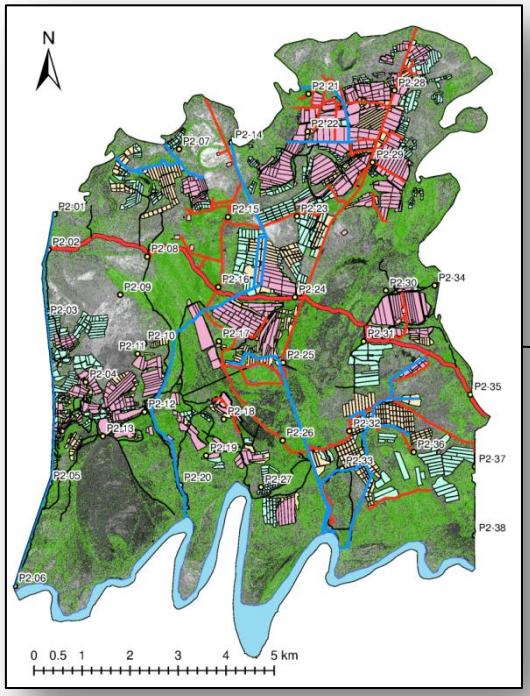
- **Groundwater recharge**
  Is it possible to quantify different water sources (floodplains, irrigation areas and Tarim River leakage) which contribute to groundwater recharge?

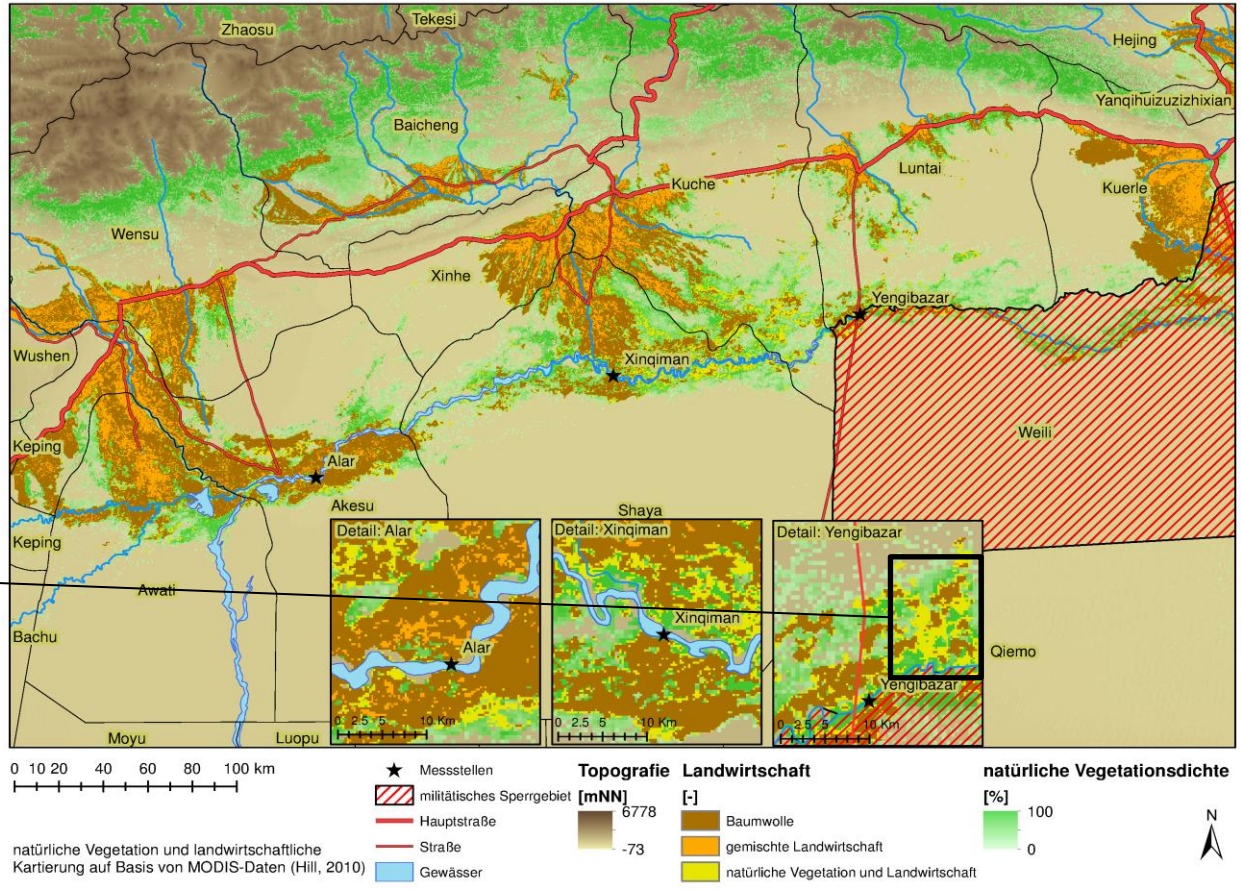
- **Influence of irrigation areas to the Tugai-vegetation**
  How do the irrigation areas effect the adjacent natural vegetation?

- **Climate and land use changes**
  What is the impact of land use and climate change to agriculture and natural vegetation?

Research Area

- Natural floodplains with direct connection to Tarim-River
- Changing patterns of agriculture and natural vegetation
- Tarim-gauging station





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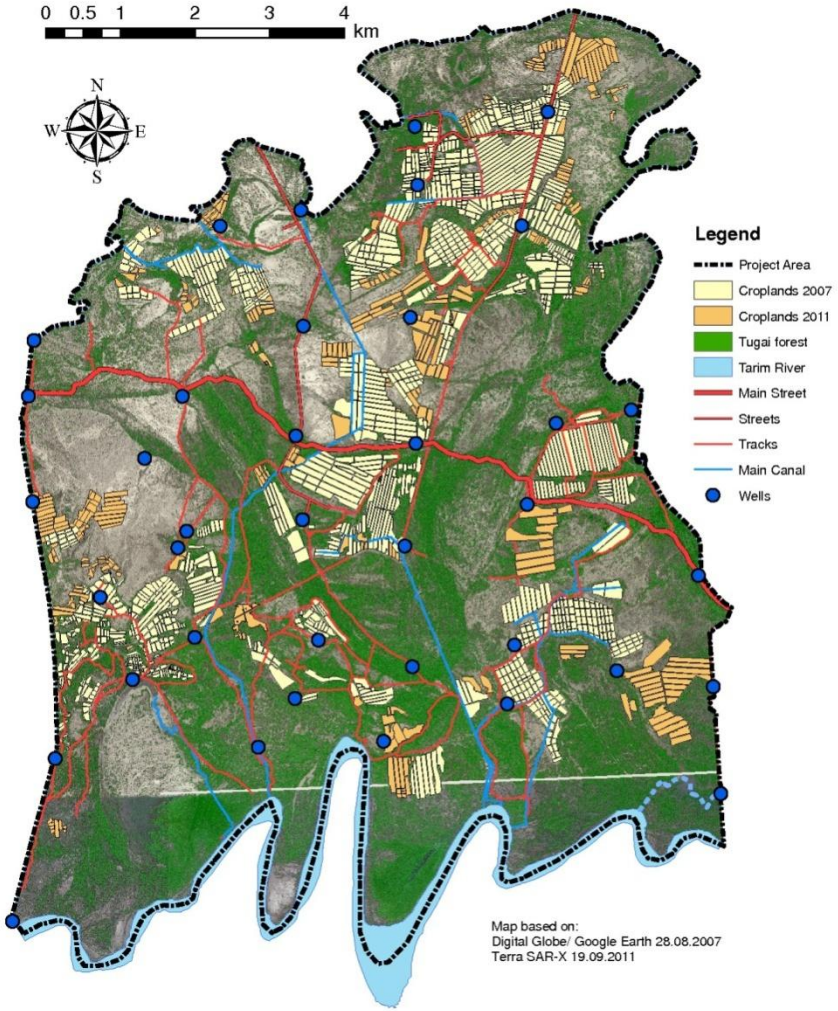
markus.disse@tum.de

Project Area Yengibazar



- area (80 km²) located in the Tarim Populus Euphratica National Forest Park
- land use systems:
  - agriculture
  - natural Tugai-forests
  - desert vegetation
- large natural floodplains
- dramatic land use change (cotton fields)

YEARS	AREA (km²)	EVOLUTION (%)
2004	11.1651	
2007	14.3025	28.10%
2011	19.4219	73.95%
2012	21.2190	90.05%
2013	25.4196	127.67%

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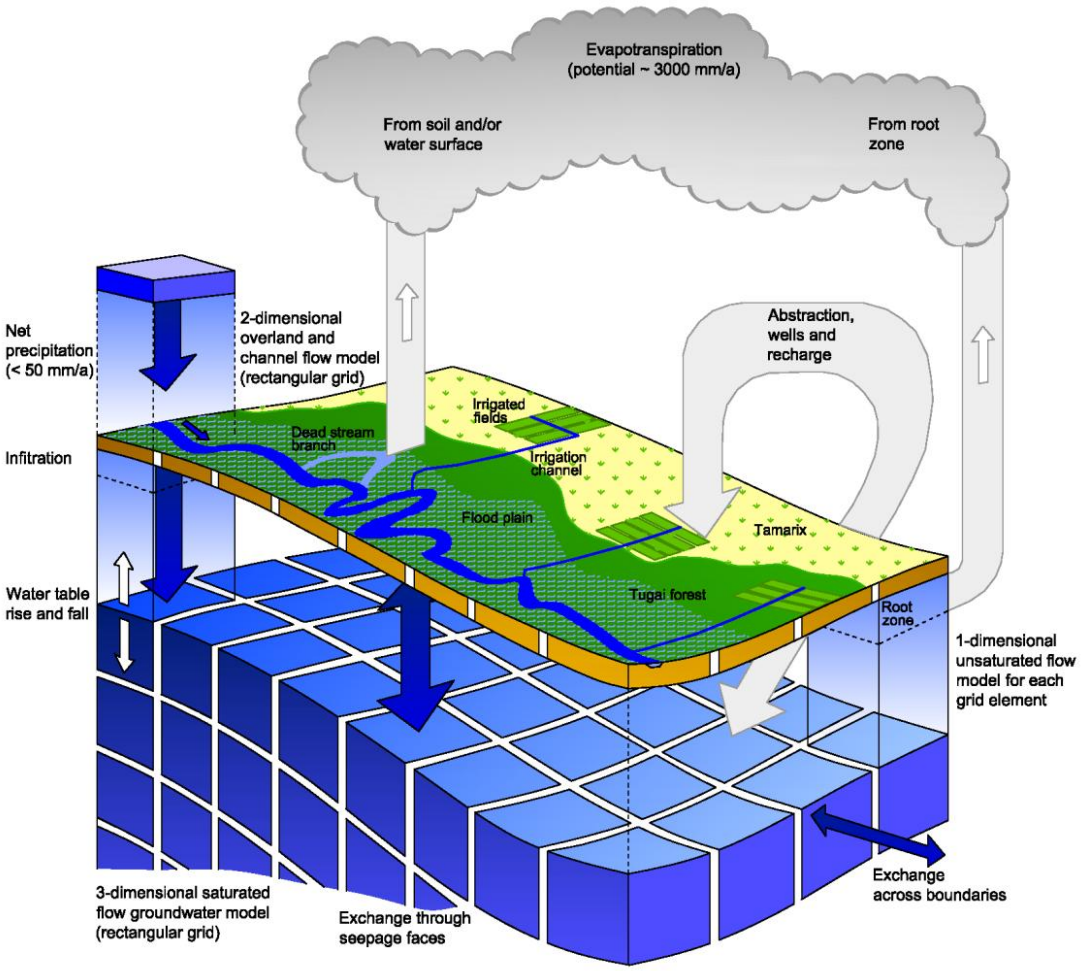
Model to calculate the hydrological processes

- 2-dimensional surface runoff
- Irrigation management
- Evapotranspiration
- Unsaturated and saturated soil water processes

Hydrological models

Hydrologischer Prozess		Hydro-Geosphere	MIKE SHE
Oberflächenabfluss	1D-Gewässernetz 2D-Diffusionswelle 2D-Kinematische Welle	2D X -	MIKE 11 X -
Evapotranspiration	Penman-Monteith andere Ansätze	X X	Input
ungesättigte Bodenzone	Richards-Gleichung	3D	1D
Bewässerung		-	X
gesättigte Bodenzone	finite Elemente finite Differenzen	3D	3D

*basierend auf der Richards-Gleichung durch angenäherte Funktion



Choise: MIKE SHE

- Modelling 2d-surface water (diffusive wave)
- Irrigation module

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Required input data

Data set	Remote sensing	Measurements in research area
Digital elevation model (DEM)	World View 1 & 2 DigitalGlobe 8 x 8 m	In field correction points
Groundwater level		38 groundwater gauging stations with data logger (Temperature, Water level and electric conductivity)
Tarim discharge		Gauging station Yengibazar (1992-2005) and own measurements since Dec. 2011
Floodplains	TerraSAR-X Spot Mode 1x1 m	11 data logger in the floodplains
River cross sections	World View 1 Satellite image	Photogrammetric images
Soil model		38 drilling cores until the saturated zone
Climate data	Precipitation: TRMM	Climate station Yengibazar (Jun. – Nov. 2012) Climate station Kucha
Natural vegetation	- Satellite image World View 1 (NDVI/EVI) - MODIS LAI	Mapping in field
Irrigation		Interviews with farmers

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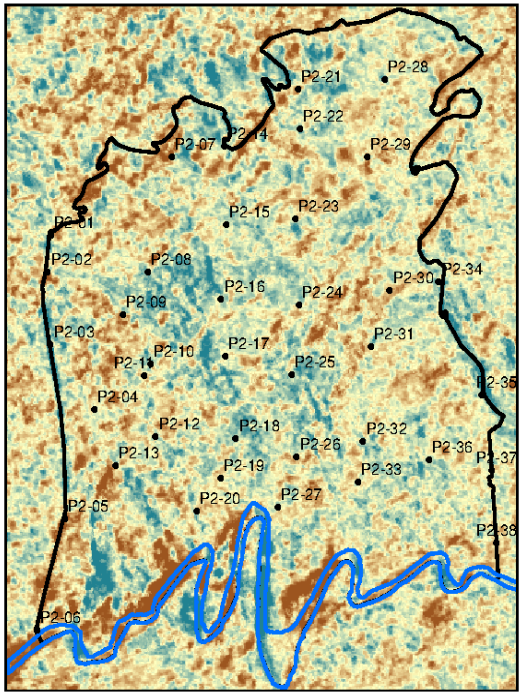
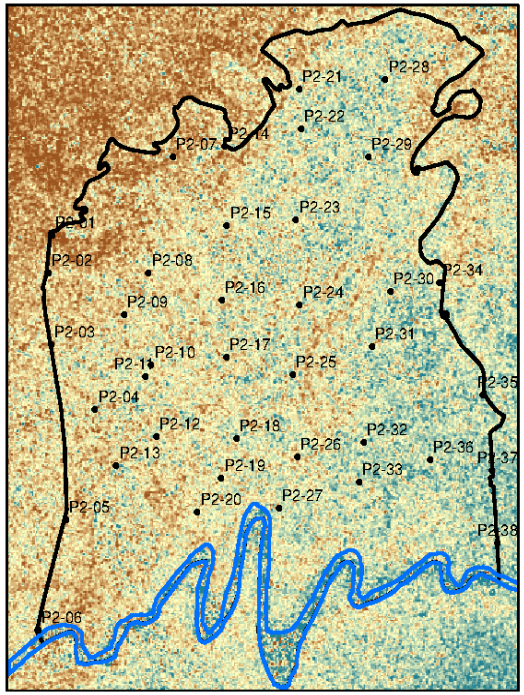
Digital elevation model

ASTER



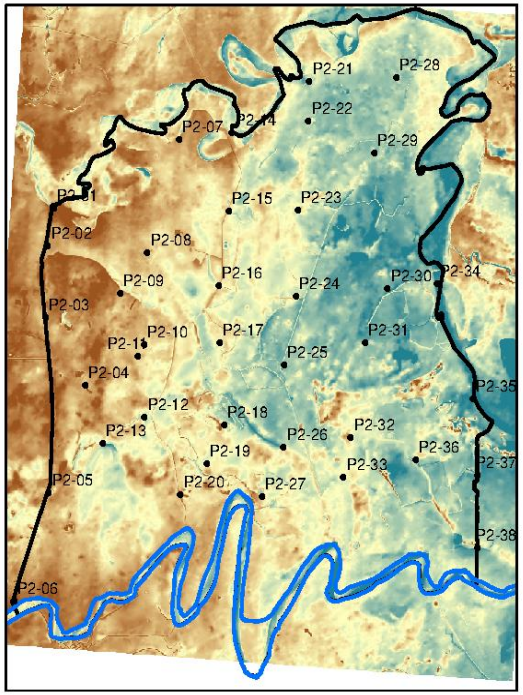
cell size: 30 x 30 m

SRTM-1



cell size: 26 x 26 m

Digital Globe



cell size: 8 x 8 m

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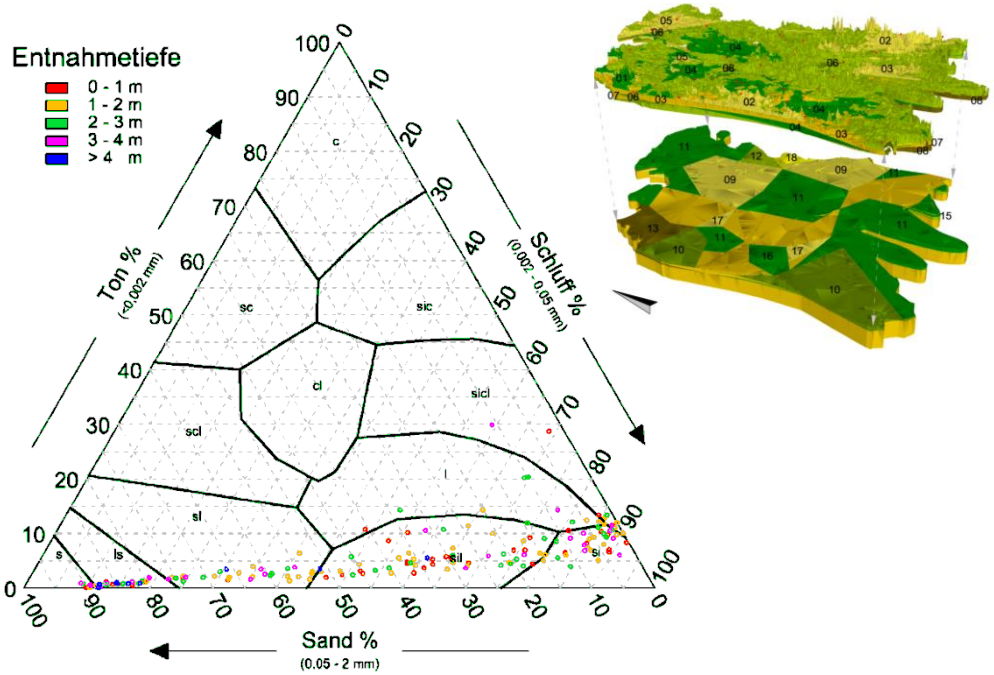
Groundwater levels & digital soil model



Drilling of 38 gauging stations with automatic data loggers

Analyzing 38 drilling cores with overall 172 soil samples

- Grain size
- Organic content
- Electrical conductivity
- Porosity

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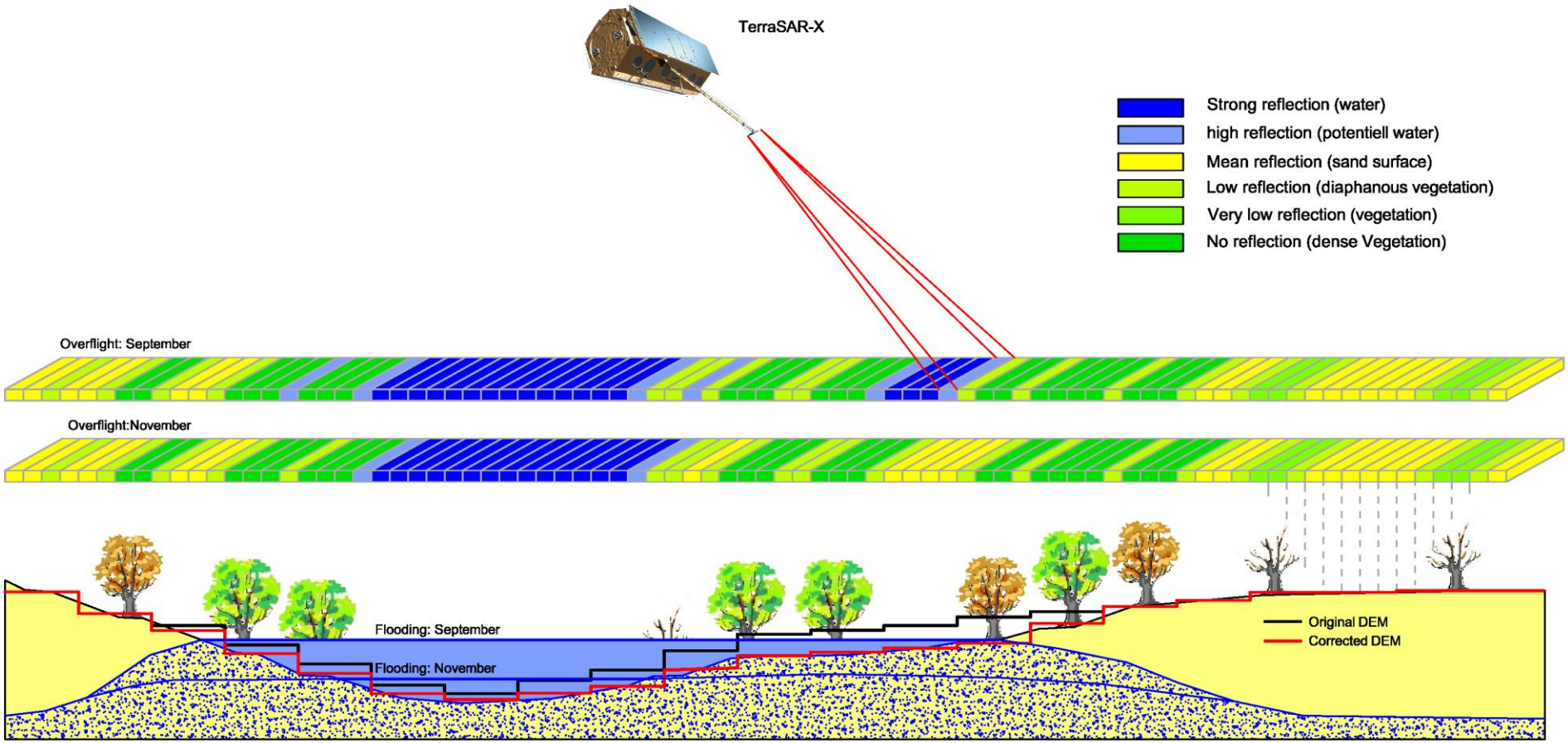
Detecting the extension of floodplains with TerraSAR-X



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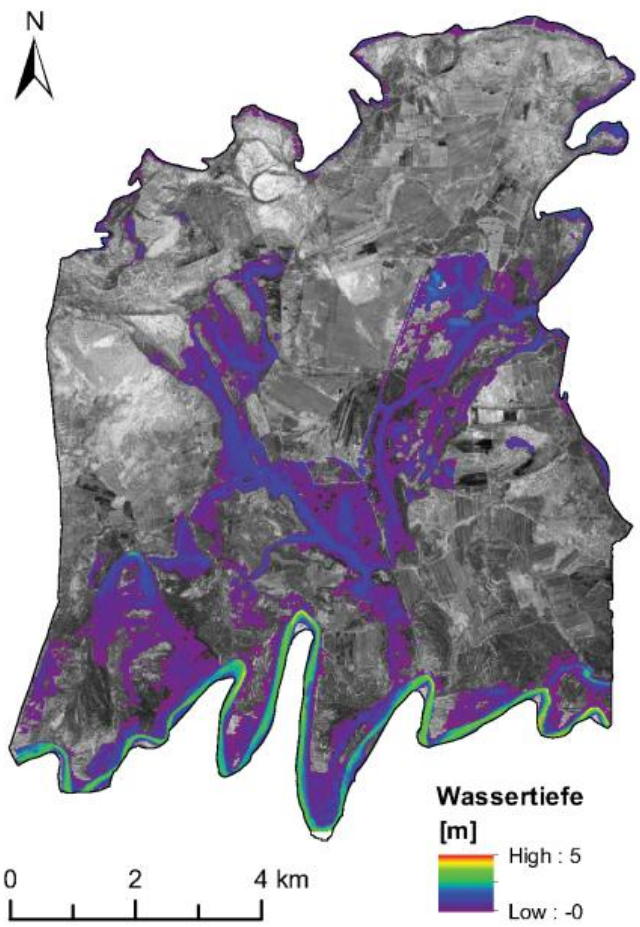
TerraSAR-X flood maps before and after correction

TerraSAR-X raw data

Calculated inundation areas



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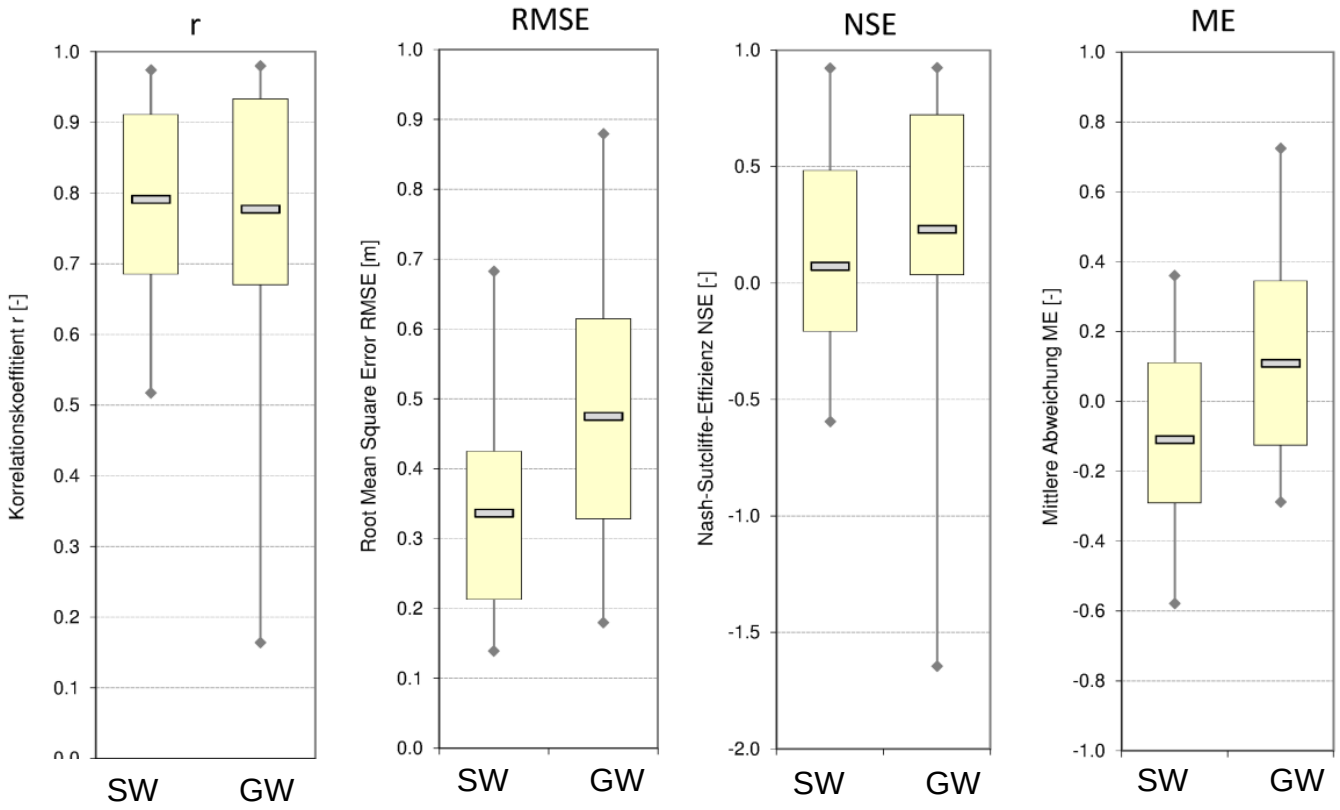
Calibration for the year 2012

1. Surface water (SW): Changing the topography and the hydraulic resistance (kst)

2. Ground water (GW): Choice of a fitting pedo-transfer-function and the hydraulic conductivity



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Validation for the year 2013

- 8 gauging stations have been destroyed by new field reclamation since 2011
- For the validation only 22 gauging wells can be used

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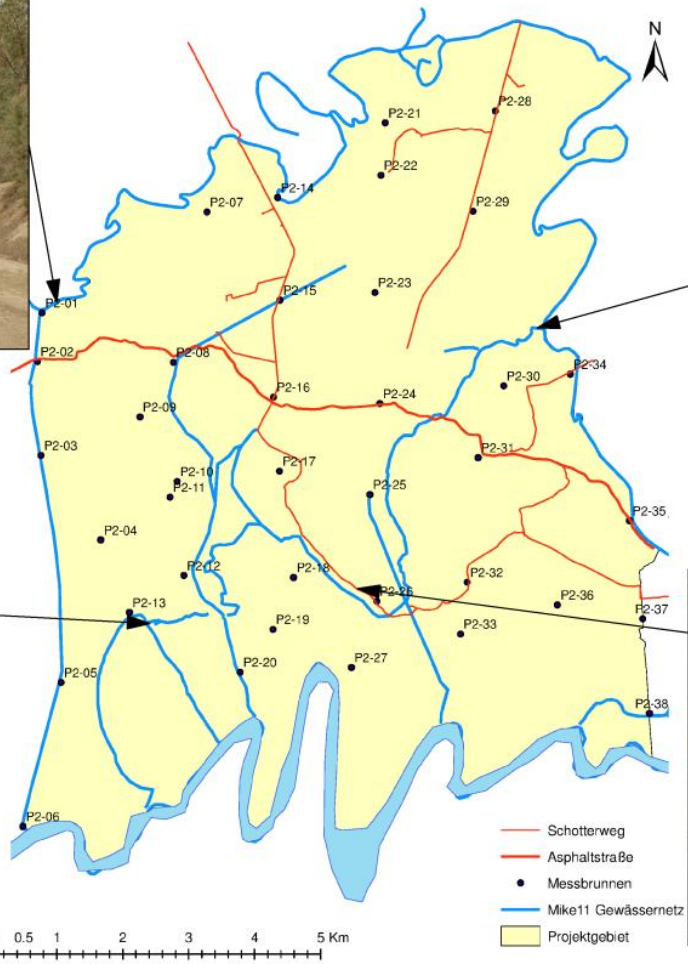
Local changes in the irrigation system



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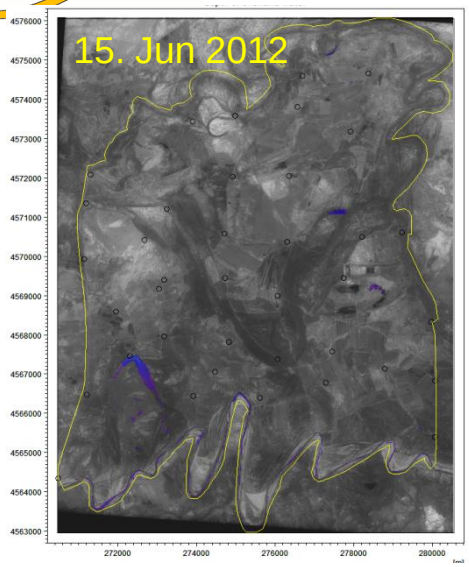
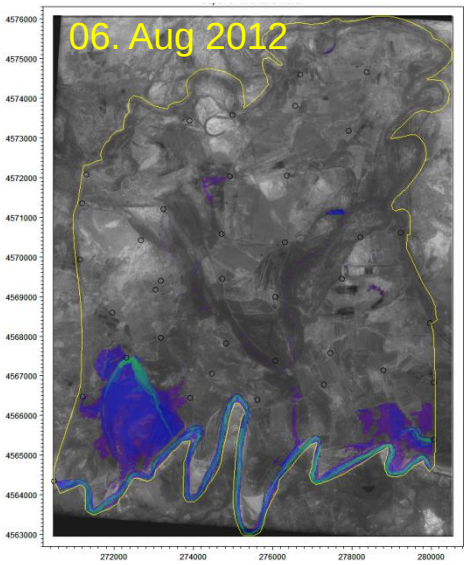
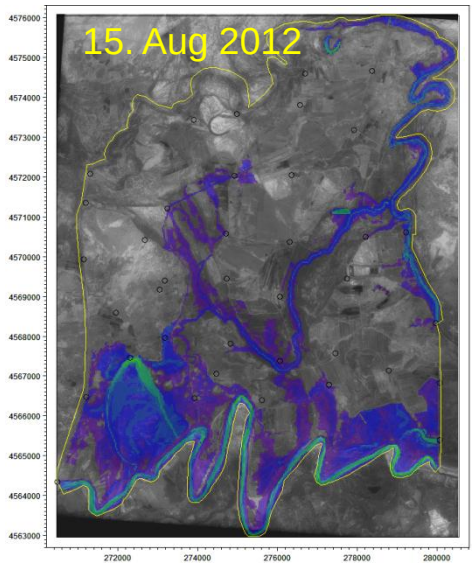
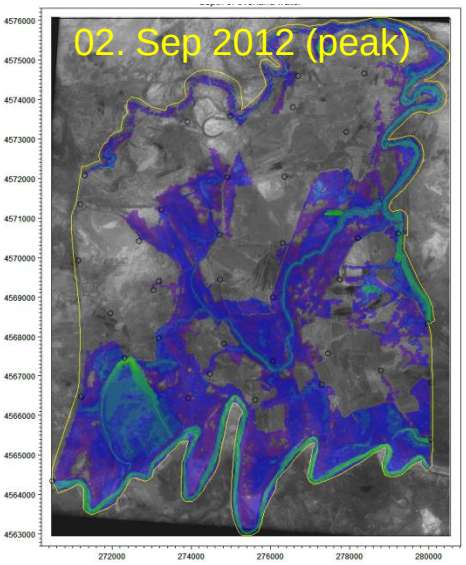
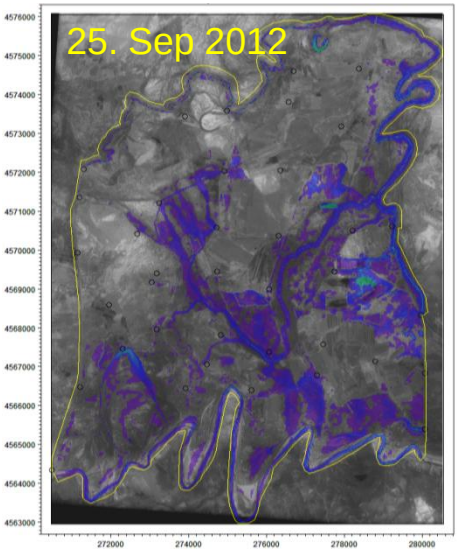
Modeled flooding for the year 2012

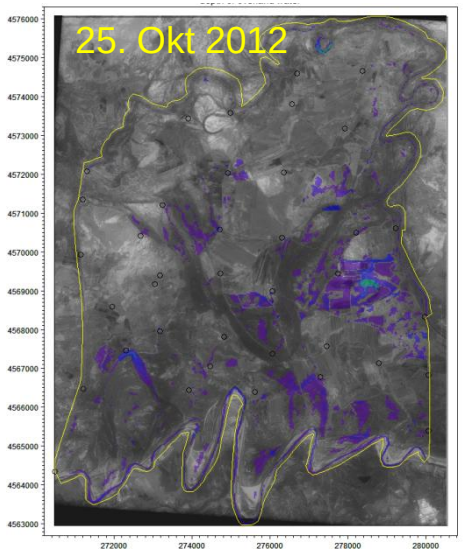


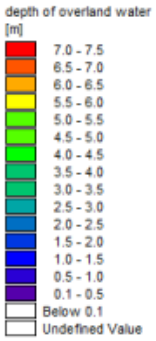












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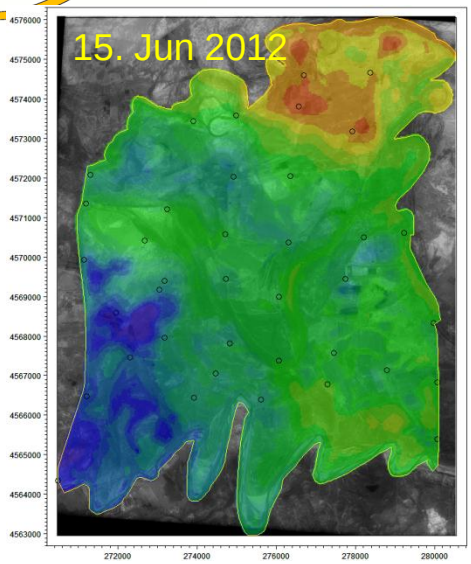
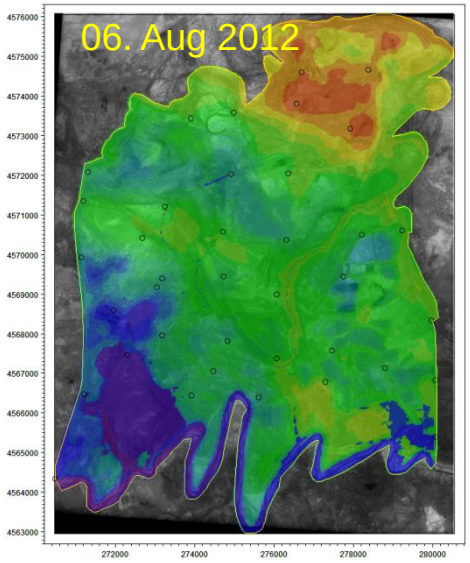
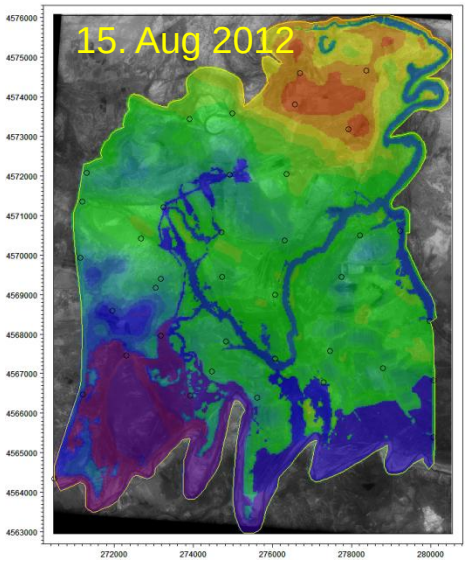
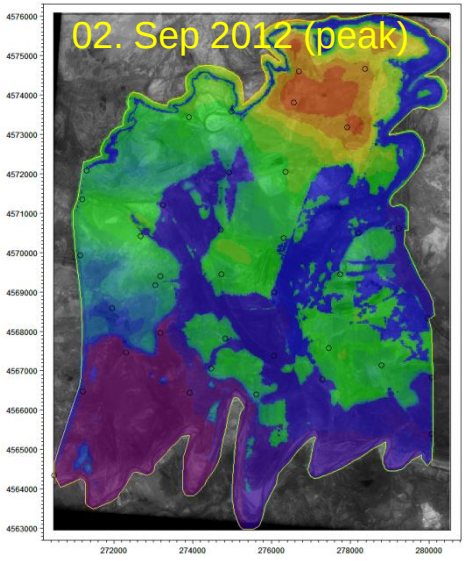
markus.disse@tum.de

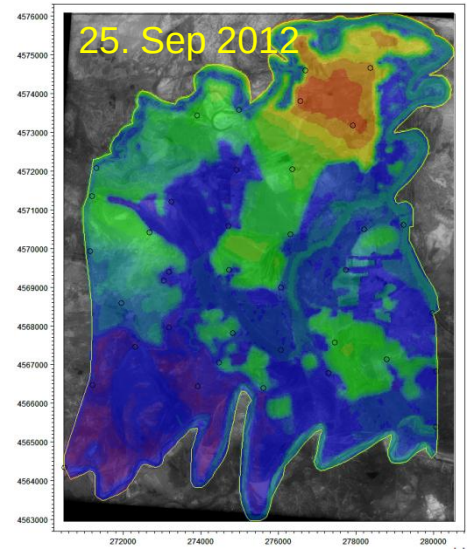
Changes in groundwater levels for the year 2012

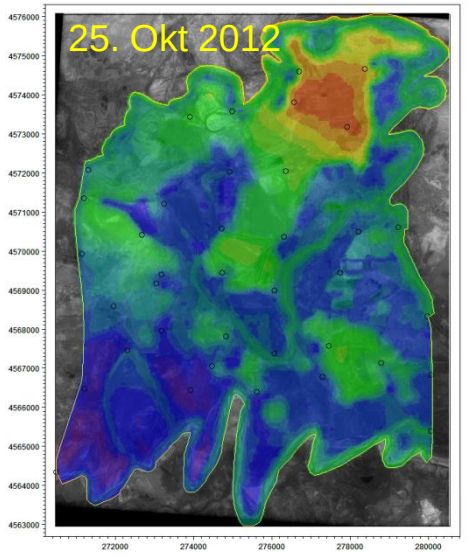


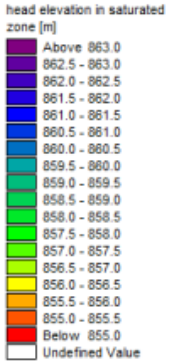












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markus.disse@tum.de

Groundwater recharge in the research area for the year 2012

Region	Area [km²]	Water volume [Mio. m³]	Groundwater recharge in overall area [mm/a]	Part [%]	Part of the positive recharge [%]
Desert area	24.3	-1.96	-23	-16.5	0.0

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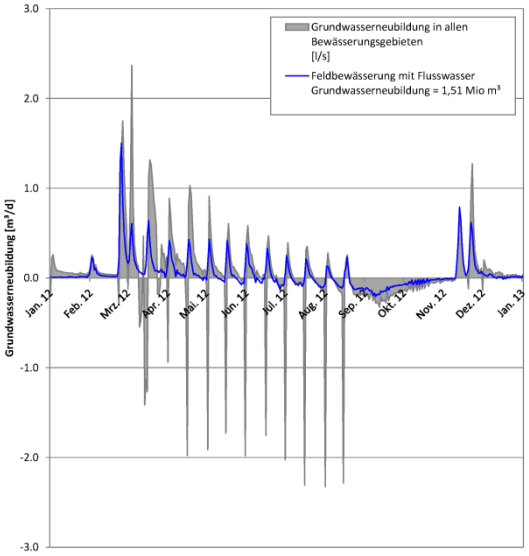
Irrigation areas	21.2	1.21	14	10.2	8.7
- Use of ground- & river water	(12.0)	(-0.30)	(-4)	(-2.5)	
- Only river water	(9.2)	(1.51)	(18)	(12.7)	

Irrigation areas



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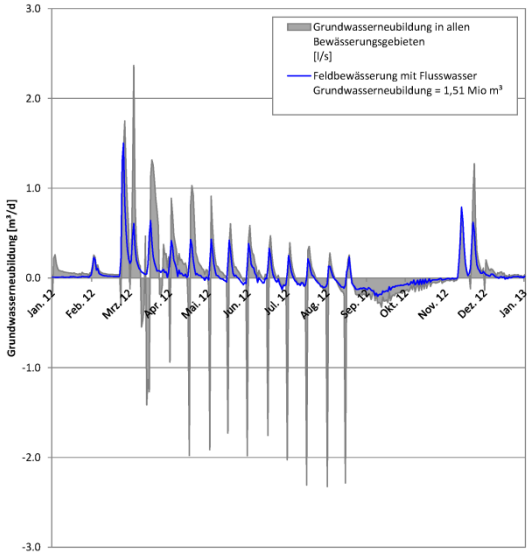
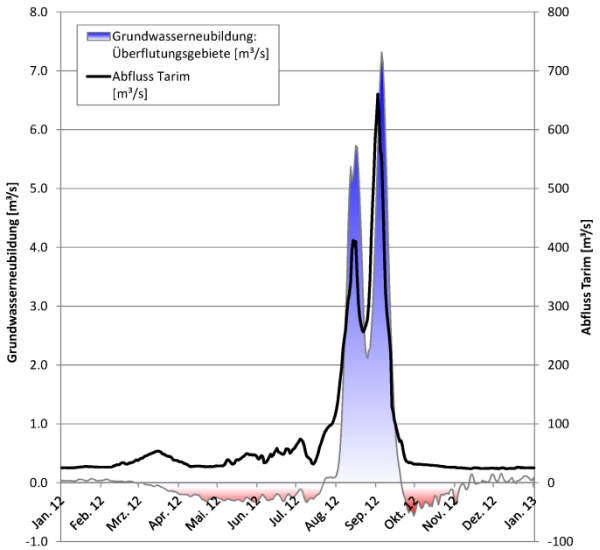


Flood plains



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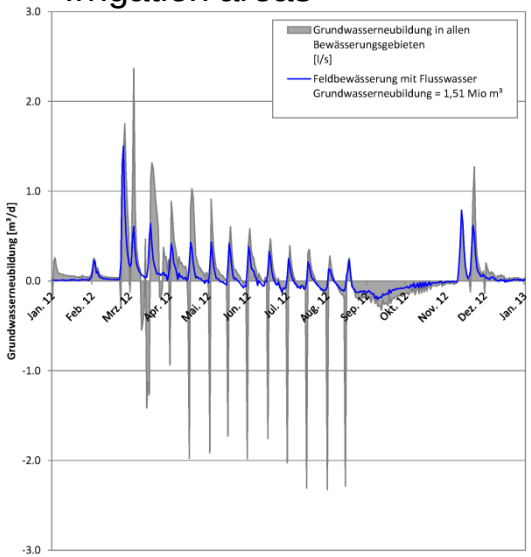
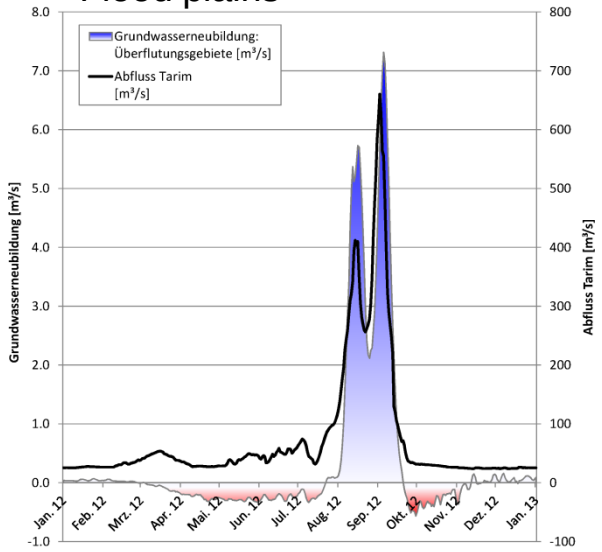
Leakage from Tarim-River	1.9	1.06	12	8.9	7.5
Sum:	85.3	11.86	139	100.0	100.0

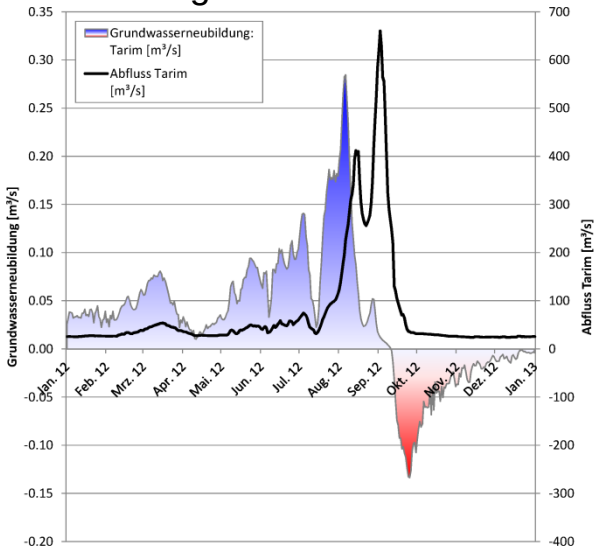
Irrigation areas



Flood plains



Leakage from the Tarim-River



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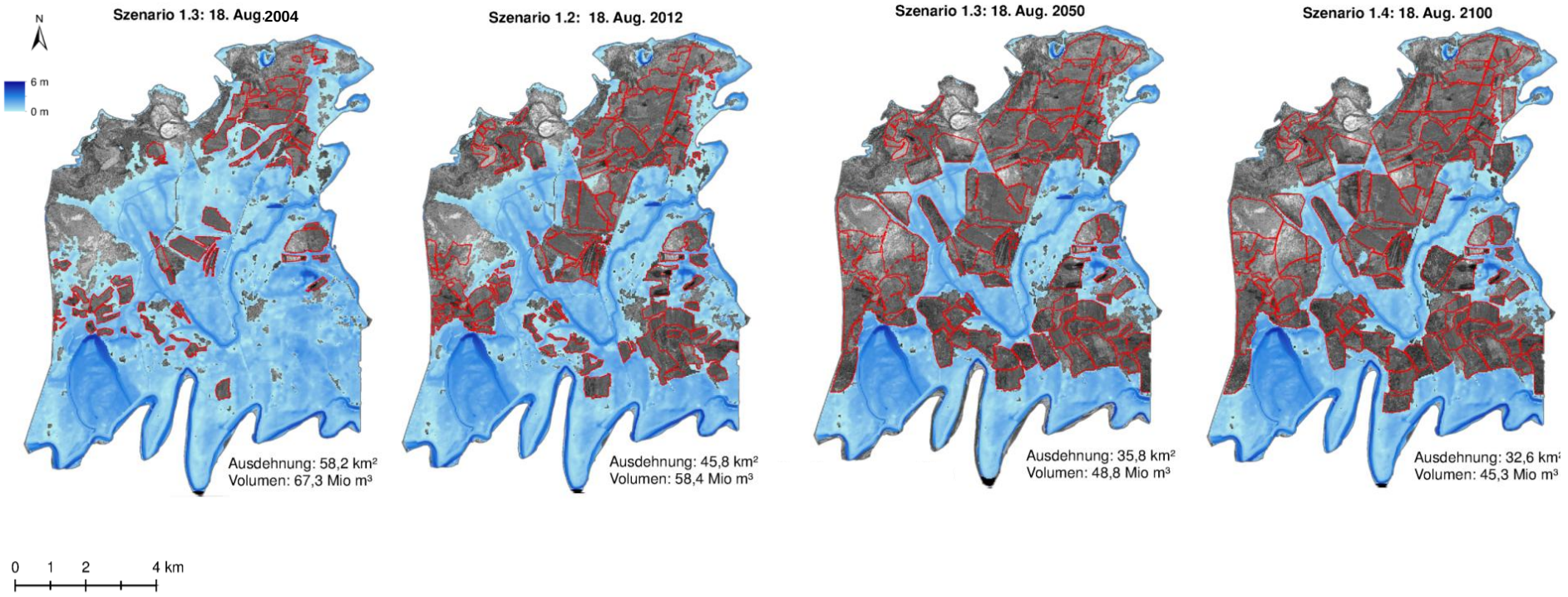
Changes in flooding by land use changes



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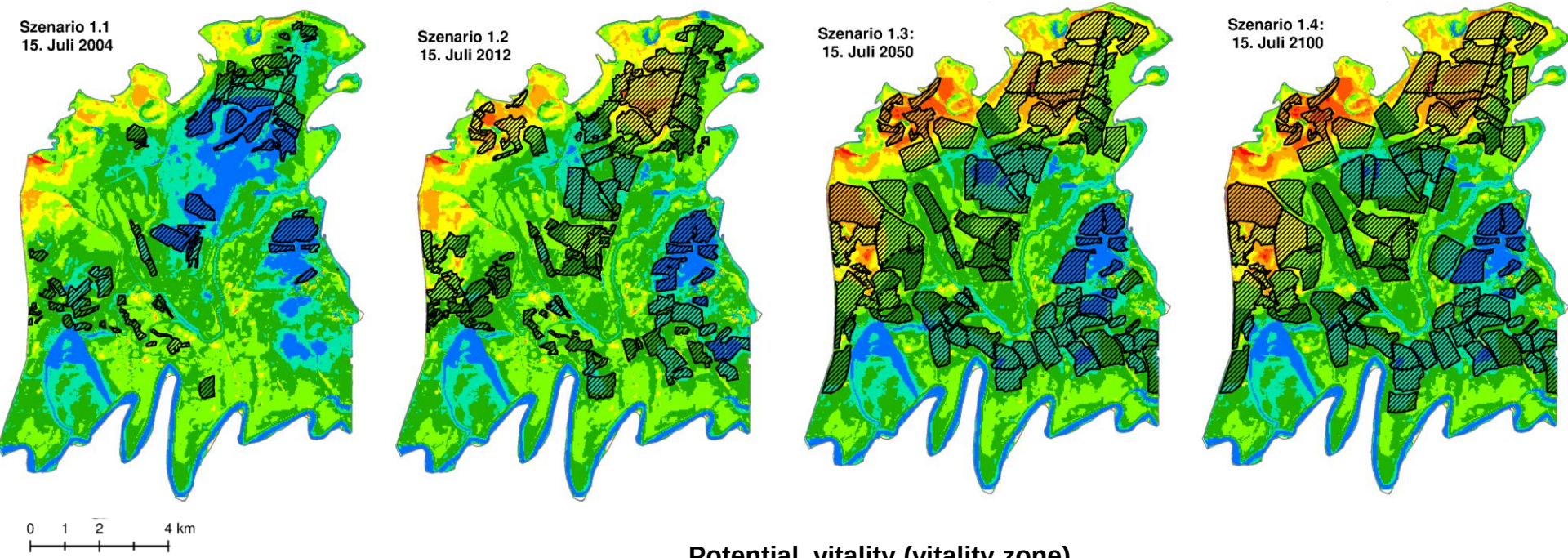
Effects to the vitality of natural vegetation by land use changes



Potential vitality (vitality zone)

- optimale Lebensbedingungen für Feuchtgebietsvegetation (Gw-Flurabstand: 0 m bis -2 m)
- optimale Lebensbedingungen für Tugai-Vegetation (Gw-Flurabstand: -2 m bis -4 m)
- Gefährdungsbereich für Pappelvegetation (Gw-Flurabstand: -6 m bis -4 m)
- Gefährdungsbereich für Wüstenvegetation (Gw-Flurabstand: -10 m bis -6 m)

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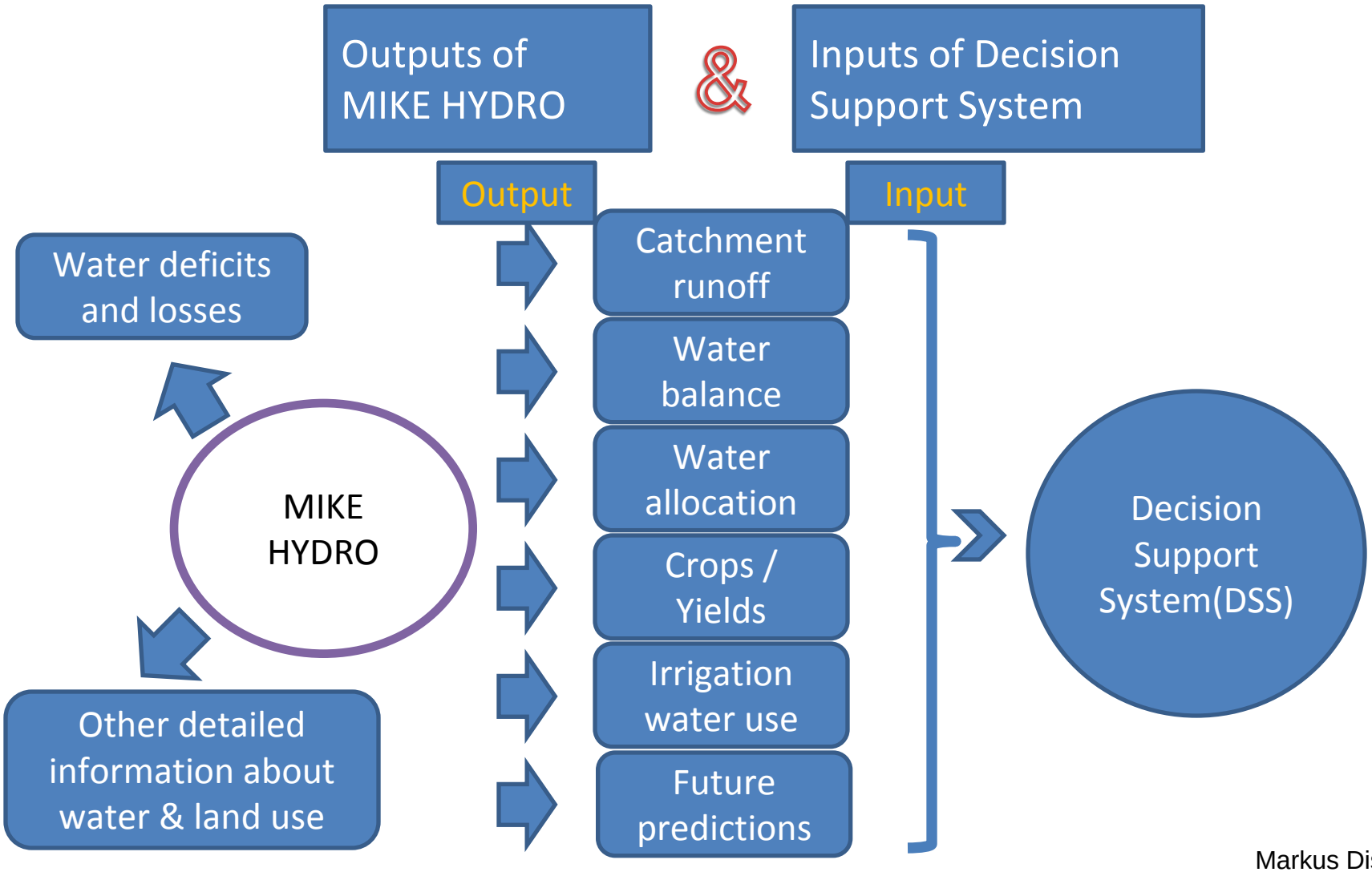
Hydrological Modeling of the entire Tarim River



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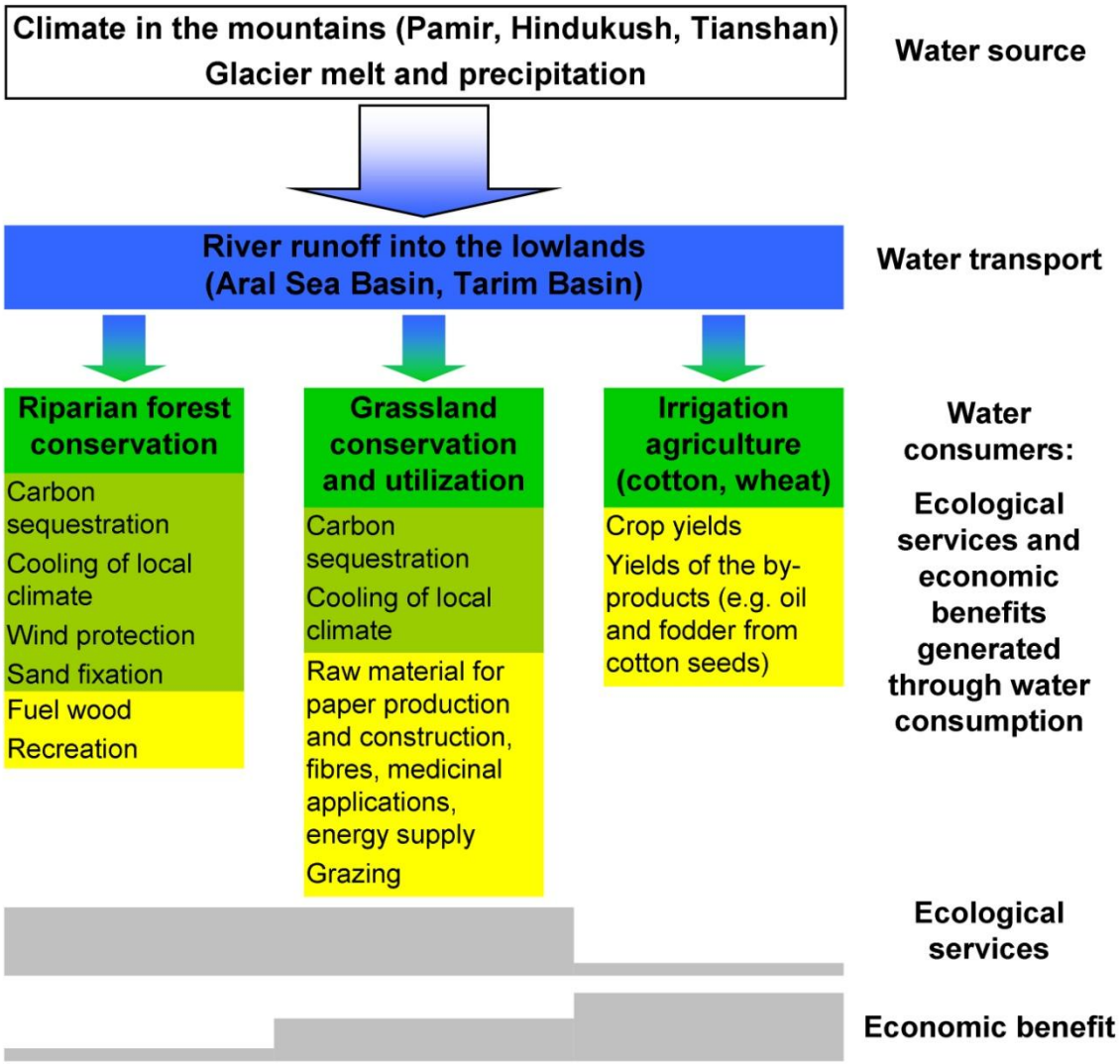
markus.disse@tum.de

Ecosystem Services Research



WB 4: Ecosystem services and Ecosystem functions along the Tarim River

- WP 4.1: Ecosystem services and Ecosystem functions of riparian ecosystems and aquatic biodiversity
- WP 4.2: Ecosystem services and Ecosystem functions of non-irrigated land use systems
- WP 4.3: Ecosystem services and Ecosystem functions of urban and peri-urban oasis vegetation

Source: Niels Thevs, Institute of Botany and Landscape Ecology Ernst-Moritz-Arndt-University Greifswald

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markus.disse@tum.de

Utilization of *Apocynum (Lop Kendir)*

Stem:

Fibres

Leafs:

Tea, medicine

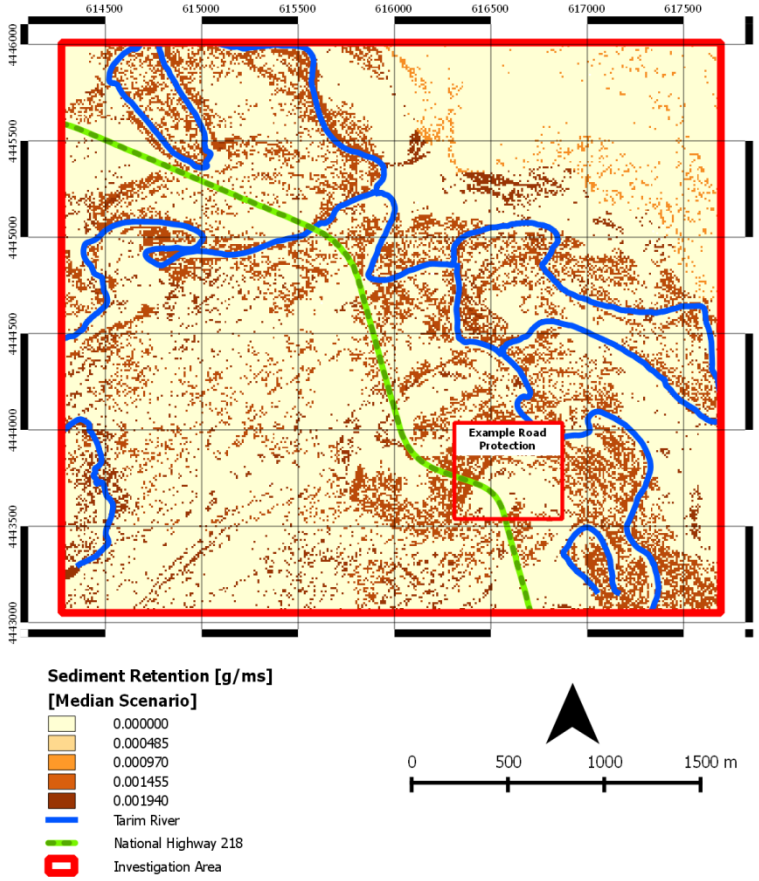
Effect against high blood pressure

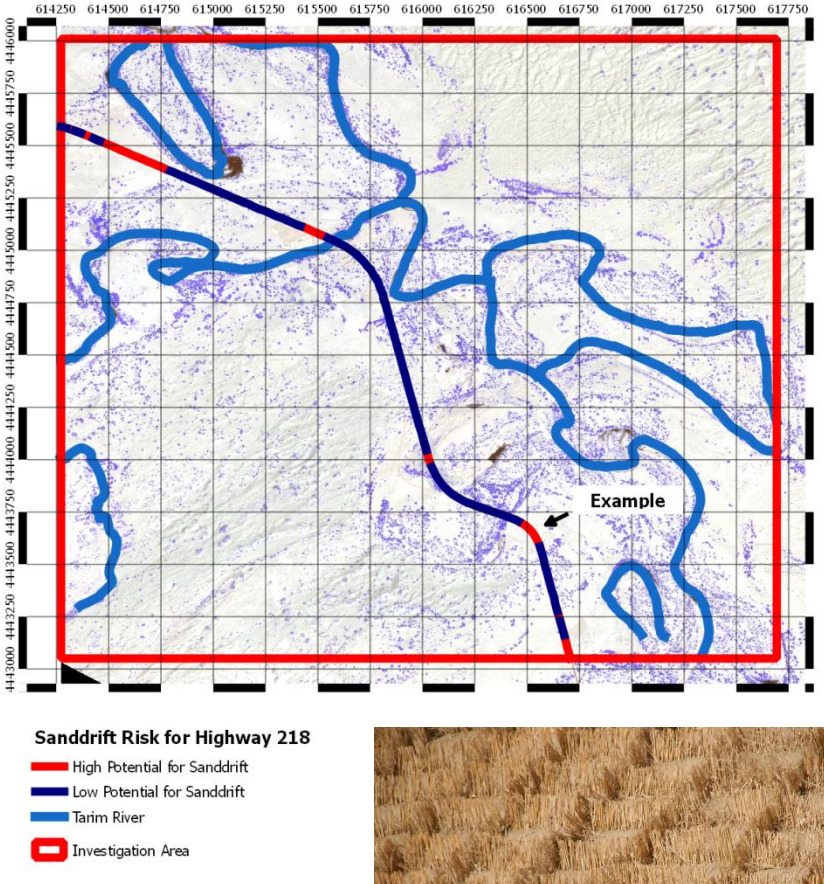
Seeds:

Local traditional medicine

Source: Thevs et al., 2008

Erosion regulation and the ESS of road protection from wind blown sand





- Within the Argan area 73% of the road are protected by vegetation.
- Avoided costs for checkboards to be build: 60 000 €!

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markus.disse@tum.de

Ecosystem services for dust weather & urban heat stress mitigation

Petra Döll, Univ. Frankfurt

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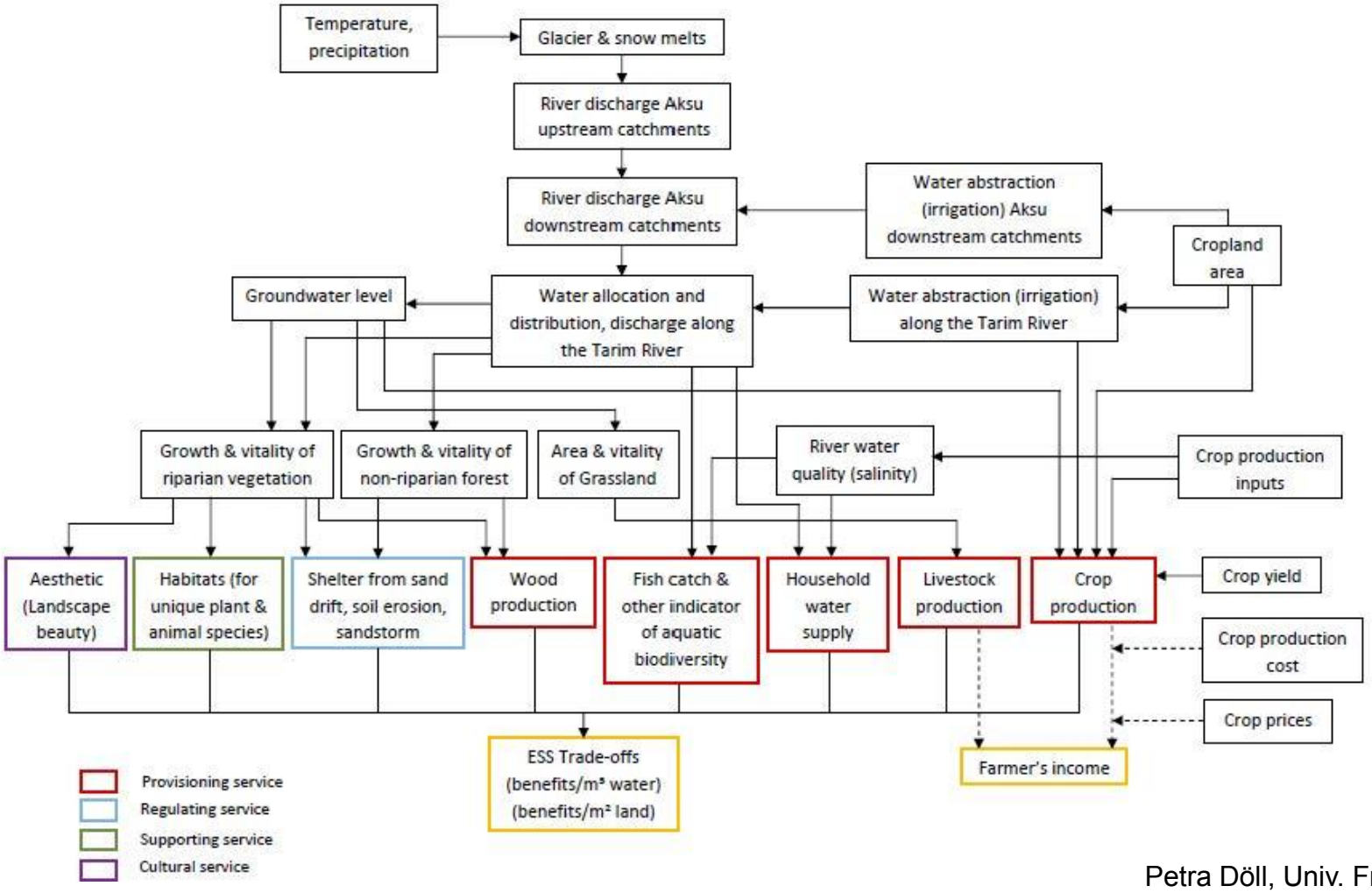
markus.disse@tum.de

SuMaRiO‘s causal network



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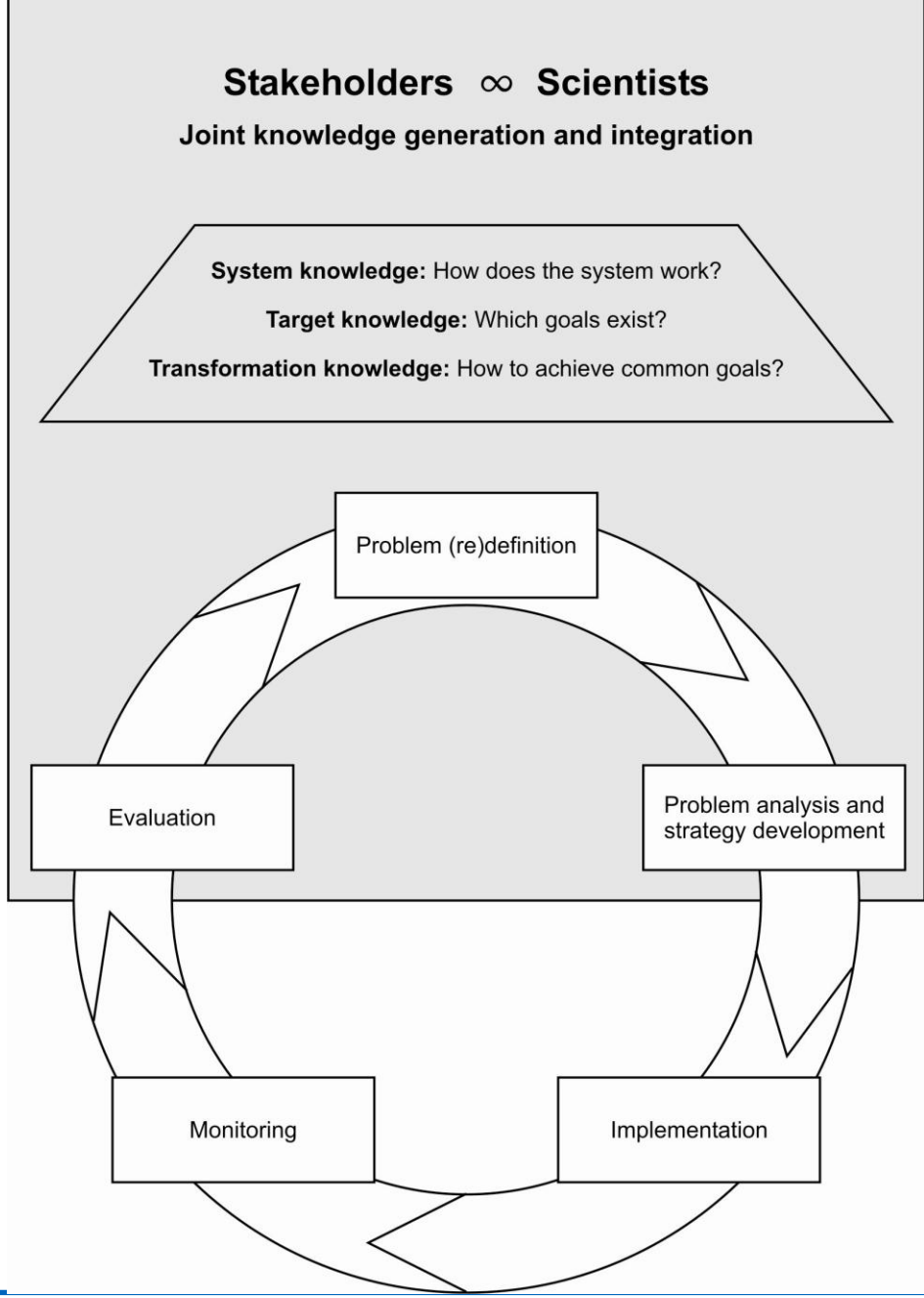
Transdisciplinary Research

WB 5: Multi-Level Socio-Economic Assessment of Ecosystem Services and Implementation Tools

- WP 5.1: Multi-level economic system assessment
- WP 5.2: Transdisciplinary assessment of ESS for urban areas regarding dust and heat stress
- WP 5.3: Actor-based decision support for land and water management

- Modeling of actor perceptions of problem field based on interviews
- Participatory modeling
  - Actor-based modeling
  - Bayesian networks
- Participatory scenario development
- Strategy development

(Siew and Döll, 2012)



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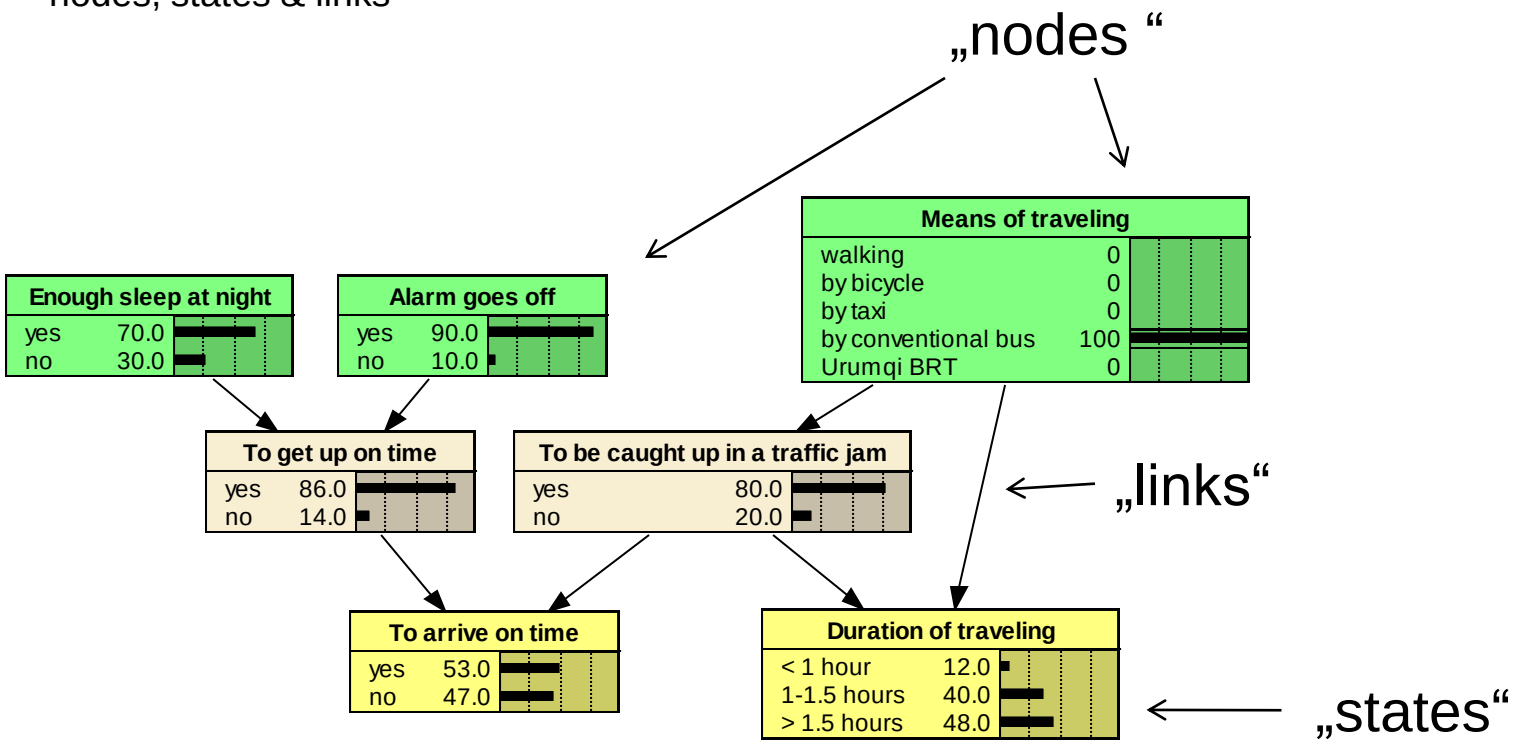
Modeling approach

- Very limited access to required (quantitative) data
- Access to experts in (urban) ecology, forestry science and urban greening
- Bayesian Network modeling is appropriate modeling approach as
  - **qualitative expert knowledge** and **quantitative data** can be combined,
  - uncertainty of knowledge is represented explicitly.

Bayesian Networks

BNs are probabilistic causal networks consisting of nodes, states & links



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Bayesian Network „To arrive on time in the morning“

Bayesian Networks

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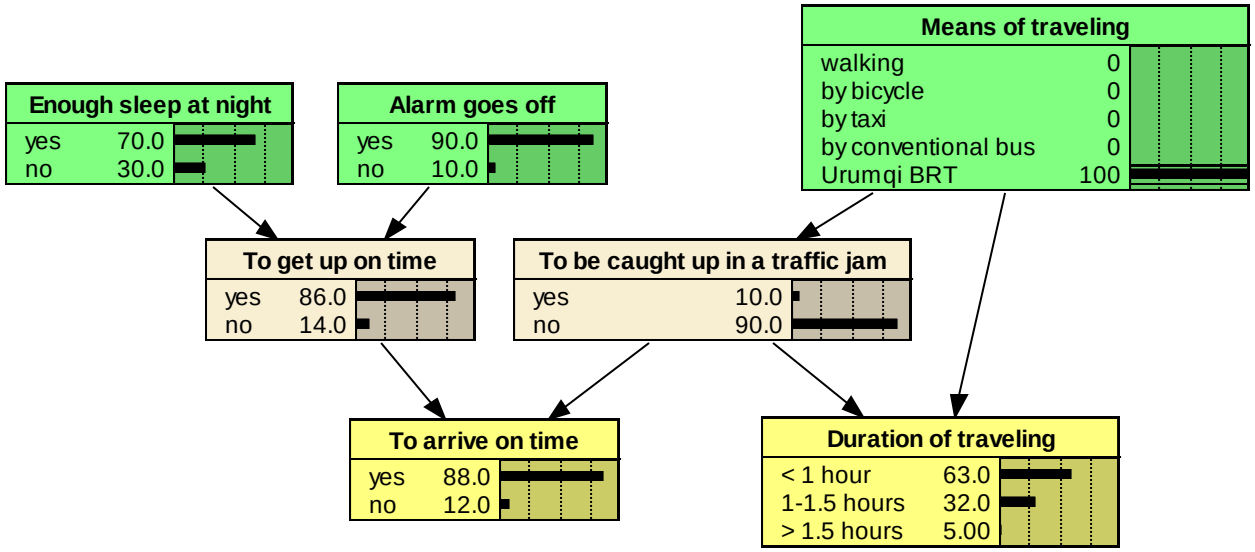

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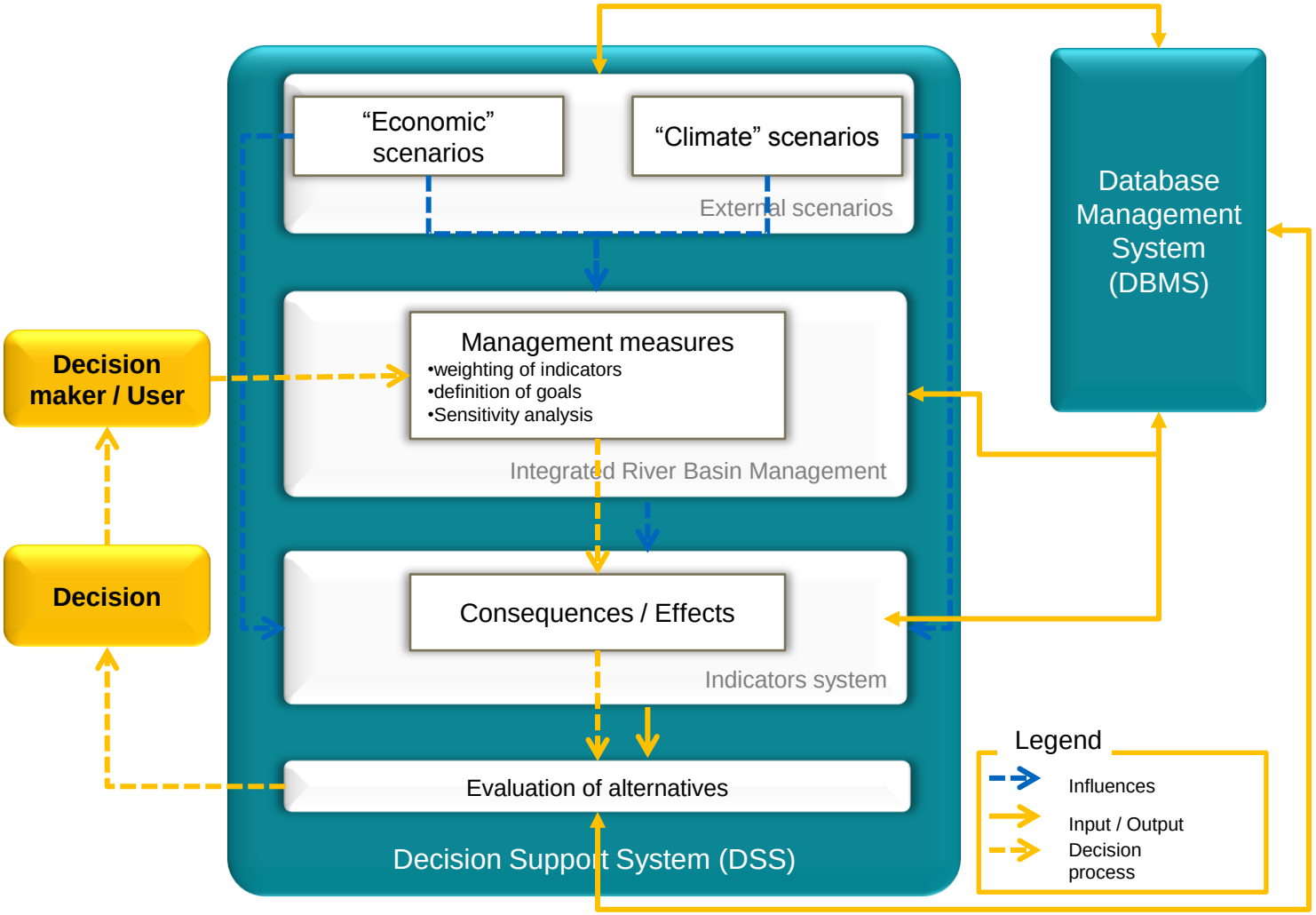
SuMaRiO DSS Concept



Andreas Brieden, UniBw Munich

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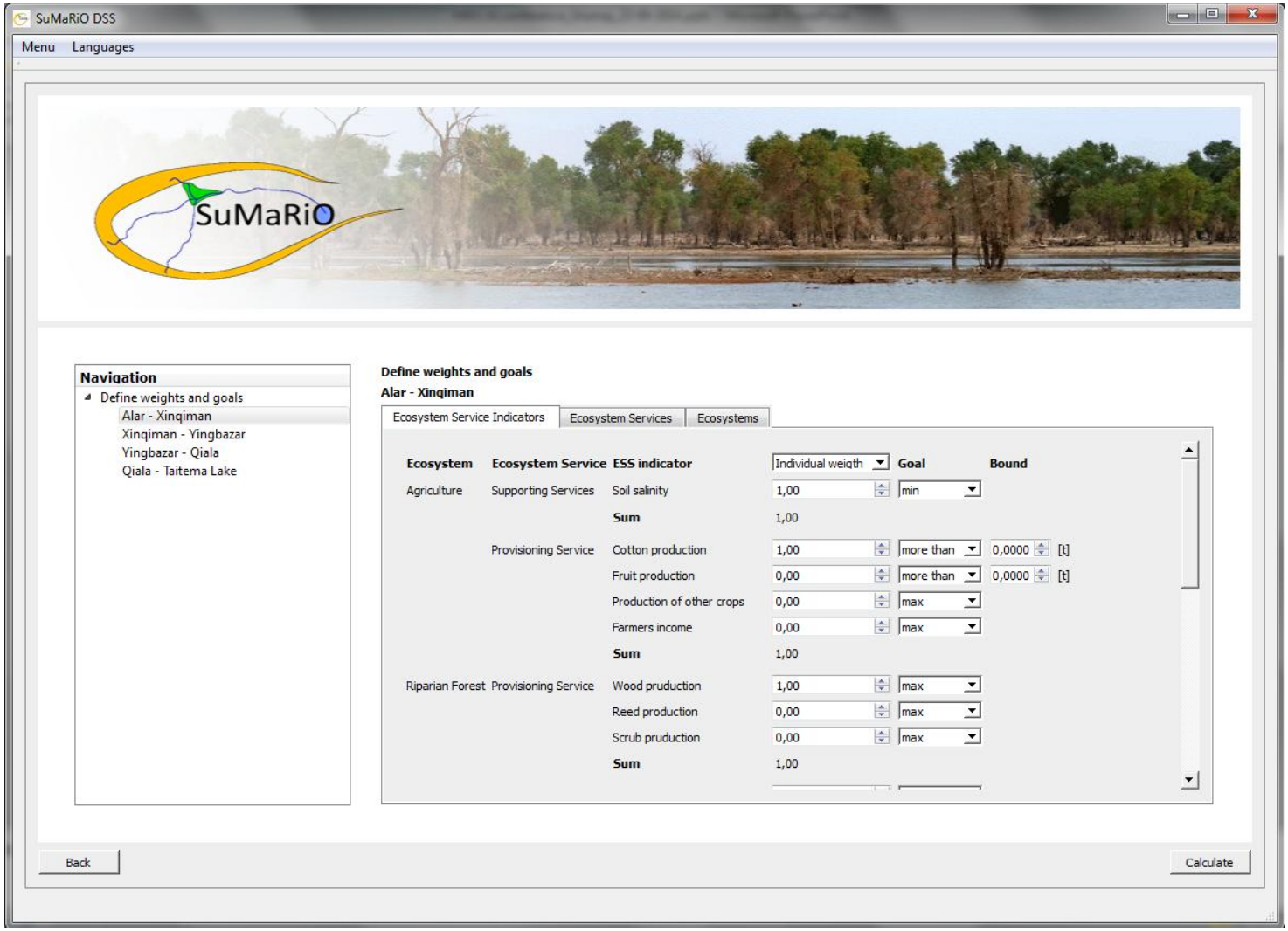

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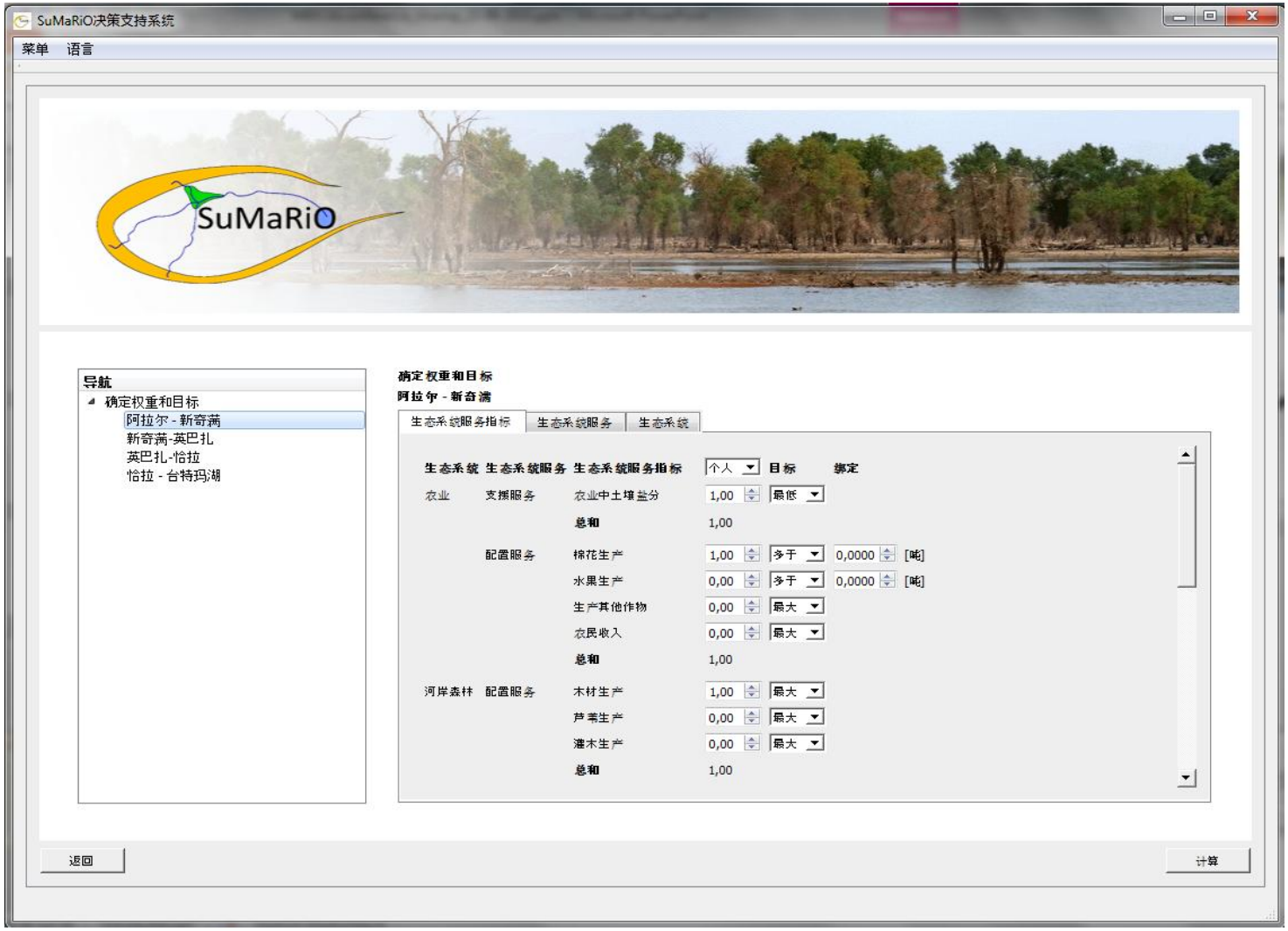

Andreas Brieden, UniBw Munich

SuMaRiO workplan until February 2016

- Finalizing DSS for serving different stakeholders (e.g. climate, hydrology, agriculture, forest, ecology, economy)
- Implementation of DSS SuMaRiO

- Serving stakeholder needs (e.g. Sino-German workshops and conferences)
- Education and capacity building (e.g. technical training, summer schools, PhD and MSc students)

- Scientific contribution for the 13th Five-Years-Plan (national, provincial, regional and basin level)
- Inviting responsible officials of the Five-Year-Plan to workshops and summer schools (communication)

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markus.disse@tum.de