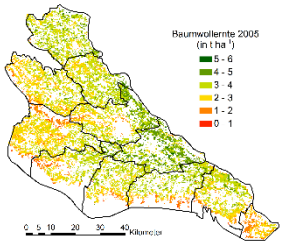
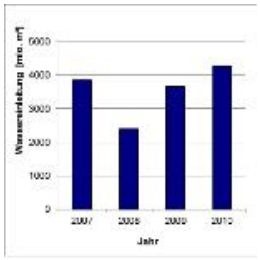
Estimation of actual evapotranspiration to derive irrigation efficiency indicators in the Aral Sea Basin, Central Asia

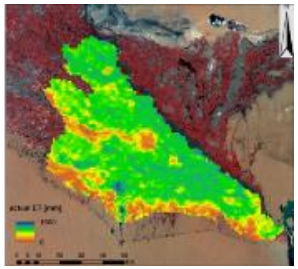
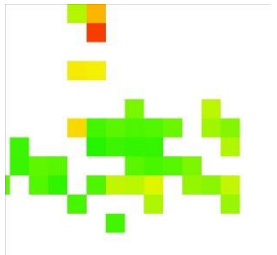
Tagung „Landschaftsprozessmonitoring mittels Multisensordaten “

5. Gemeinsamer Workshop der AKs

„Auswertung von Fernerkundungsdaten“ der DGPF e.V. und „Fernerkundung“ der DGfG e.V.

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About the project

Work package III (University of Wuerzburg):

WUEMoCA (Water Use Efficiency Monitor in Central Asia):

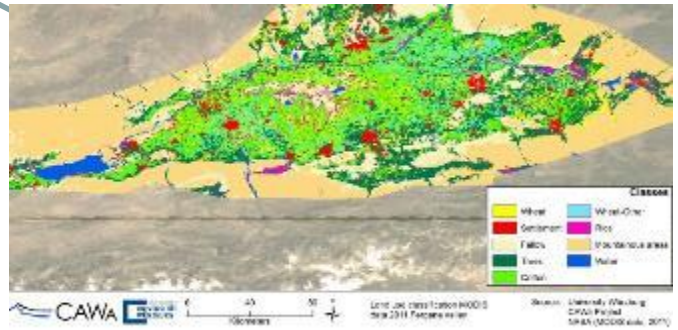
→ automated monitoring and visualization instrument addressing sustainable land management, decision making, and planning processes

CAWa was designed to **support scientific cooperation and communication between the CA countries** (and Germany) in the sector of water resource management

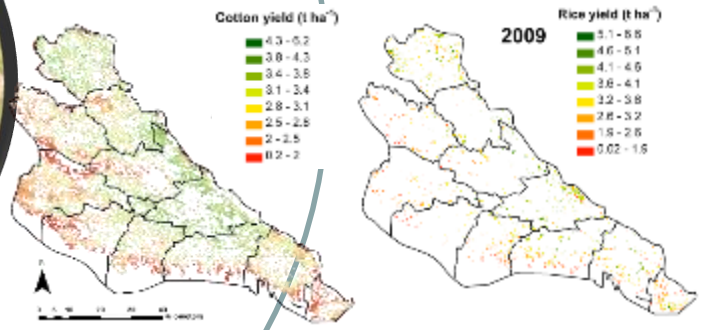
Aims and Partners

Use of satellite remote sensing (multi-temporal multi-sensor mapping), Information about crops for each field parcel

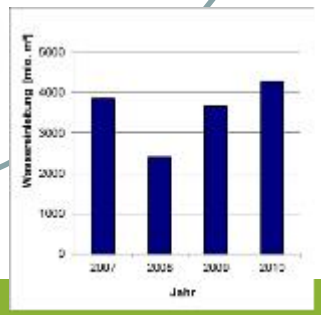
Land use (cotton, rice, wheat, fallow, etc.)

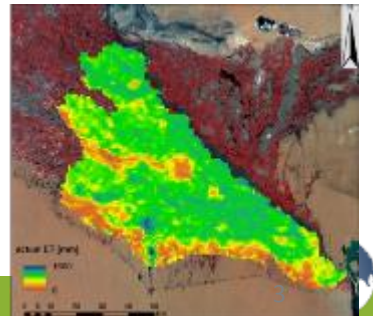


Crop yield/biomass development



Water flow / use efficiency





Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

green spin

carec

KRASS
Khorezm Rural Advisory Support Service

Water Use Efficiency Indicators:

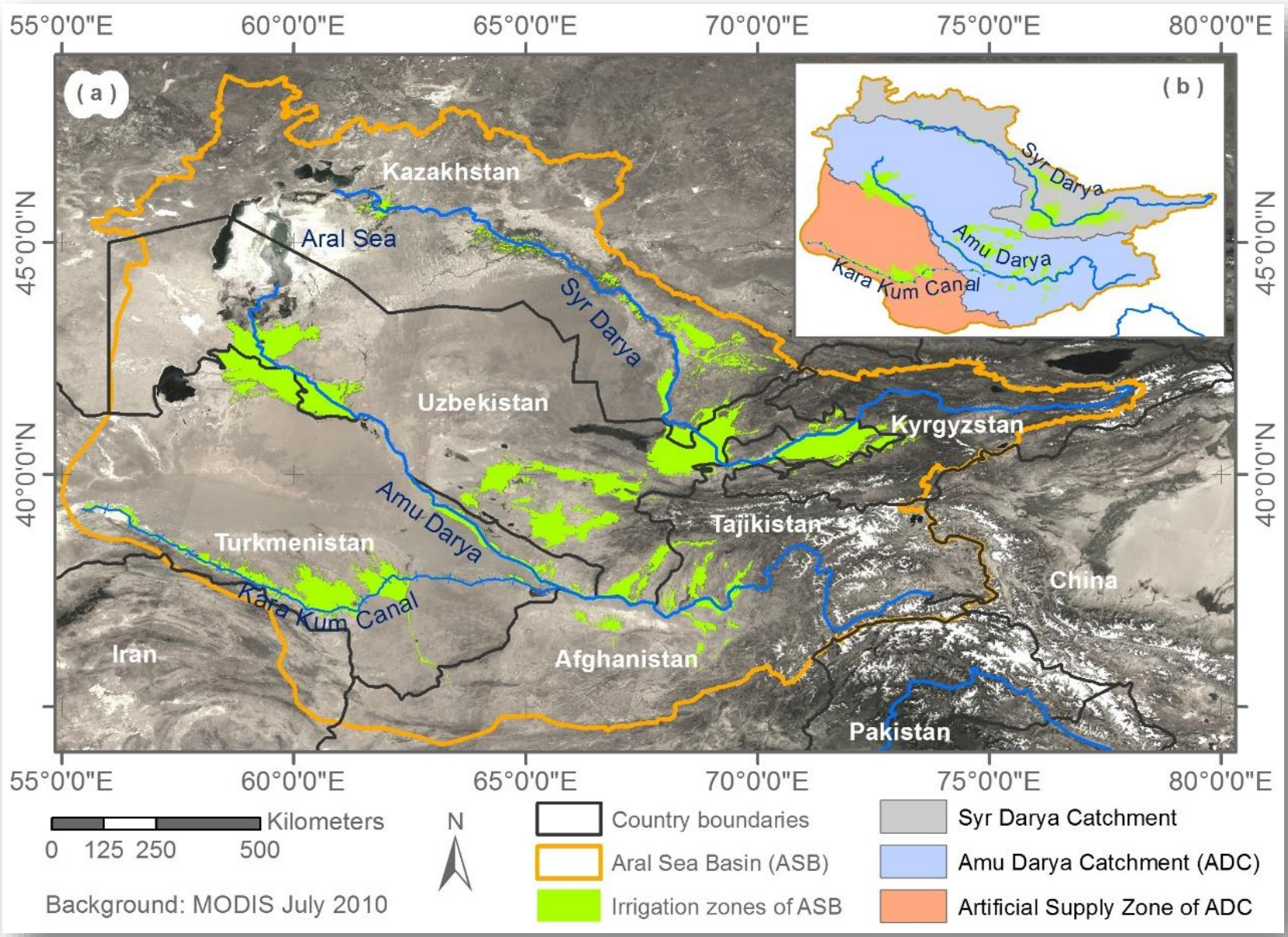
Irrigation Efficiency: ET_a/W

ET_a : actual Evapotranspiration
W : water withdrawal at the boundary of district

Crop water productivity : Y/ET_a in kg/m^3

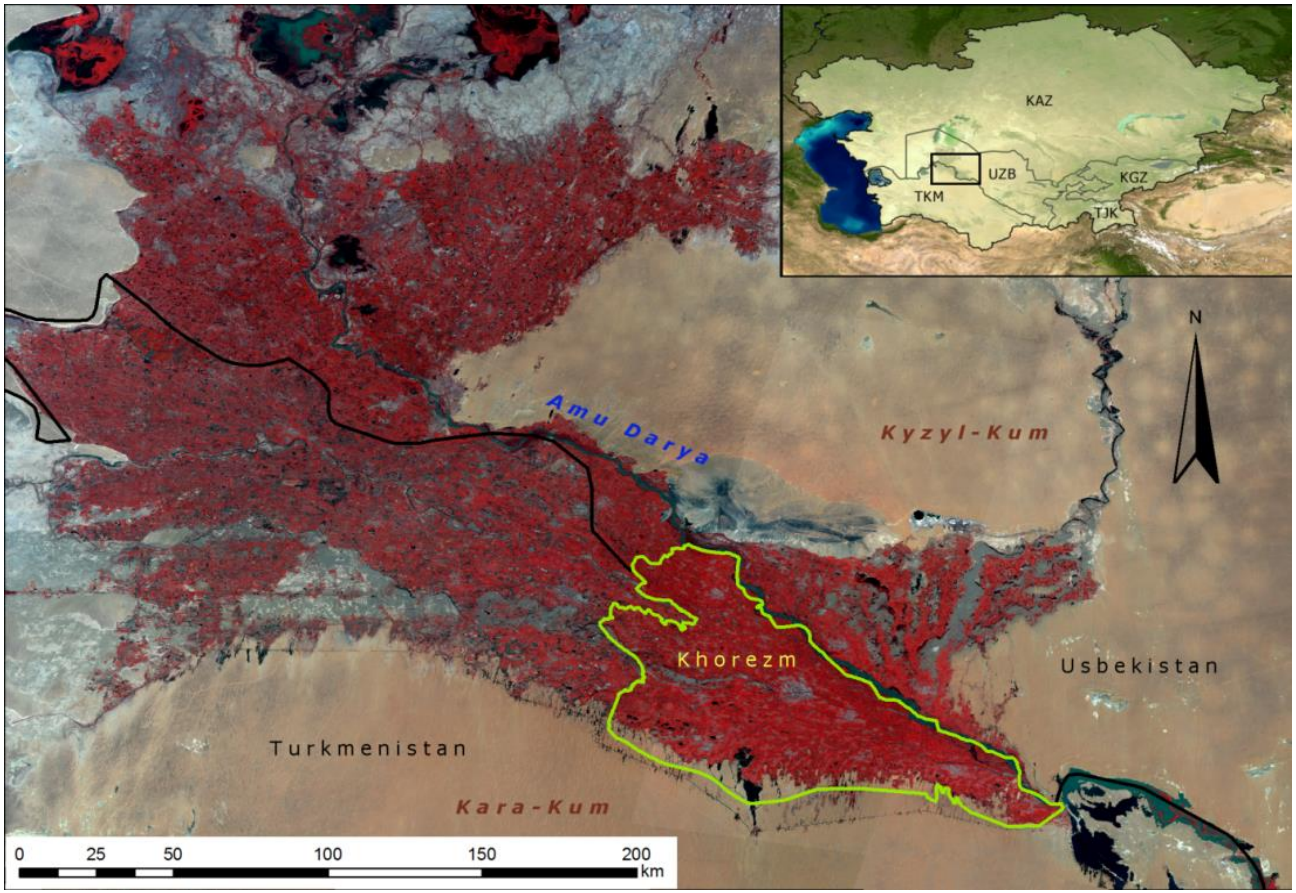
Y: Crop specific yield

Non-sustainable irrigation water use in the Aral Sea Basin



Focus area

Khorezm is a textbook example of the problems of irrigated agriculture in the Aral Sea Basin (Vlek et al., 2012)

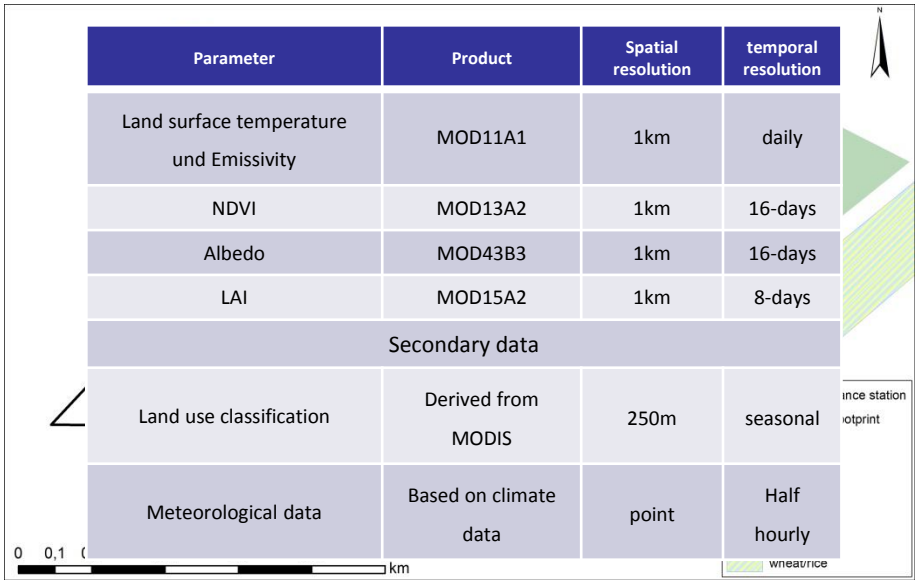


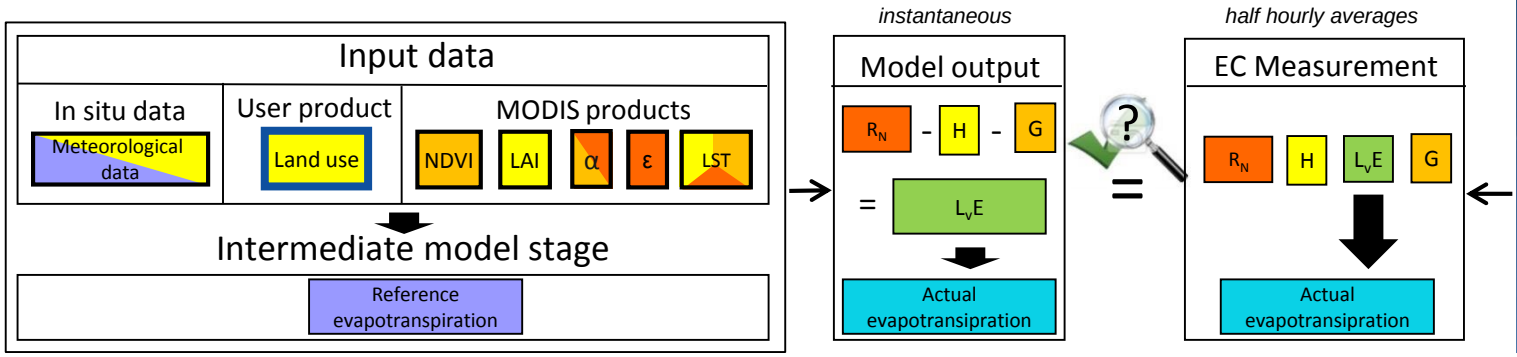
Bildquelle: Landsat-5 2010, Falschfarbendarstellung

ET modelling and validation

Test fields

Parameter	Product	Spatial resolution	temporal resolution
Land surface temperature und Emissivity	MOD11A1	1km	daily
NDVI	MOD13A2	1km	16-days
Albedo	MOD43B3	1km	16-days
LAI	MOD15A2	1km	8-days
Secondary data			
Land use classification	Derived from MODIS	250m	seasonal
Meteorological data	Based on climate data	point	Half hourly

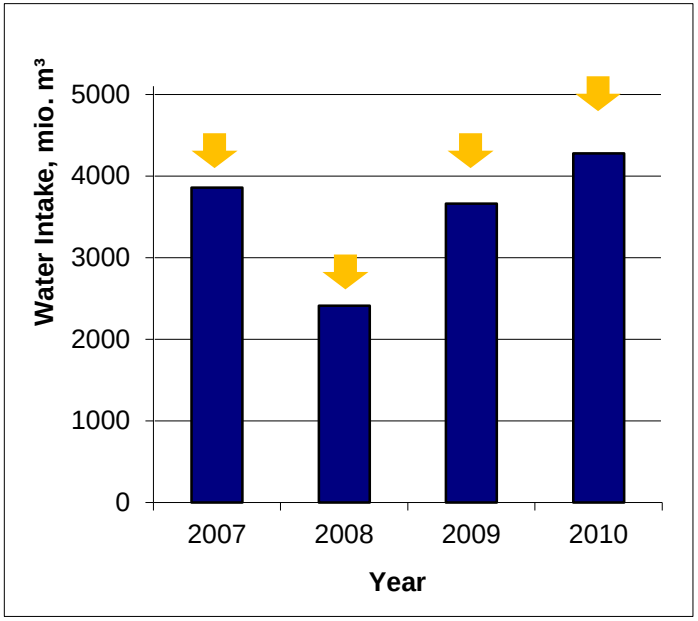




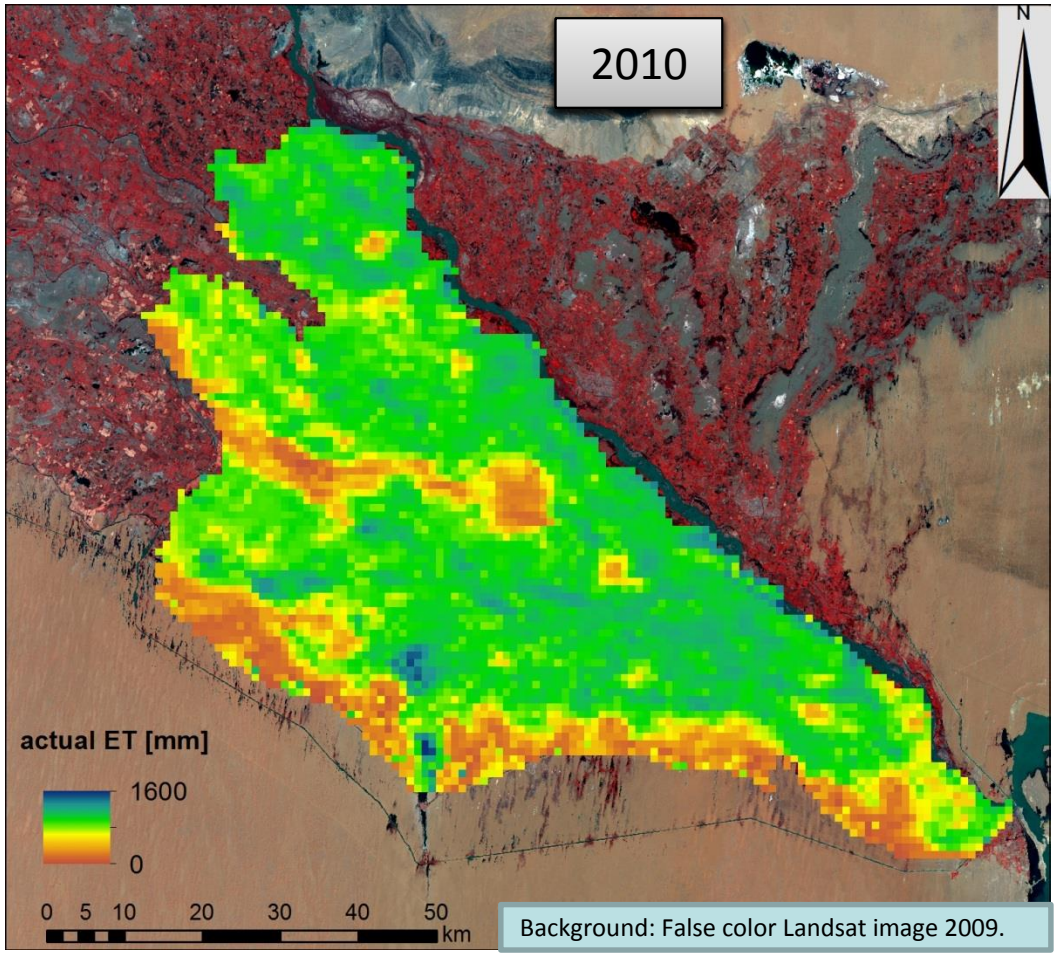
R_N: Net radiation
λET: latent heat flux
H: sensible heat flux
G: soil heat flux

Irrigation efficiency

Water intake into Khorezm irrigation system

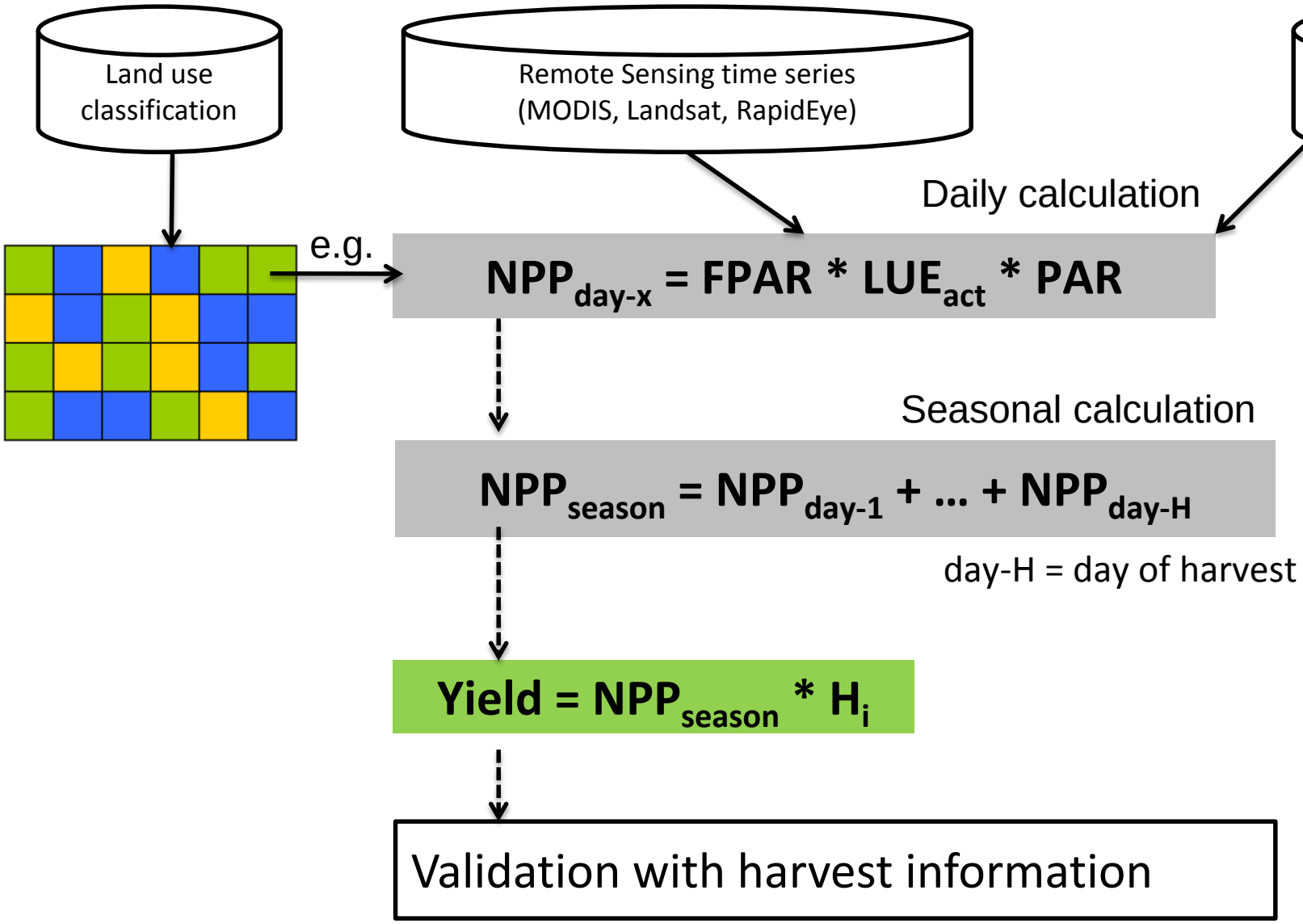


Year	Seasonal ET	Water intake	Estimated efficiency
2003	3.36	3.58	0.54
2004	4.04	3.68	0.62
2005	3.60	3.93	0.52
2006	3.28	3.68	0.52
2007	3.31	3.1	0.64
2008	3.11	1.69	0.96
2009	3.53	3.44	0.72



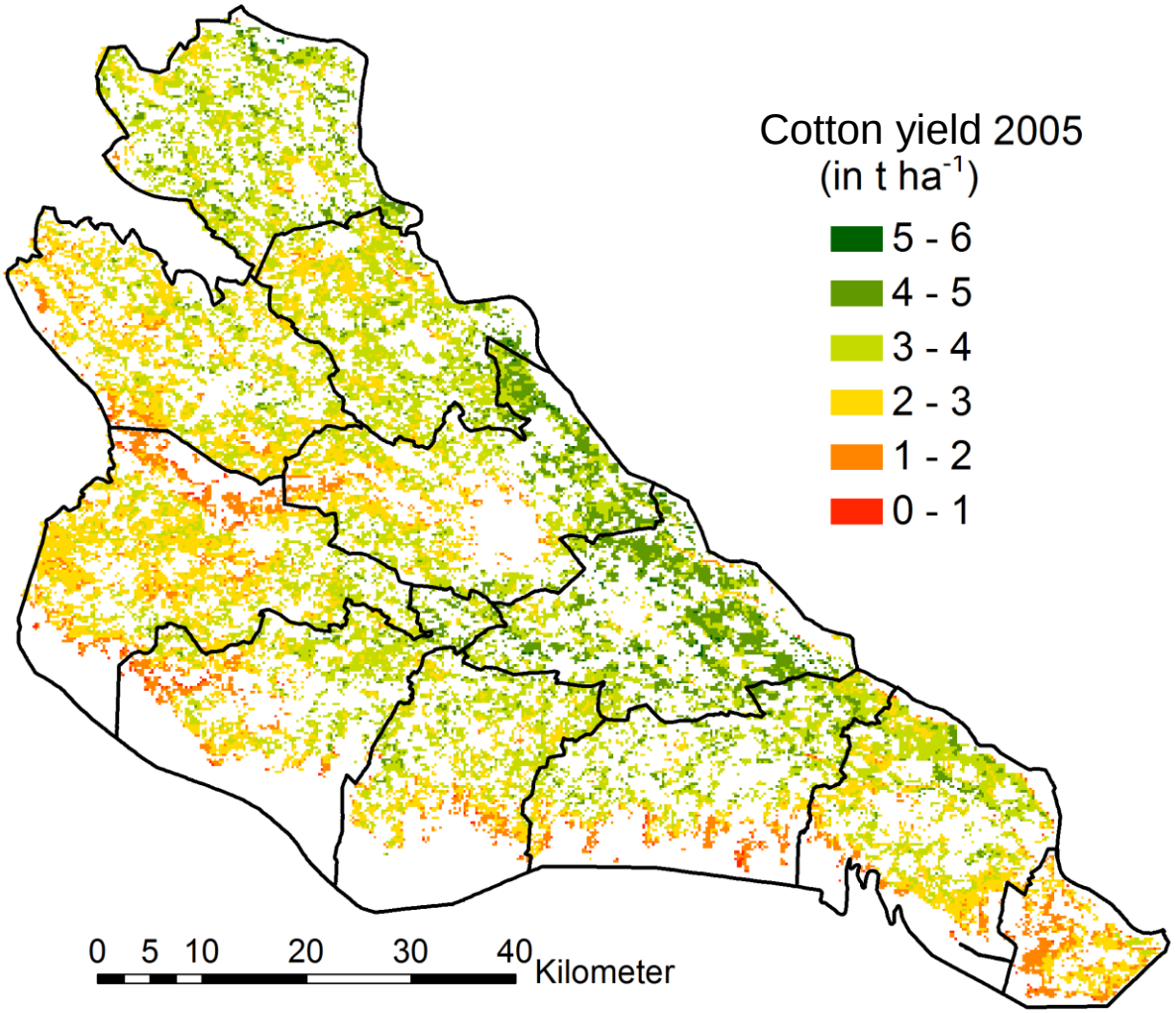
Background: False color Landsat image 2009.

Yield modeling – Light Use Efficiency



Fritsch, 2013

Yield results MODIS 250m for 2005 and 2008



Source : Fritsch et al. 2013

Water productivity

Due to spatial resolution of input data the "***water productivity***" is calculated based the coarse resolution → 1km pixel with homogenous land use (threshold: 80% of same land use)

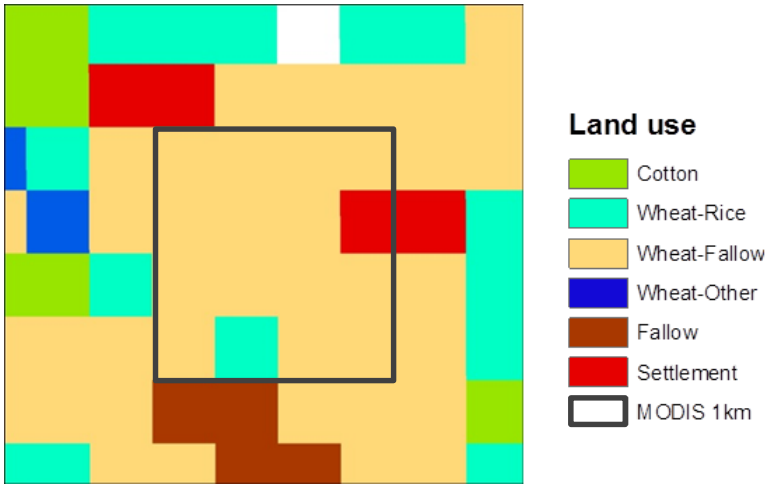
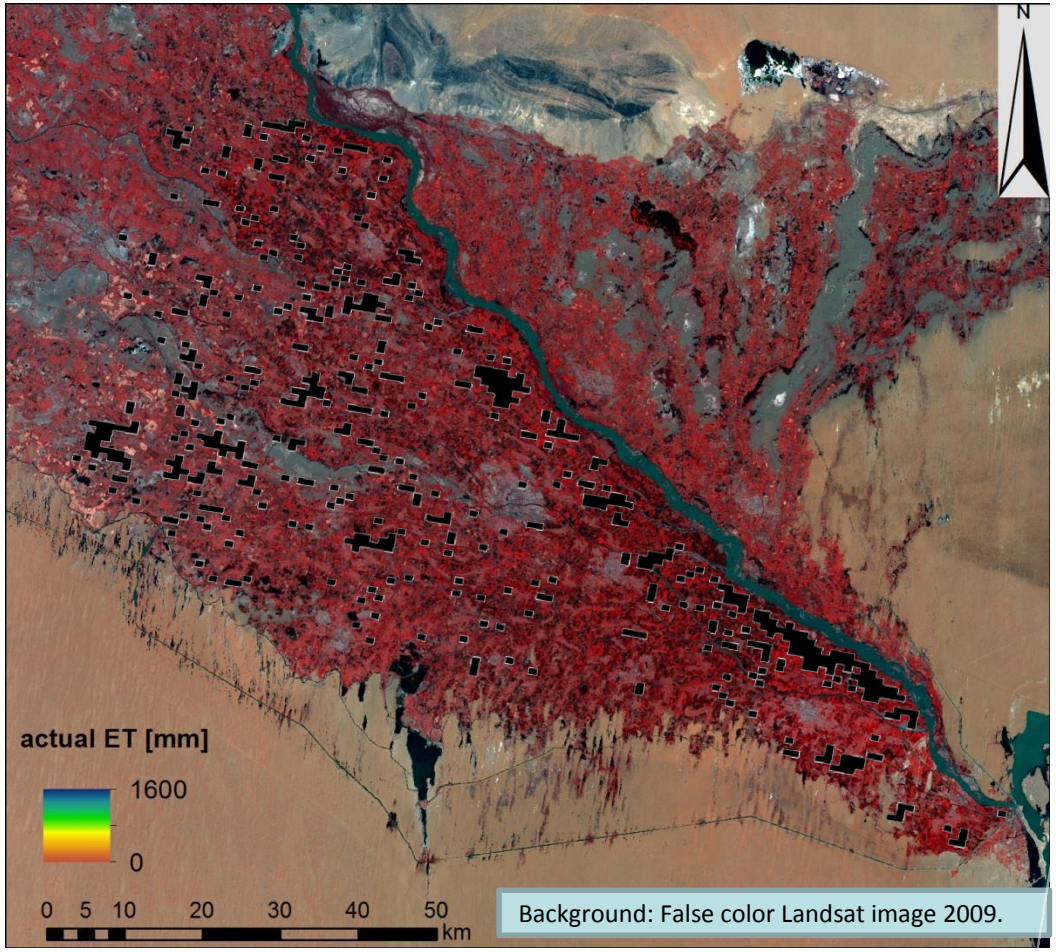


Table: Number of homogeneous pixel per year

	2003	2004	2005	2006	2007	2008	2009
Cotton	486	659	661	573	672	366	629
Wheat-Rice	0	0	0	2	1	1	8
Wheat-Fallow	0	6	1	2	0	0	0
Wheat-Other	46	29	58	67	37	48	46
Rice	101	58	34	31	25	12	6
Fallow	461	485	458	475	518	821	563

Results: Water productivity (cotton)

Year	mean water productivity cotton
2003	0.28
2004	0.25
2005	0.27
2006	0.28
2007	0.31
2008	0.22
2009	0.30



Results – Indicator calculation

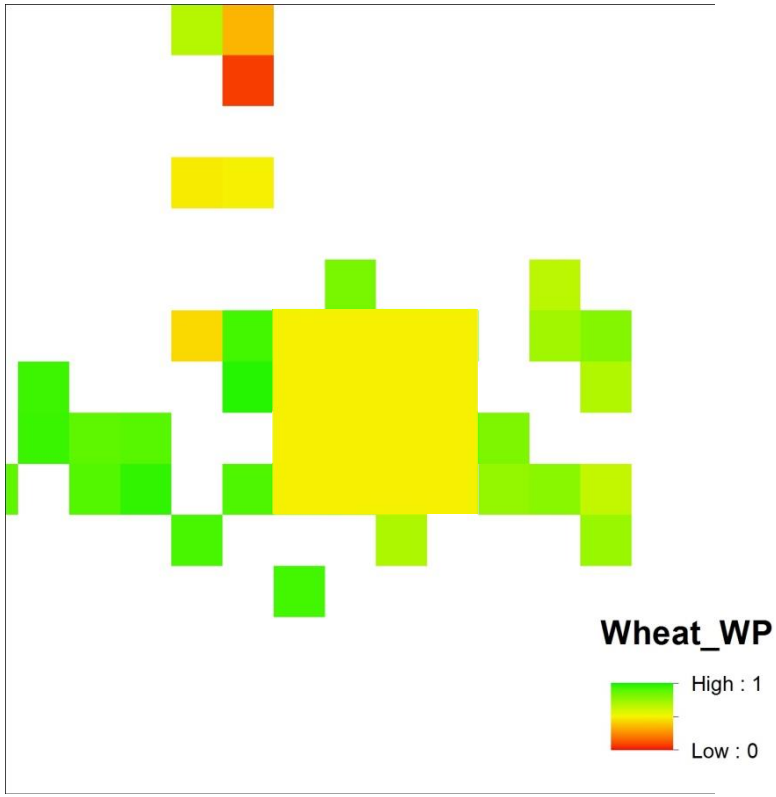
Analysis of cotton water productivity based on 1km homogenous pixel is suitable, but for other crop this approach is insufficient.

→ Disaggregation of LST

→ Disaggregation of evaporative fraction (ETF) based on ETF - NDVI relation (Eswar et al., 2013)

Year	wheat WP 1km	wheat WP 250m
2003	-	-
2004	0.340	-
2005	0.385	-
2006	0.449	0.388
2007	-	-
2008	-	-
2009	-	-

Wheat WP 2006



Summary

- Low irrigation efficiency in Khorezm (0.58). Official water withdrawal statistics are not suitable for calculation due to underestimation.
- Problems of ET modelling in dry years.
- To evaluate wheat WP disaggregation approach should be performed
- Regions mean WP is 0.41 (literature: 0.48) kg/m³ for winter wheat and 0.26 (0.23) kg/m³ for cotton. Thus, WP is small compared to other irrigation systems of the world (< 2.4 kg/m³).

Thanks for your attention

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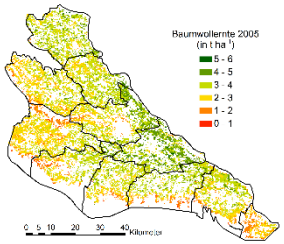


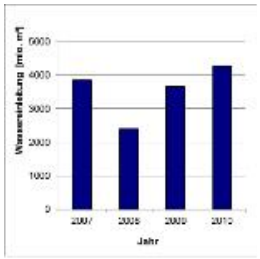

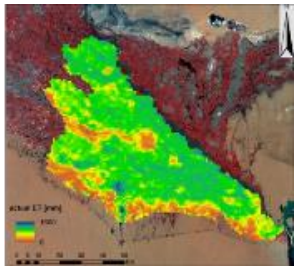
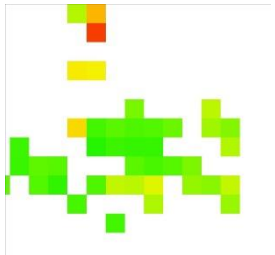

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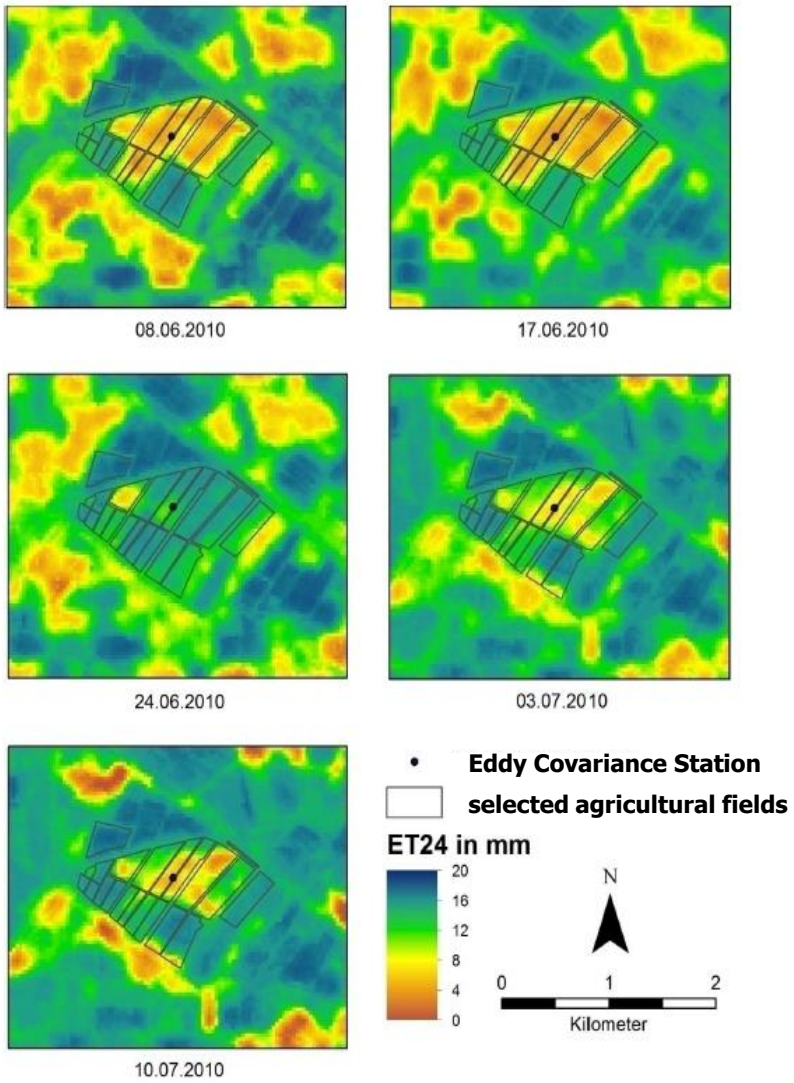
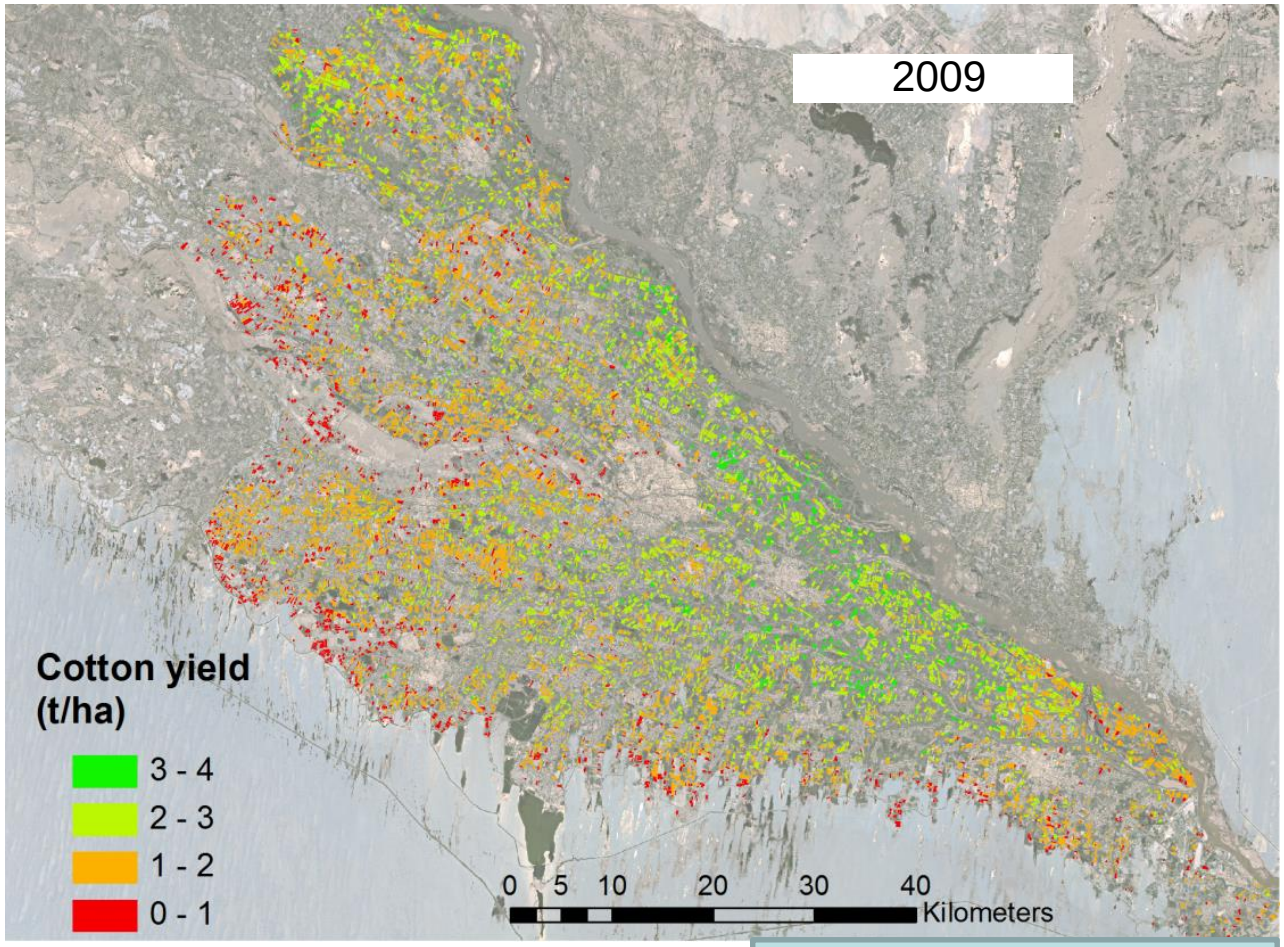
Results – Seasonal ET (Landsat)

Problem of temporal resolution for derivation of seasonal ET product

→ interpolation of Landsat ETF an apply on reference ET.

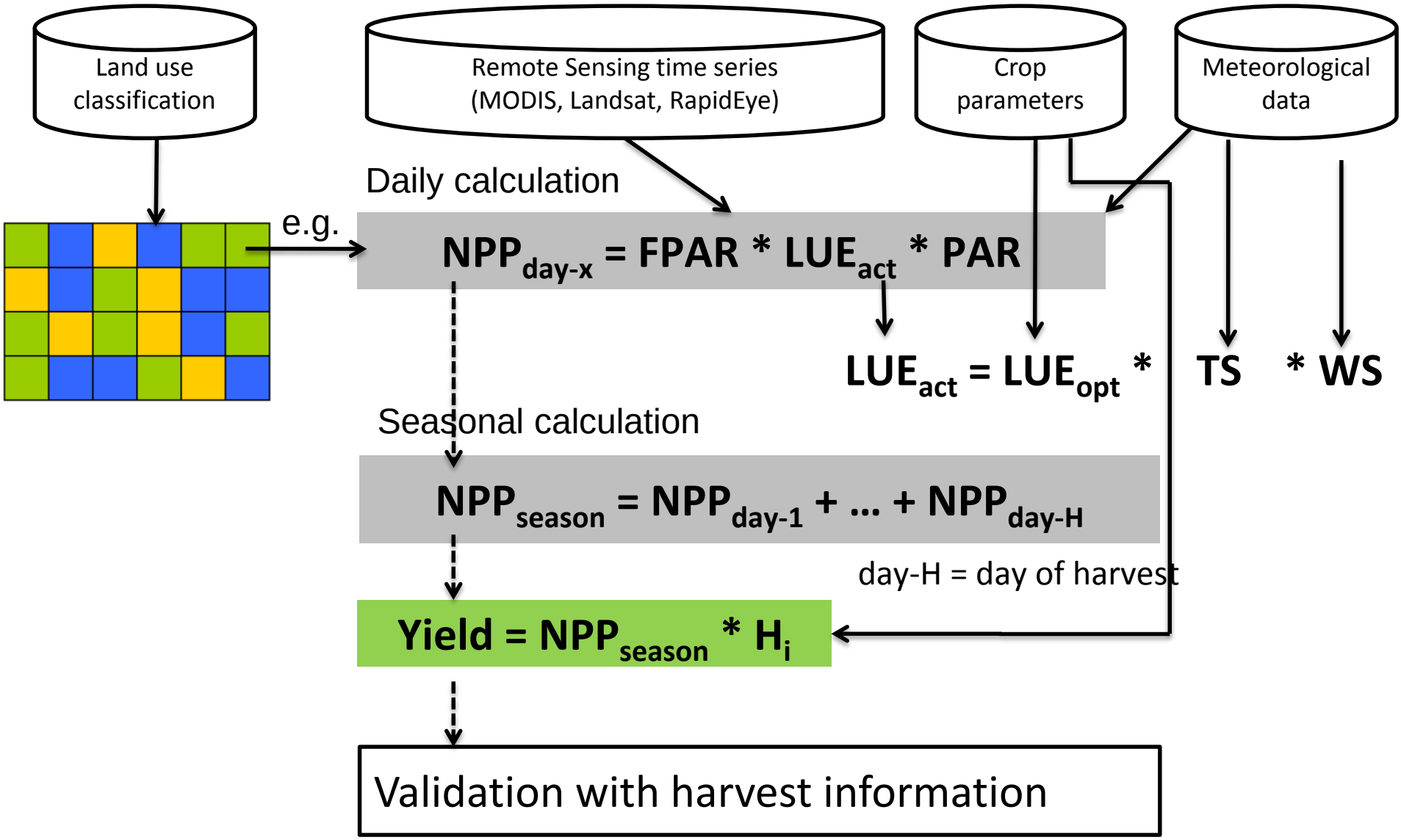


Yield estimation based on Radid Eye (experimental)



Source : Fritsch et al. 2013

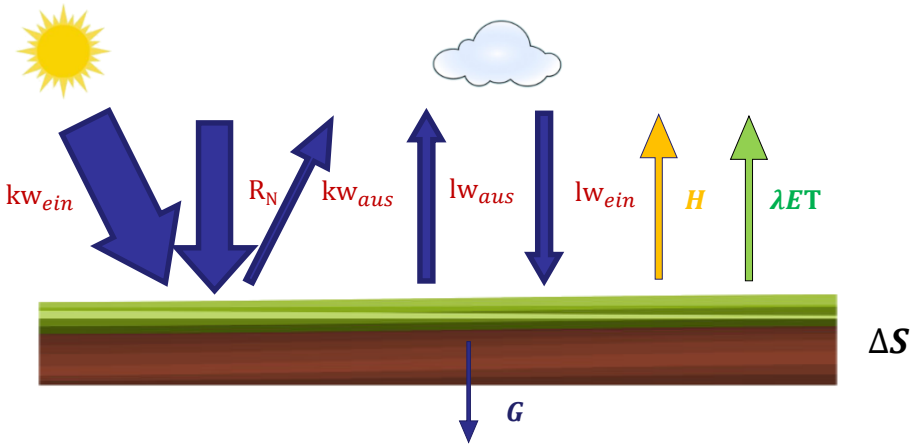
Yield modeling – Light Use Efficiency



Fritsch, 2013

Energiebilanz an der Erdoberfläche

$\mathrm{kw}_{aus} = \mathrm{Albedo}\ der\ Oberfläche \cdot \mathrm{kw}_{ein}$



$$R_N - H - \lambda ET - G = 0$$

R_N: Strahlungsbilanz
H: fühlbarerer Wärmestrom
λET: latenter Wärmestrom
G: Bodenwärmestrom
ΔS: gespeicherte Energie

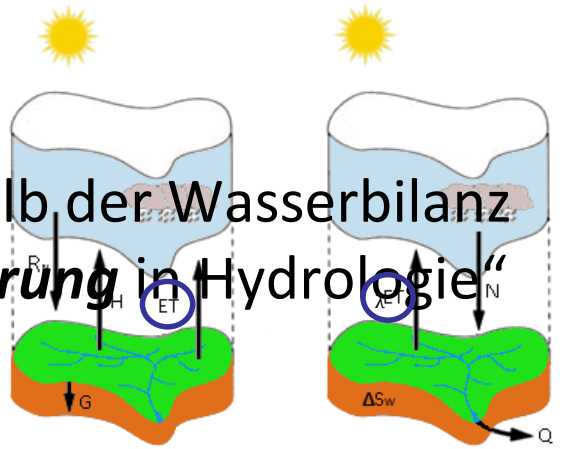
Vereinfachte Energiebilanzgleichung:

Bedeutung der Energiebilanz

„Das Verständnis des ***Energie-*** sowie des ***Wasserkreislaufes*** ist zur Beschreibung der komplexen Wechselwirkungen innerhalb des Klimasystems der Erde essentiell.“ (Kuttler, 2009)

„Realistische Abschätzung der ET innerhalb der Wasserbilanz zählt zu den ***wesentlichsten Herausforderung*** in Hydrologie“ (Li et al., 2009)

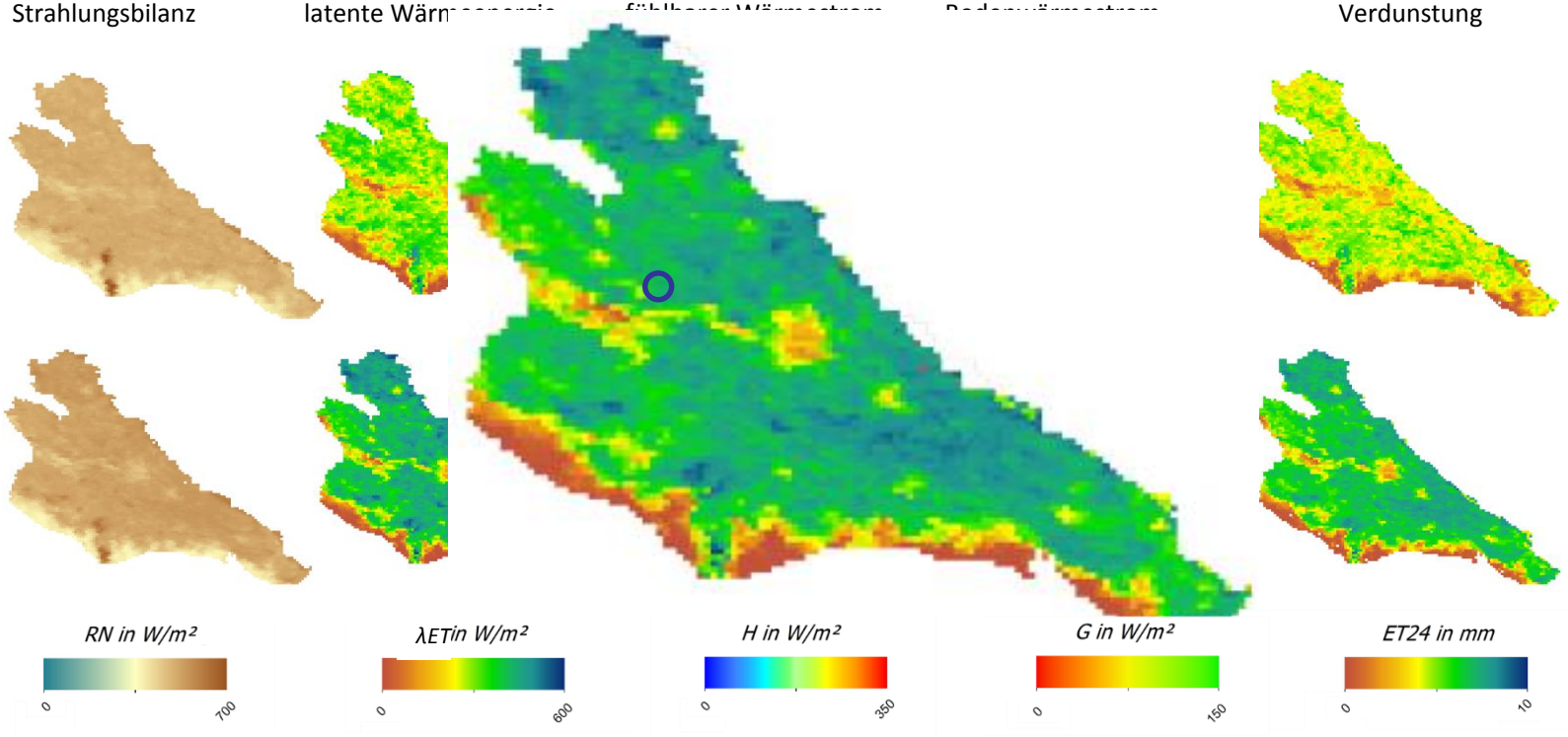
„Besondere Bedeutung der Evapotranspiration (ET) da sie Teilkomponente ***beider Kreisläufe*** ist“ (Foken, 2006)



$R_N - H - \lambda ET - G = 0$
Energiebilanz

$N + ET + Q \pm \Delta S_W = 0$
Wasserbilanz

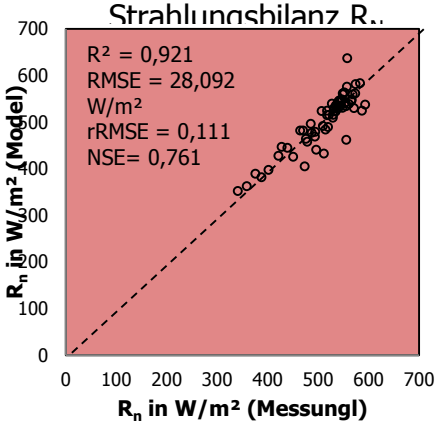
Ergebnisse der Energiebilanzmodellierung

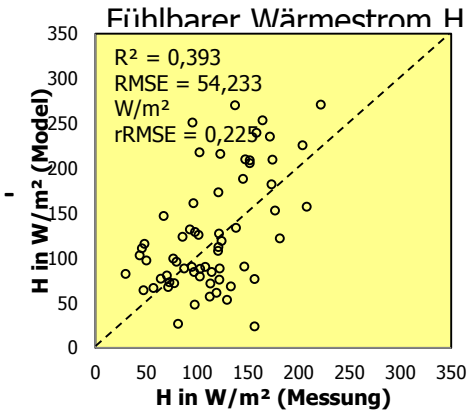


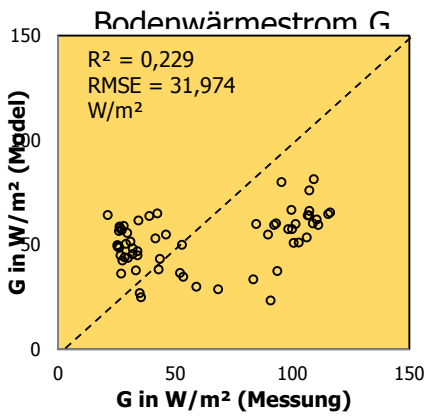
Modellvalidierung

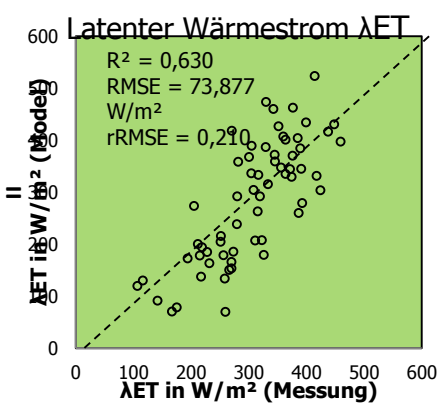
Ermittelte Gütemaße für das Jah

Qualität	R^2 und NSE	rRMSE
Sehr gut	> 0,75	< 0,2
Gut	> 0,5	< 0,3
ausreichend	> 0,25	< 0,4
unzureichend	< 0,25	> 0,4

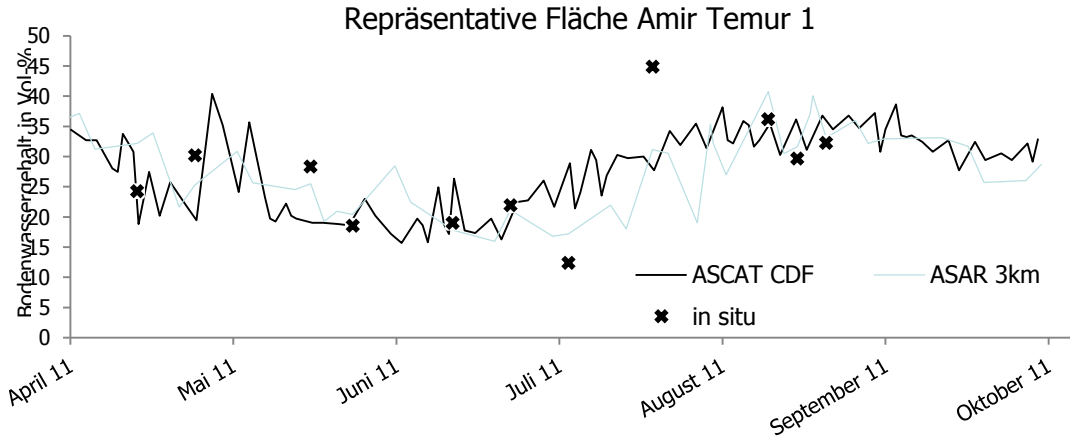


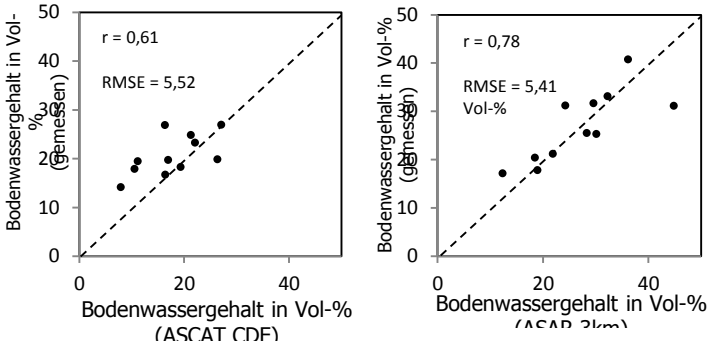






Produktvalidierung: Radarbodenfeuchte



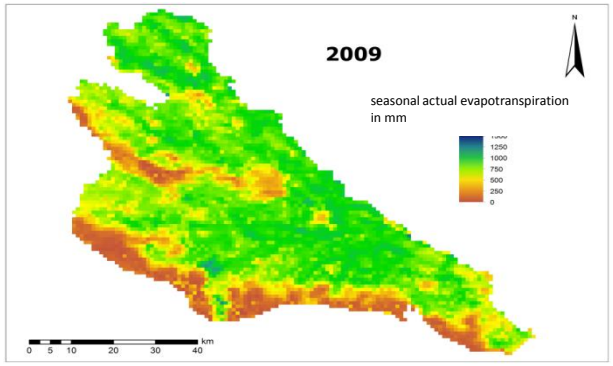


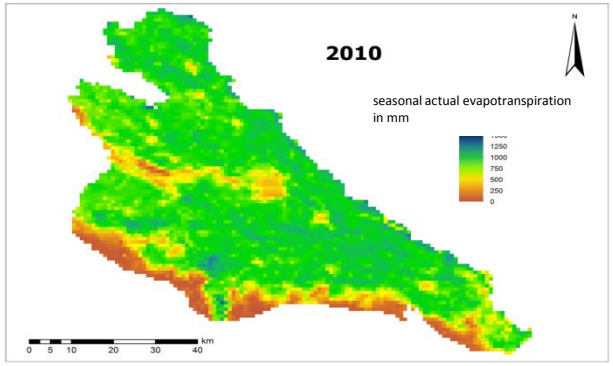
Produktvalidierung → geeignete Qualität des Radarbodenfeuchteprodukts

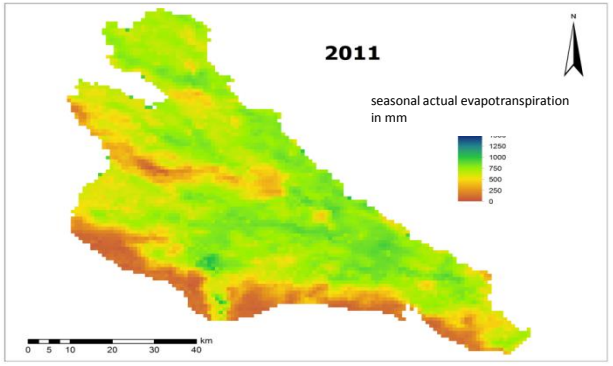
3. Forschungsziel: **Entwicklung und Evaluierung eines neuen Berechnungsansatzes zur Bestimmung des Bodenwärmestroms**

Model results

Seasonal evapotranspiration



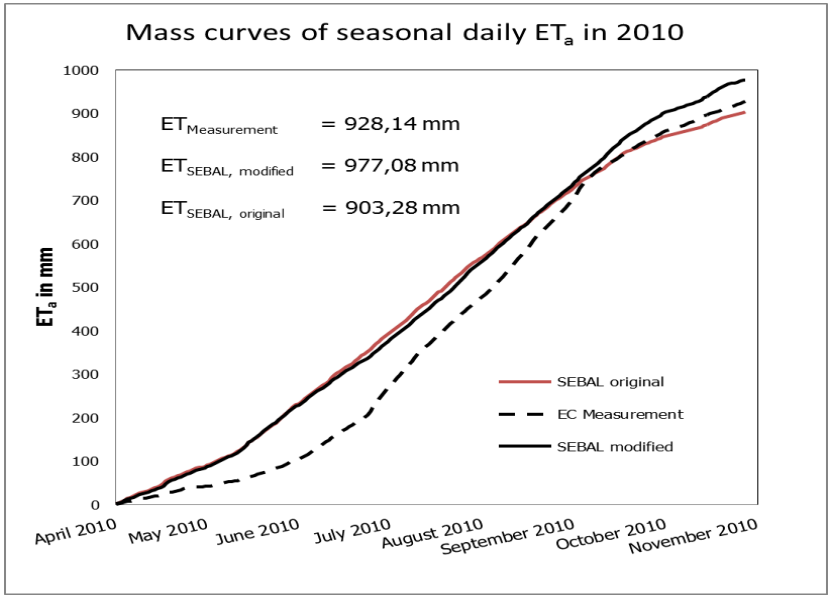


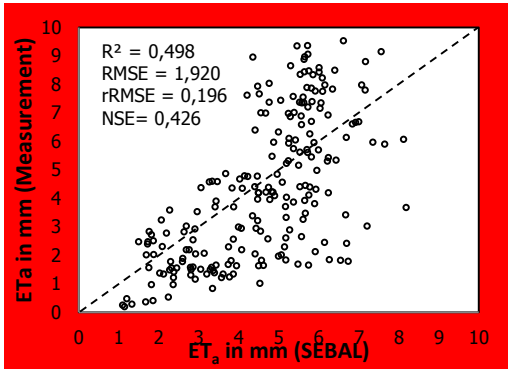


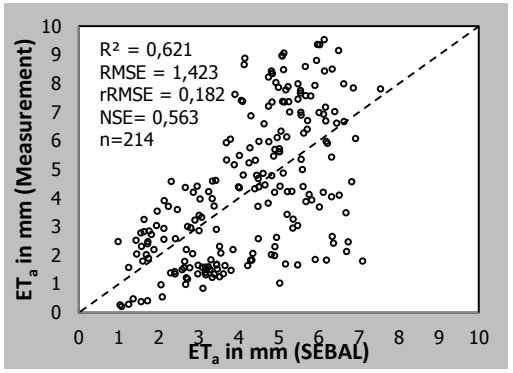
Year	Min in mm	Max in mm	Mean in mm	Variance in mm	seasnonal ET_a in km^3	yearly available irrigation water[1] in km^3
2009	4.9	1250.5	676.4	194.6	3,534	3,440
2010	5.4	1372.3	790.6	224.4	4,146	4,278
2011	4.1	1041.9	606.6	173.5	3,184	2,958

[1]Data source : SIS ICWC (2012)

Evaluation of ET_{24}







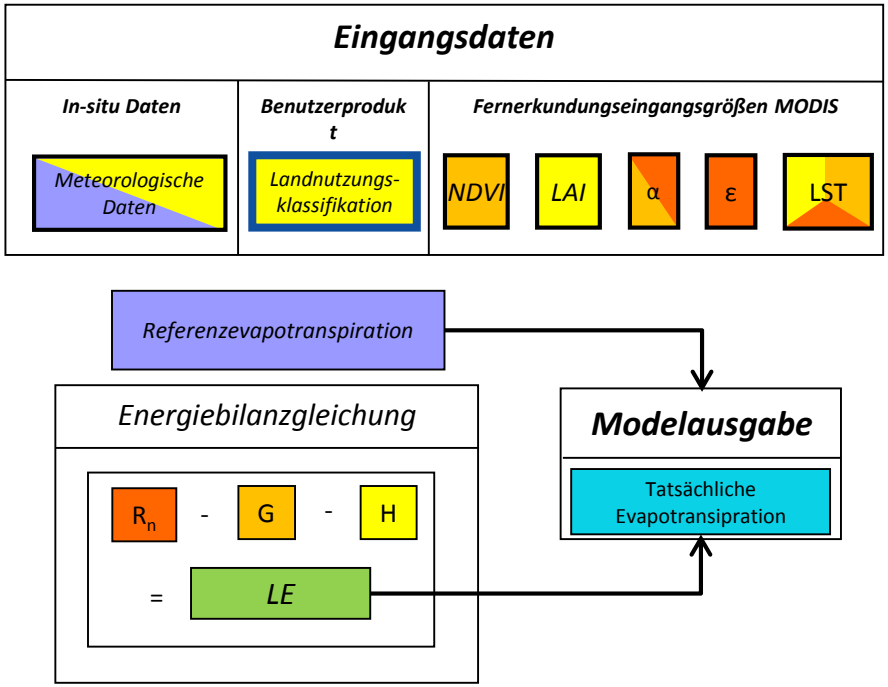
Remote Sensing Data

- SEBAL was implemented based on MODIS time series to estimate seasonal ET
- Microwave remote sensing data was implemented to estimate G
- Selection of useable MODIS scenes based on quality criteria

Year	Valid MODIS scenes after QA
2009	48
2010	63
2011	60

Parameter	Product	Instrument	Platform	Spatial resolution	Temporal resolution
Land surface temperature and Emissivity	MOD11A1 (LST)	MODIS	Terra	1km	daily
Vegetation index	MOD13A2 (NDVI)	MODIS	Terra	1km	16-day
Albedo	MOD43B3	MODIS	Terra	1km	16-day
Leaf area index	MOD15A2 (LAI)	MODIS	Terra	1km	8-day
Soil moisture	ASCAT SSM ASAR SSM	ASCAT ASAR	MetOp Envisat	25km 1km	daily 3-day
Secondary data					
Land use classification	Derived from MODIS data			250m	seasonally
Meteorological information	Derived from regional climate stations			point	half hourly

SEBAL Modellierung



Parameter	Produkt	Räumliche Auflösung	Zeitliche Auflösung
Landoberflächentemperatur und Emissivität	MOD11A1	1km	täglich
Vegetationsindex	MOD13A2	1km	16-Tage
Albedo	MOD43B3	1km	16-Tage
Blattflächenindex	MOD15A2	1km	8-Tage
Sekundäre Daten			
Landnutzungsklassifikation	Abgeleitet aus MODIS data	250m	saisonal
Meteorologische Daten	Ermittelt von regionalen Klimatstationen	Punkt	Halb-stündlich

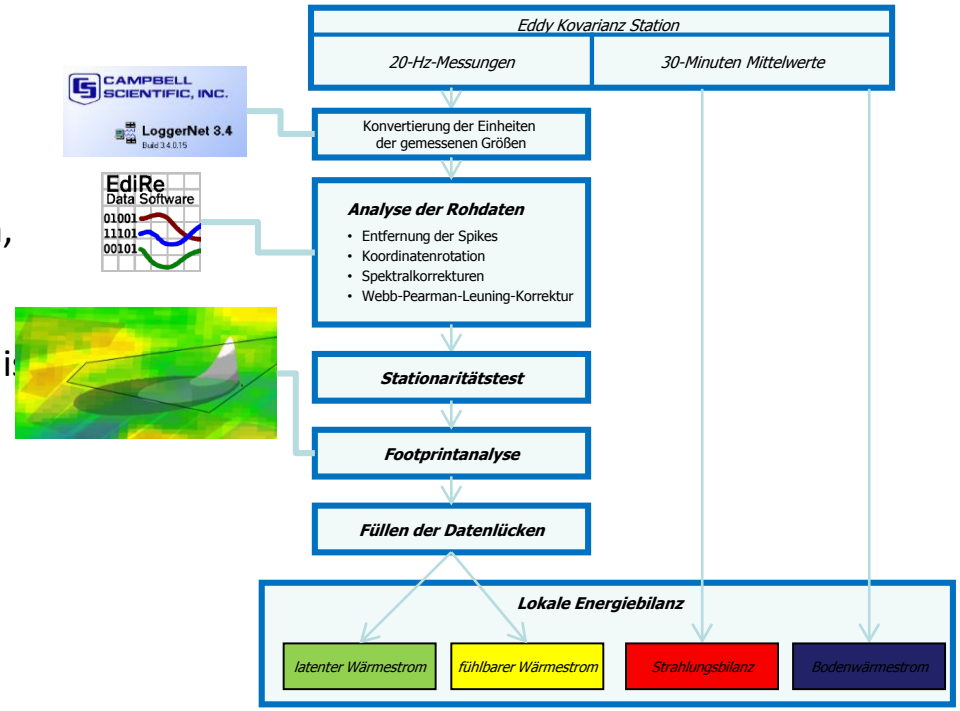
Eddy Kovarianz Datenverarbeitung

Rohdatenverarbeitung und

Qualitätsanalyse u.a.:

- atmosphärischer Schichtung,
- Rohdatenqualität (z.B. Spikes, Rauschen, usw.),
- Windrichtung (z.B. Störquellen, Hindernis
- Schubspannungsgeschwindigkeit,
- Footprint (Homogenität des Messuntergrundes).

→Datenausfallrate ca. 65%



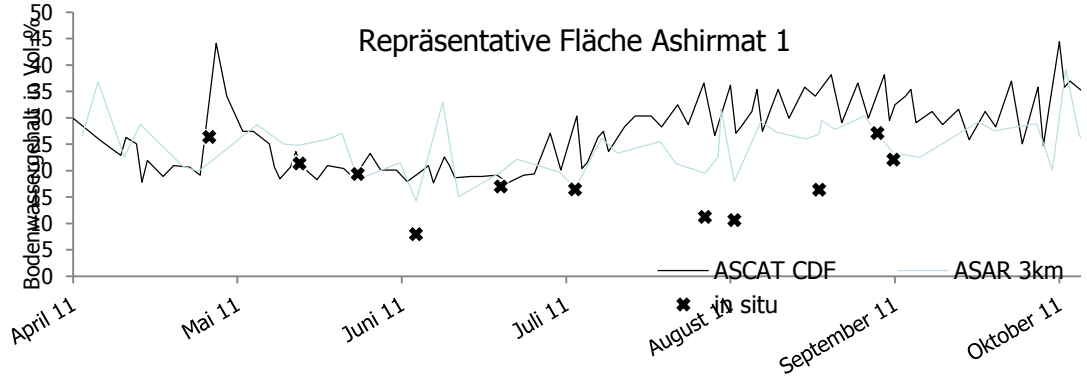
ET-Modellierung

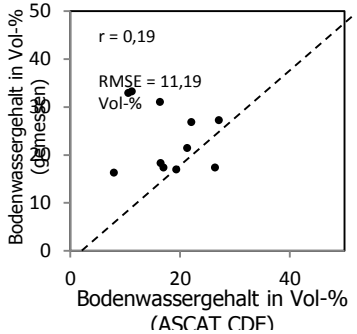
Implementierung des auf Landsat Datenbasis entwickelten SEBAL Algorithmus
für MODIS Daten

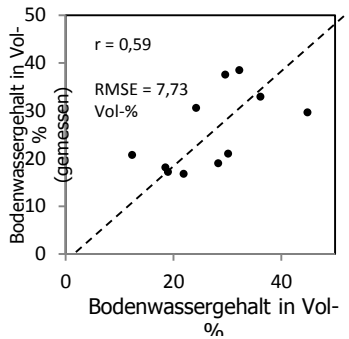
Begrenz ngsten räumlich

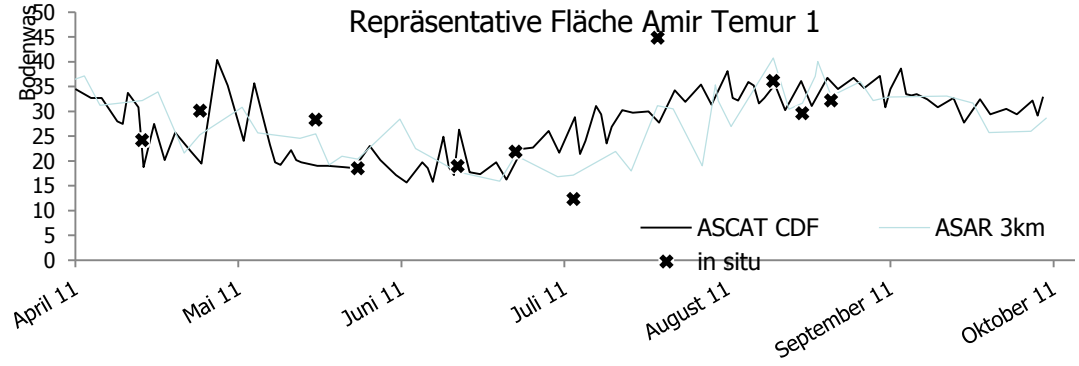
Parameter	Produkt	Instrument	Platform	Räumliche Auflösung	Zeitliche Auflösung
Landoberflächentemperatur und Emissivität	MOD11A1	MODIS	Terra	1km	täglich
Vegetationsindex	MOD13A2	MODIS	Terra	1km	16-Tage
Albedo	MOD43B3	MODIS	Terra	1km	16-Tage
Blattflächenindex	MOD15A2	MODIS	Terra	1km	8-Tage
Bodenfeuchte	ASCAT SSM ASAR SSM	ASCAT ASAR	MetOp Envisat	25km 1km	täglich 3-Tage
Sekundäre Daten					
Landnutzungsklassifikation	Abgeleitet aus MODIS data			250m	saisonal
Klimastationsinformationen	Ermittelt von regionalen Klimatstationen			Punkt	halbstündlich

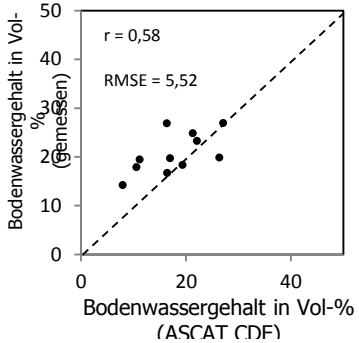
Produktvalidierung: Radarbodenfeuchte

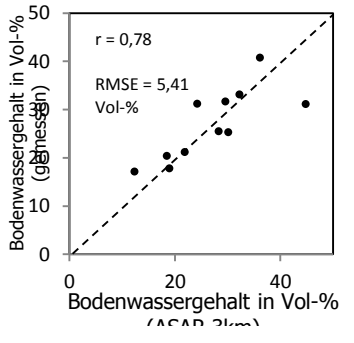






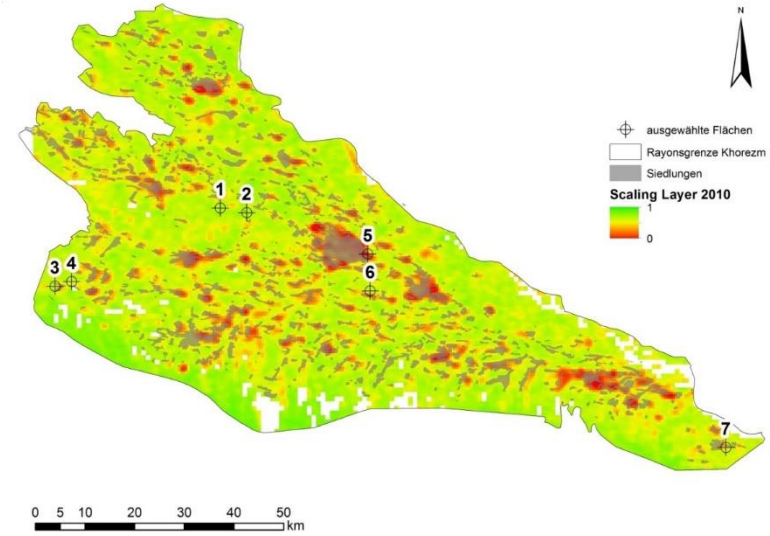






Validierung der Bodenfeuchte

Messung an repräsentativen Orten → Anzahl der in-situ Messpunkte eines Bodenfeuchtenetzwerkes kann demnach minimiert



ität vo

SSM (

und Θ

trächt

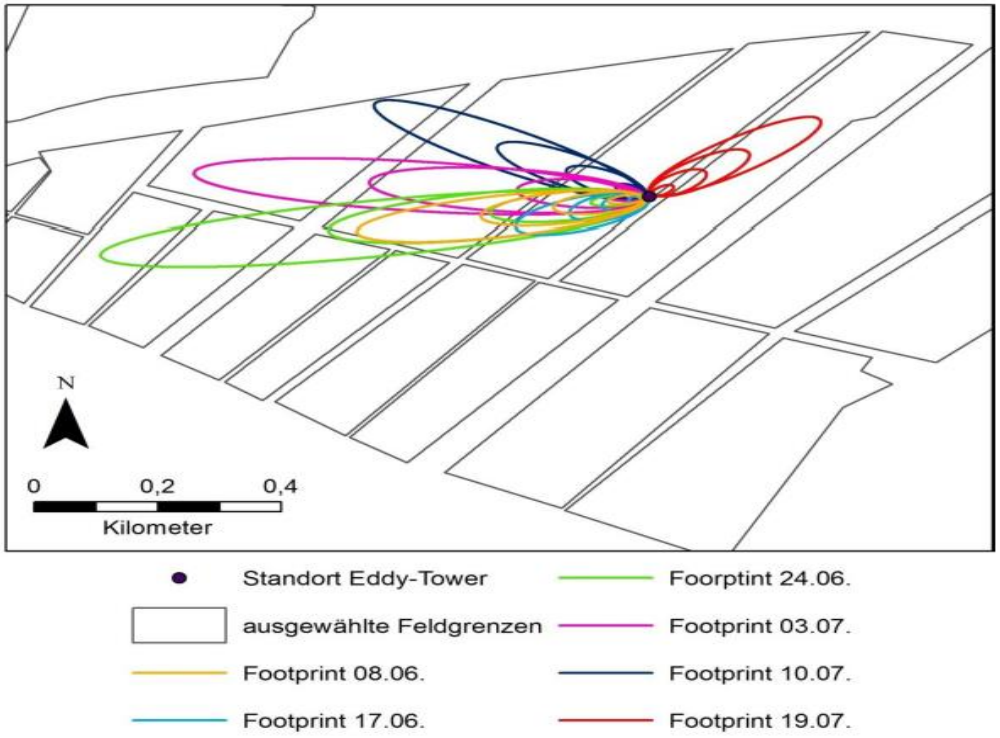
Nr.	Bezeichnung der Messstelle	Werte des SL-2010	Saisonale zeitliche Stabilität 2011
1a	Amir Temur 1	0,617	0,507
1b		0,636	0,578
2	Amir Temur 2	0,702	0,579
3a	Ashirmat 1	0,571	0,332
3b		0,598	0,367
3c		0,503	0,344
4a	Ashirmat 2	0,597	0,546
4b		0,582	0,502
4c		0,540	0,416
5	CRI	0,093	0,291
6	Khanka	0,311	0,307
7a	Pitnak	0,373	0,503
7b		0,343	0,560
7c		0,473	0,503

3. Ergebnisse und Validierung - Footprintanalyse

Zur Bestimmung der gültigen Tage der Flussmessungen wurde eine Footprintanalyse durchgeführt.

(Tage an denen der Footprint überwiegend im zu betrachtenden Subökosystem liegt, hier: Baumwollökosystem)

Vorherrschende Windrichtung ist SSW bis WSW.

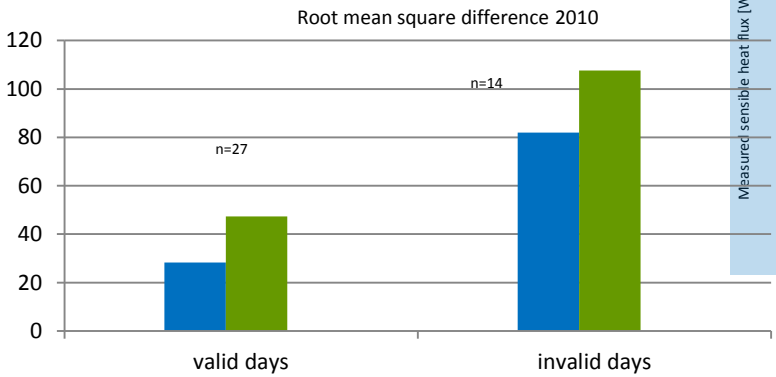


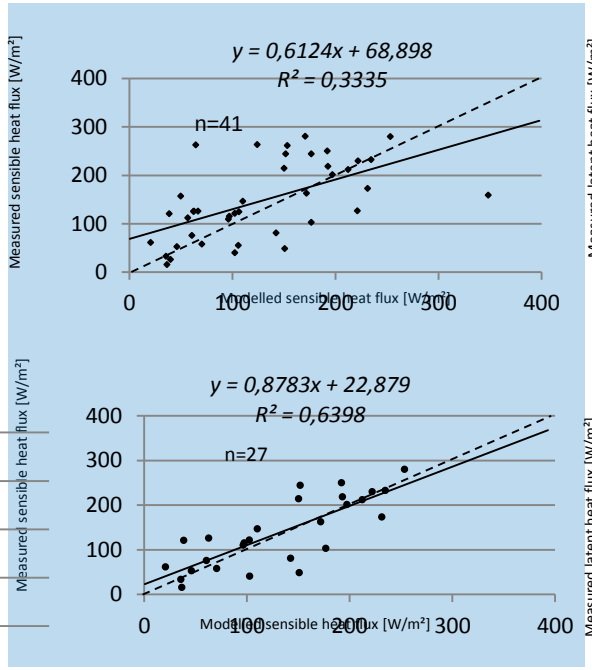
3. Ergebnisse und Validierung - Footprintanalyse

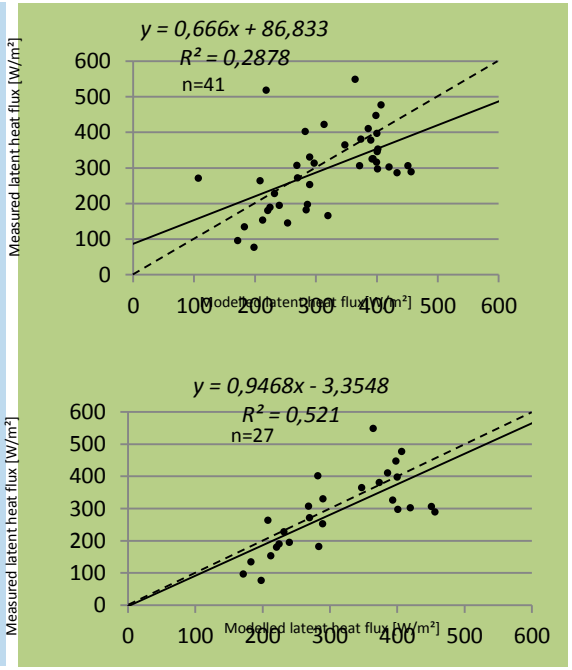
Die Durchführung einer Footprintanalyse führt zu geringeren RMSD verglichen mit den RMSD für alle Tage für die ein Modelllauf durchgeführt wurde.

Schwächere Korrelation zwischen Mess- und Modellwerten ohne Footprintanalyse.

Nach der Footprintanaylse stärkerer Zusammhang.

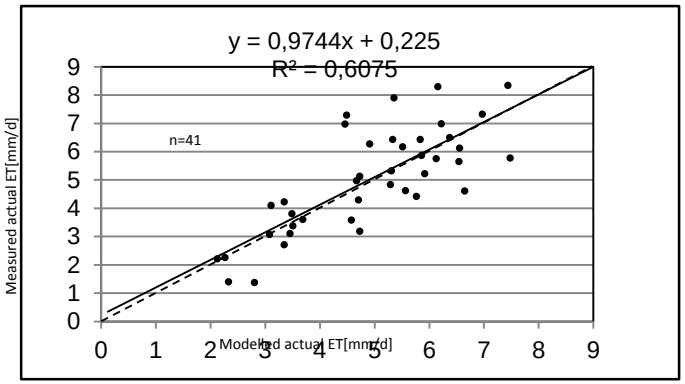




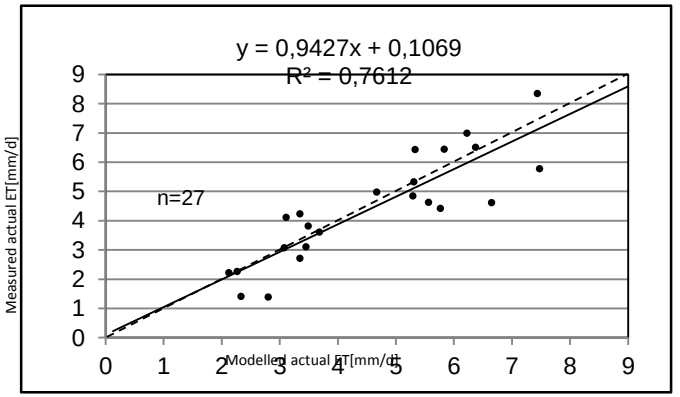


3. Ergebnisse und Validierung - Footprintanalyse

Tägliche tatsächliche Evapotranspiration 2010



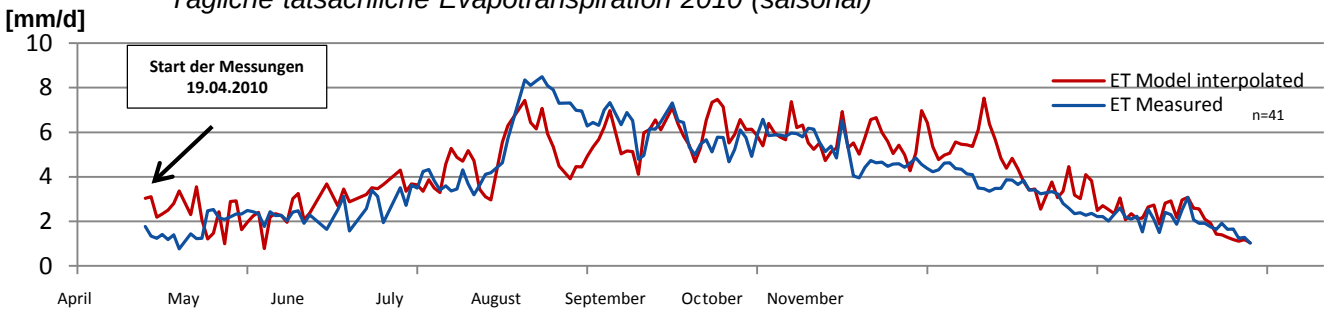
Tage mit gültigen MODIS Szenen



Tage mit gültigem Footprint

3. Ergebnisse und Validierung - Footprintanalyse

Tägliche tatsächliche Evapotranspiration 2010 (saisonal)



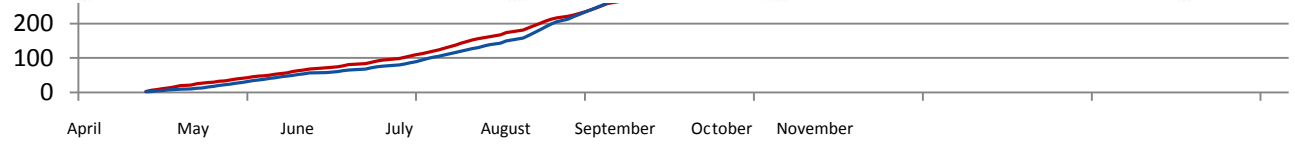

Leaf development


Main stem elongation

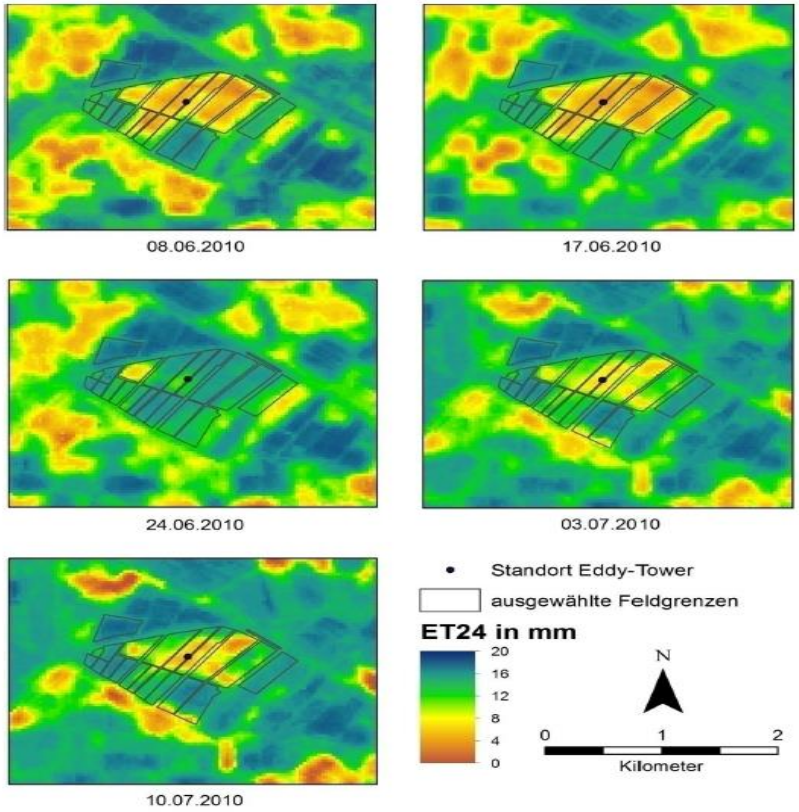

Flowering


Fruit development


Beginning of Ripening



ET24 für die gültigen Tage nach der Footprintanalyse 2010.



Energy balance closure (Landsat)