Forestry Group Meeting
16th & 17th July 2019

NEE/GPP data vs. Remote sensing – integrating results of two models

By Koffi Dodji Noumonvi

This project has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation (H2020-RUR-2017-2) under grant agreement No. 774234. This document reflects the views of the author, and the European Union cannot be held responsible for any use which might be made of the information contained therein.

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Outline

- ✓ Introduction
- ✓ Study area
- ✓ Methodology
- ✓ Results
- ✓ Conclusion

Introduction

Contribution to global carbon cycle

Grasslands → Widespread vegetation type **14-26% of the earth surface**

Abandonned grassland ➔ regrowth, + carbon sequestration

Eddy covariance method ➔ Measurements of fluxes : atmosphere-ecosystem

EC: Podgorski kras grassland (2008) → Monitor carbon fluxes

Limited footprint!!

How to estimate carbon fluxes outside the tower footprint?

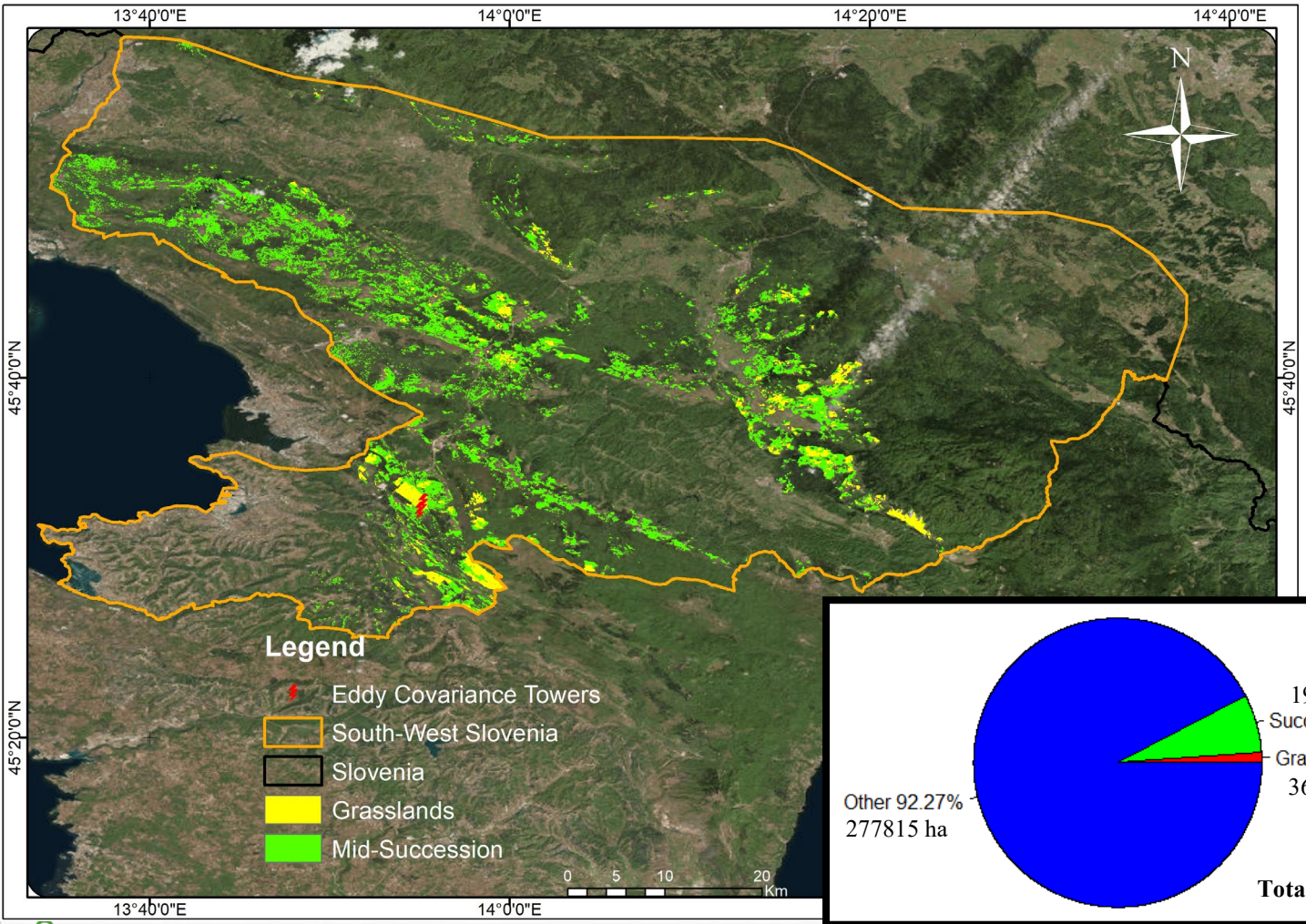
Introduction

Objectives

Objective:
Estimate carbon fluxes for SW Slovenian karst grasslands and mid-succession sites, by combining EC data with VIs.

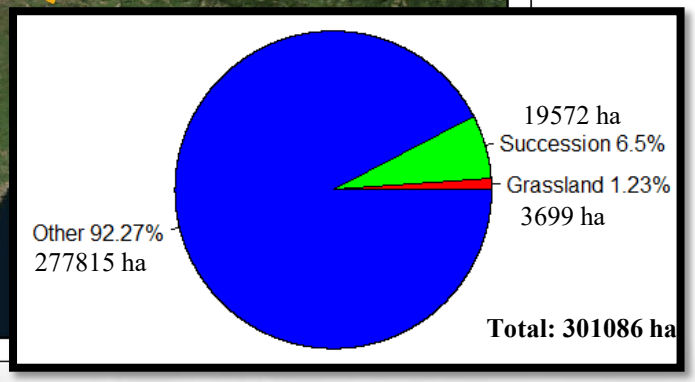
- ✓ Estimate NEE and GPP using different vegetation indices in statistical modelling
- ✓ Select the best models based on accuracy metrics
- ✓ Integrate the best performance models to map NEE and GPP for a given period in the study area

Study area



Karst area in S.W. Slovenia

- Karst ➔ limestone, rocky, superficial soils
- Climate ➔sub-Mediterranean
- Growing season ➔ March/April to October



Proportion of grassland and succession

Methodology

Grassland

Data

Eddy Covariance + Meteo

-NEE & GPP
-Tair, VPD, P, PAR/Rg…

Footprint

Vegetation indices

300m, 10d -Proba-V ($NDVI_{PV}$)
30m, 16d -Landsat 8

$$NDVI = (NIR - R) / (NIR + R)$$

$$GNDVI = (NIR-G) / (NIR + G)$$

$$EVI = (2.5 * (NIR - R)) / (NIR + 6R - 7.5B + 1)$$

$$SAVI = ((1 + L)(NIR - R)) / (NIR + R + L)$$

Greenness-related

$$LSWI = (NIR-SWIR1) / (NIR + SWIR1)$$

$$MNDWI = (G - SWIR1) / (G + SWIR1)$$

$$NDSVI = (SWIR1 - R) / (SWIR1 + R)$$

Water-related

Methodology

Grassland

Data

Eddy Covariance + Meteo

-NEE & GPP
-Tair, VPD, P, PAR/Rg…

Footprint

Vegetation indices

300m, 10d -Proba-V ($NDVI_{PV}$)
30m, 16d -Landsat 8

Models

1. NEE or GPP = a*VI + b
2. GPP = a*(VI*PAR) + b
3. GPP = (a*VI+b)*PAR

Sources:
Rossini et al. (2012)
Nestola et al. (2016)
Noumonvi et al. (2019)

➔Results

-Accuracy metrics (R^2, RMSE, AIC) ➔ **Best models**

Methodology

Grassland

Data

Eddy Covariance + Meteo

-NEE & GPP
-Tair, VPD, P, PAR/Rg…

Footprint

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Models

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➔Results

-Accuracy metrics (R^2, RMSE, AIC) ➔ **Best models**

-Aggregation of flux data:

(1) Midday (11am-4pm) vs. daily (24h) avg of 30 min fluxes

(2) To match VI data: 10 days average for Proba-V & 5 days average for Landsat

-Separation of the growing season in 2 phases based on VPD (1500 Pa)

Methodology

Mid-Succession

Models

1. Empirical models

Log(-GPP)=a*VI+b

Log(-NEE+c)=a*VI+b

2. Vegetation Production Model

GPP = PAR * fAPAR * LUEmax * Ws * Ts

Sources(2):
(Xiao et al., 2005)

Entire growing season as one!

No MNDWI & NDSVI

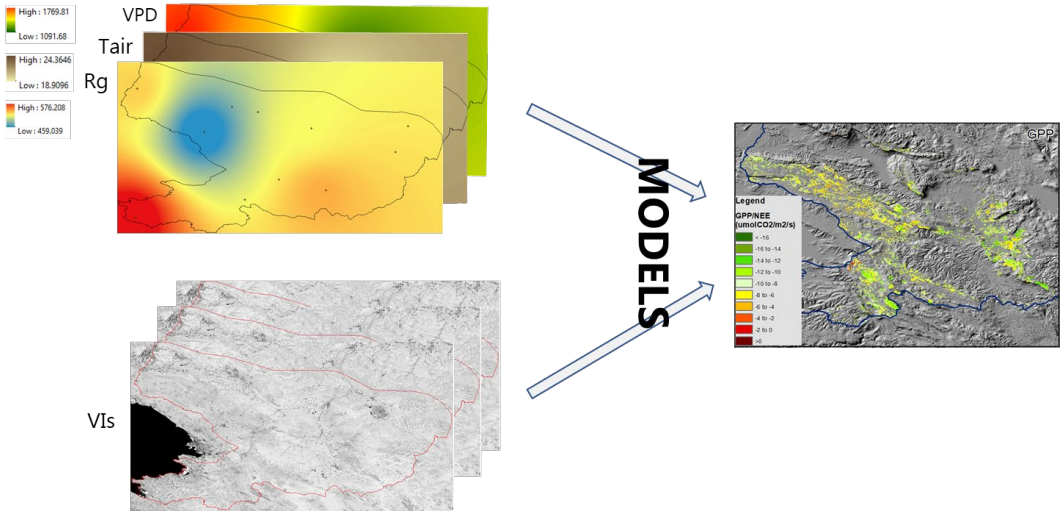
$$W_{scalar} = \frac{1+LSWI}{1+LSWImax}$$

$$T_{scalar} = \frac{(T-Tmin)(T-Tmax)}{[(T-Tmin)(T-Tmax)-(T-Topt)^2]}$$

Methodology

Integration

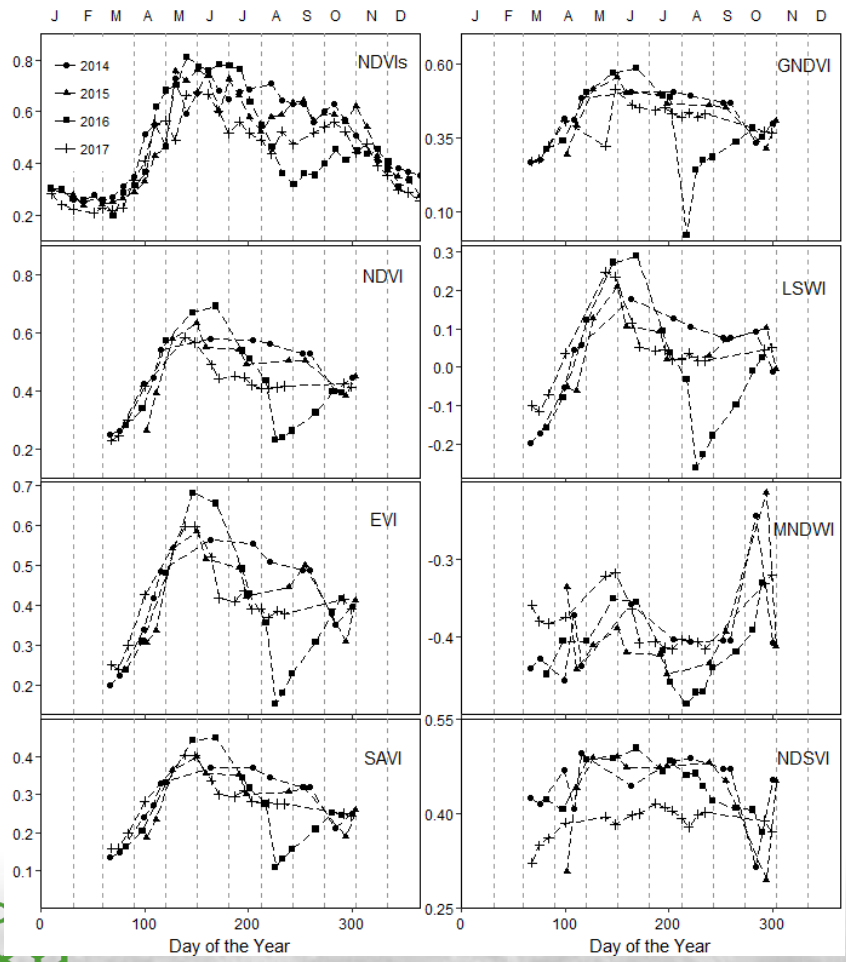
- ✓ Calculation of midday and daily fluxes for a period for illustration (Landsat)
  - -Data (meteo data from ARSO, landsat image downloaded using GEE)
  - -Integration of the 2 sets of model to calculate carbon fluxes.



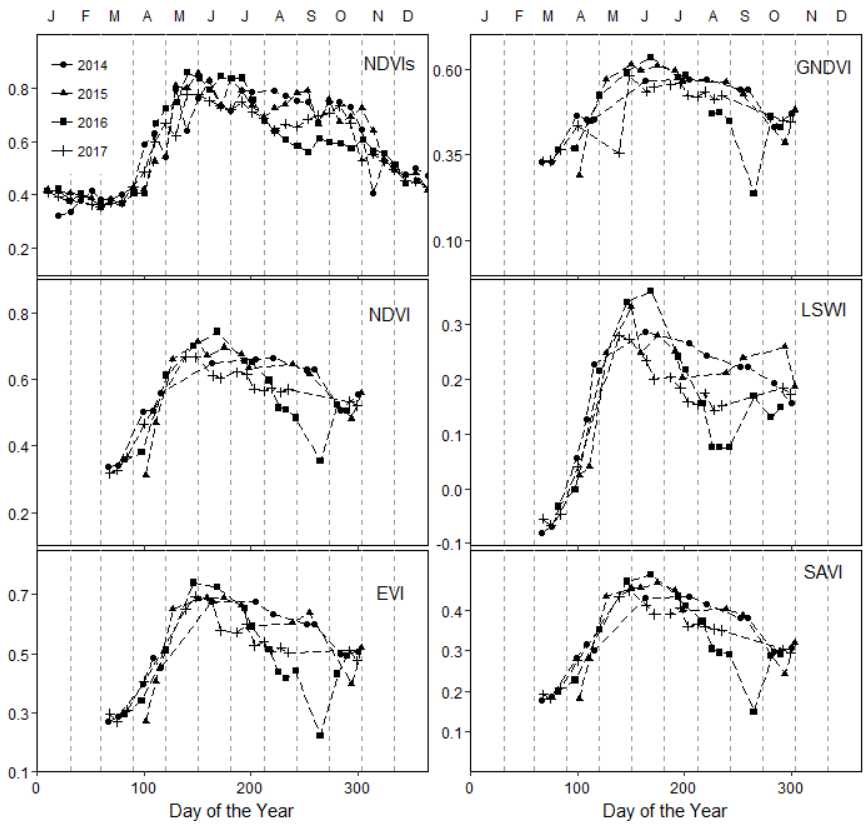
- ✓ Summary of carbon fluxes per land cover

Results (VIs)

Grassland

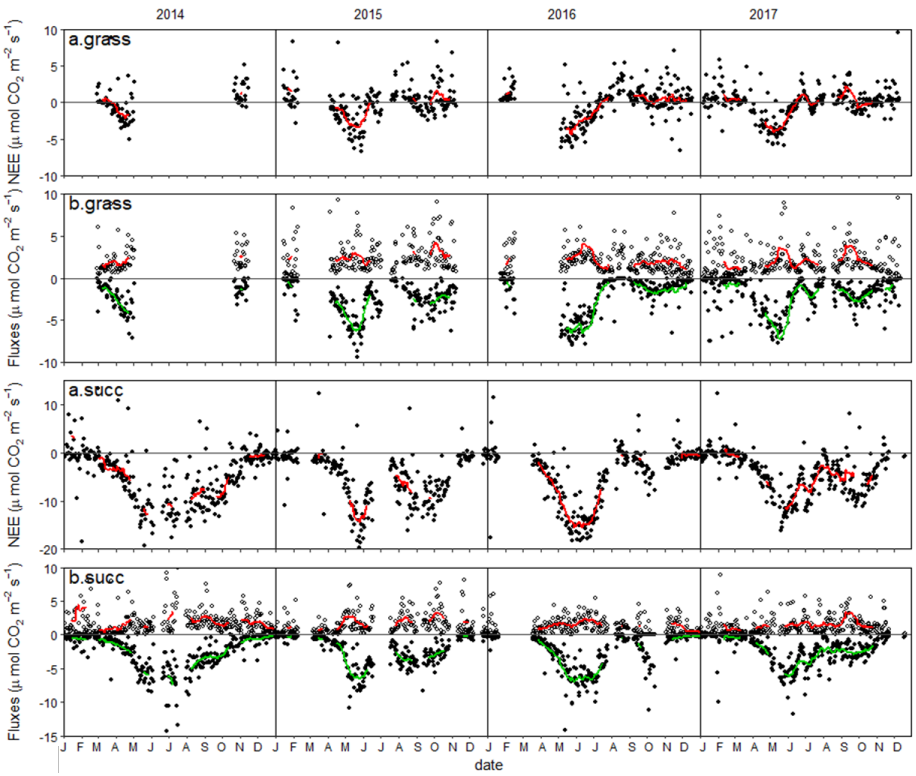


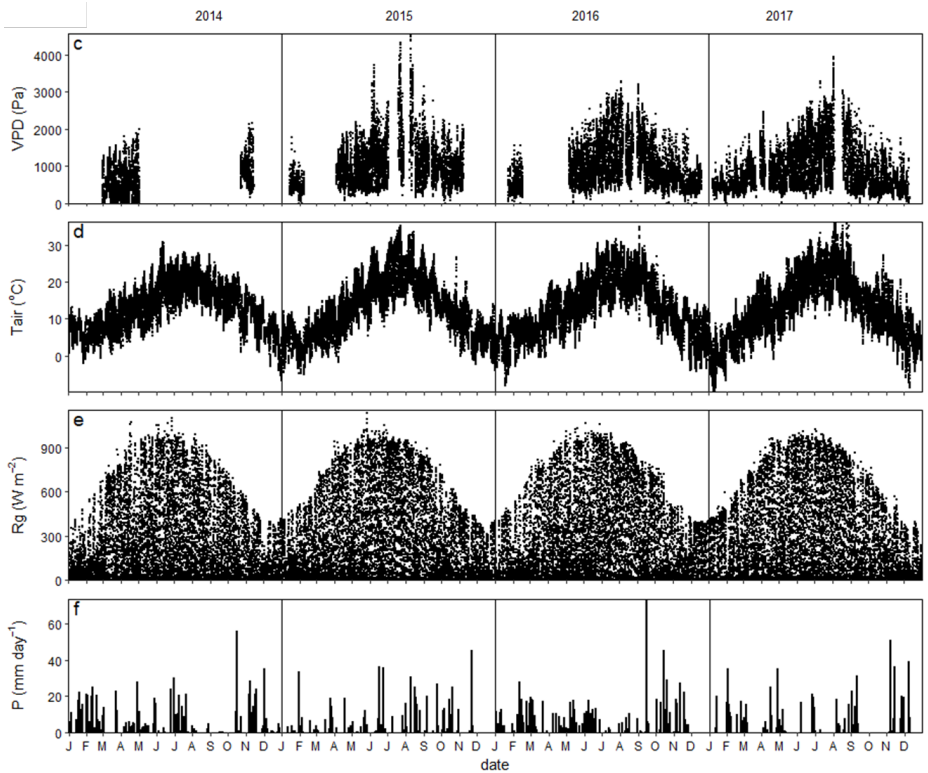
Mid-succession



Results

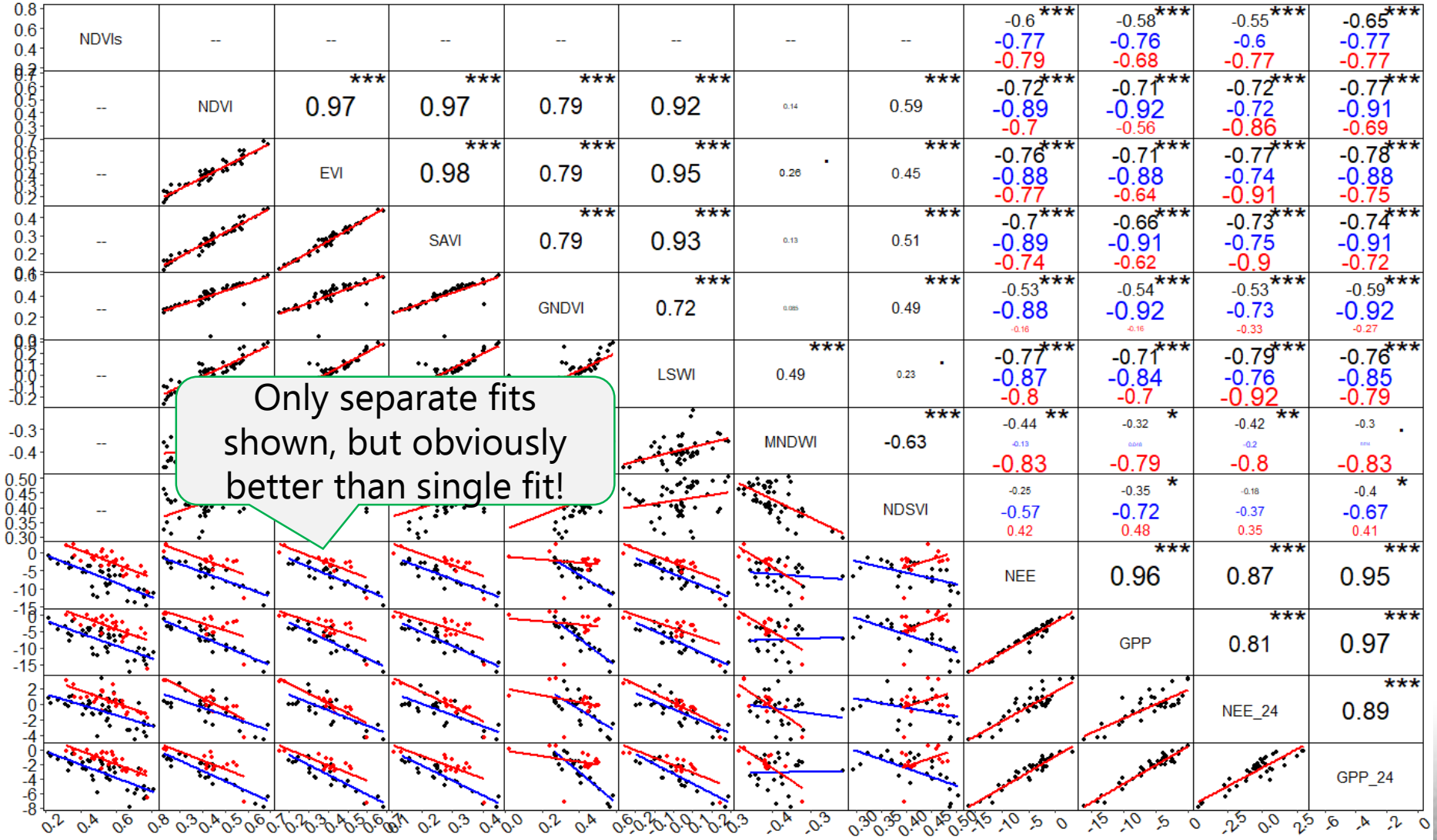
(Fluxes & Env. Params)





Results

Grassland



Results

Grassland

- Not really possible to make absolute comparison **Landsat**-Proba V
- Regression accuracy metrics ➔ High R^2, Low RMSE & AIC ➔ Best models

Aggregate	VI source	Flux	Greening phase	Dry phase
Midday	Landsat	GPP	-26.34*NDVI+4.17, $R^2=0.85$	-64.9*MNDWI-30.7, $R^2=0.63$
	Proba-V		-0.03*(NDVIs*PAR)-0.71, $R^2=0.73$	-19.17*NDVIs+7.17, $R^2=0.46$
	Landsat	NEE	-26.03*NDVI+4.76, $R^2=0.80$	-73.81*MNDWI-33.52, $R^2=0.69$
	Proba-V		-19.35*NDVIs+3.13, $R^2=0.59$	-18.49*NDVIs+7.75, $R^2=0.62$
Daily	Landsat	GPP	(-0.044*NDVI+0.004)*PAR, $R^2=0.91$	-29.05*MNDWI-13.93, $R^2=0.69$
	Proba-V		(-0.033*NDVIs)*PAR, $R^2=0.80$	(-0.028*NDVIs+0.01)*PAR, $R^2=0.60$
	Landsat	NEE	-10.72*LSWI-0.57, $R^2=0.58$	-12.34*LSWI+0.3, $R^2=0.86$
	Proba-V		-6.81*NDVIs+2.61, $R^2=0.36$	-7.97*NDVIs+4.88, $R^2=0.59$

Results

Grassland

- Direct correlation (Flux=a*VI+b) = best in many cases ➔

  Green biomass explains most of the variability of GPP in this type of ecosystem

- NDVI ➔ best for the greening phase, MNDWI & LSWI ➔ best for dry phase

Aggregate	VI source	Flux	Greening phase	Dry phase
Midday	Landsat	GPP	-26.34*NDVI+4.17, $R^2=0.85$	-64.9*MNDWI-30.7, $R^2=0.63$
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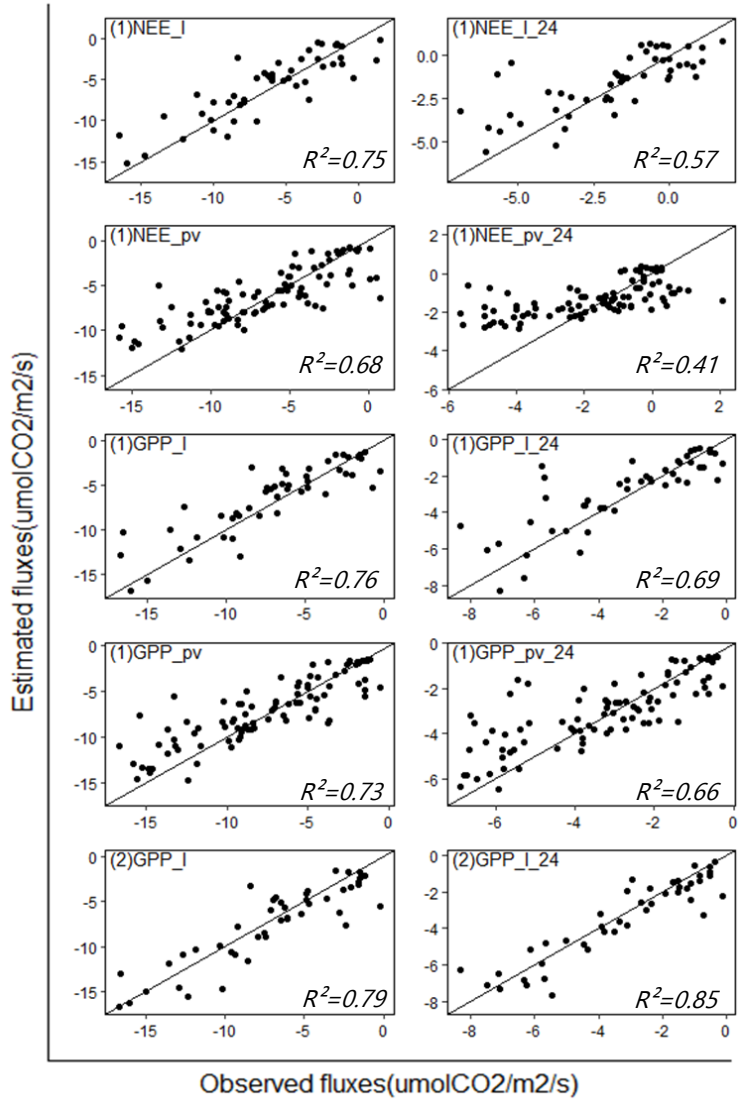
Results

Mid-succession



1. Empirical models

Log(-GPP)=a*VI+b

Log(-NEE+c)=a*VI+b

2. Vegetation Production Model

GPP = PAR * fAPAR * LUEmax * Ws * Ts

- ✓ Better performance with landsat compared to Proba-V
- ✓ VPM model gave better results

Results

Mid-succession

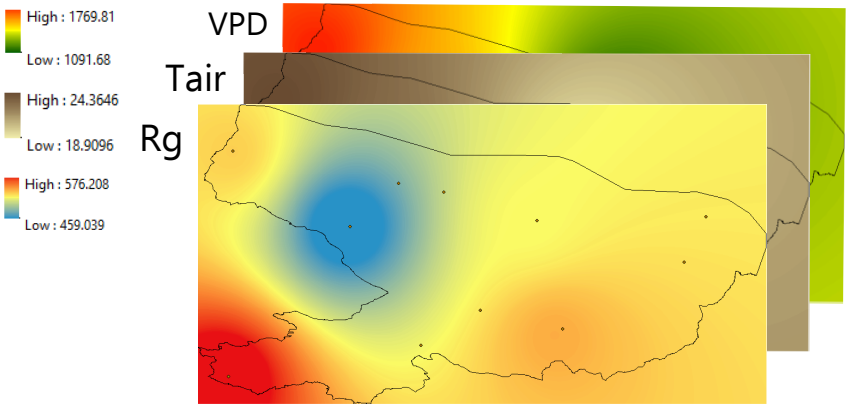
Model	VI source	Flux	Midday	Daily
1	Landsat	NEE	-exp(4.031*EVI -0.133)+2, R^2=*0.75*	-exp(3.679*EVI -0.694)+2, R^2=*0.57*
	Proba-V		-exp(3.234*$NDVI_{PV}$ -0.119)+2.1, R^2=*0.68*	-exp(2.106*$NDVI_{PV}$ -0.209)+2.1, R^2=*0.41*
	Landsat	GPP	-exp(4.924*EVI -0.817), R^2=*0.76*	-exp(5.598*EVI -2.023), R^2=*0.69*
	Proba-V		- exp(4.558*$NDVI_{PV}$ -1.219), R^2=*0.73*	-exp(4.874*$NDVI_{PV}$ -2.319), R^2=*0.66*
2	Landsat	GPP	-0.0325 * EVI * W_s * T_s * Rg, R^2=*0.79*	-0.0363 * EVI * W_s * T_s * Rg, R^2=*0.85*

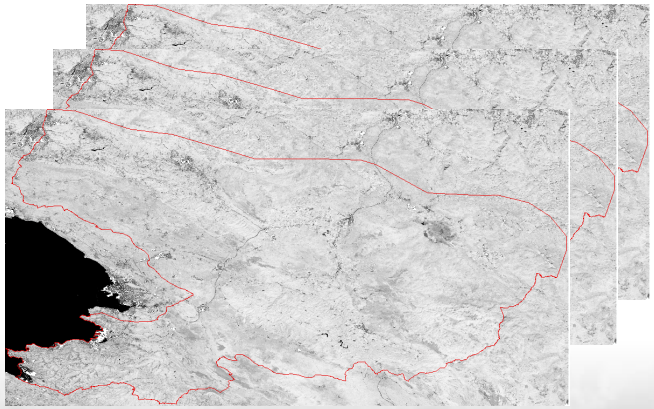
- ✓ EVI was always the best VI (model 1) ➔ Confirms the fact that EVI is more suited for trees than NDVI due to saturation.

- ✓ The VPM model gave higher R^2 than linear regression.

Results

Grassland & Succession Integration (second half 09/2018)





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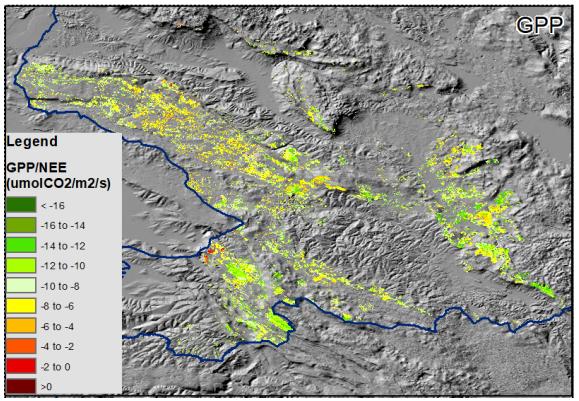
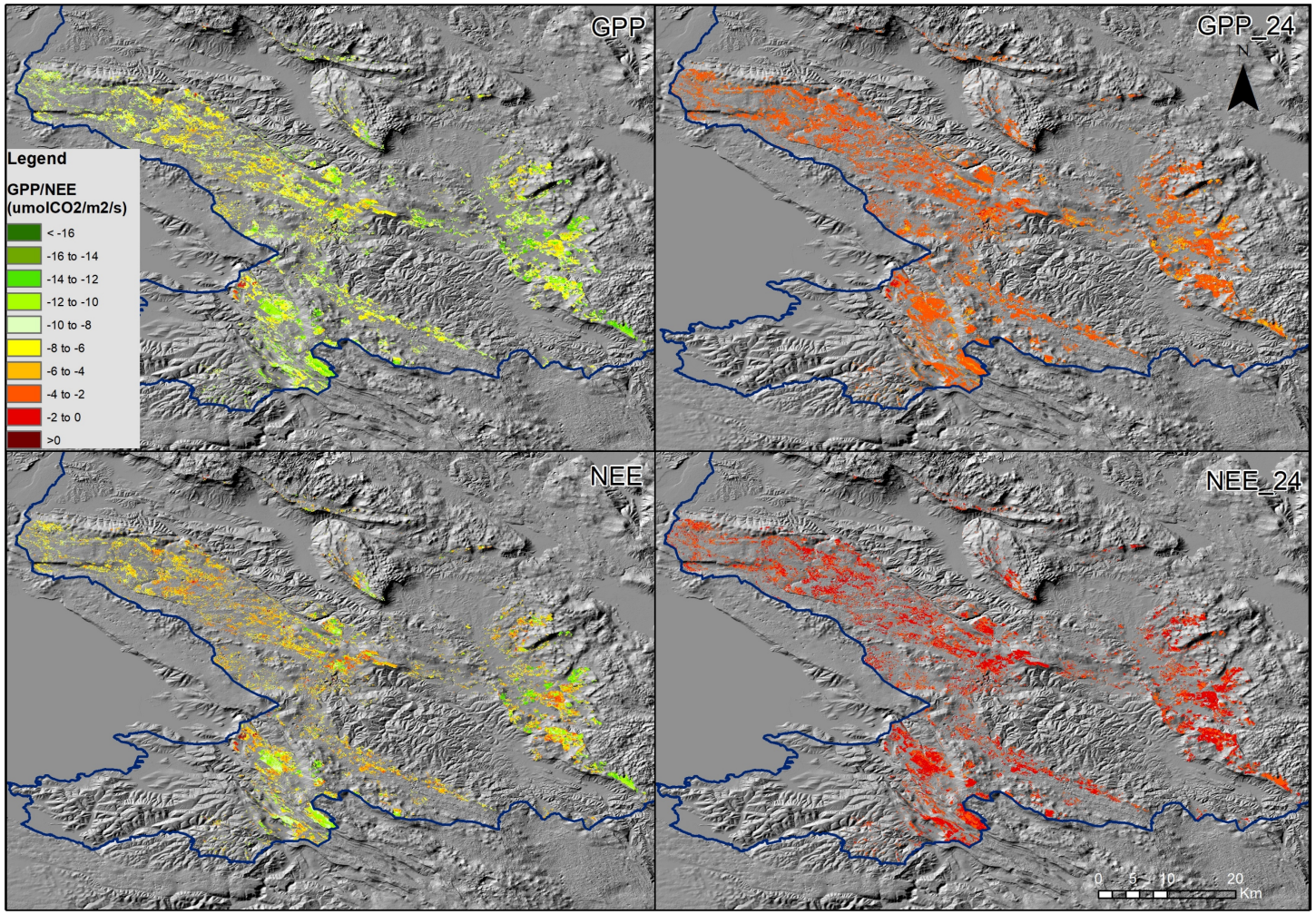
	Proba-V		-0.03*(NDVIs*PAR)-0.71, R^2=0.73	-19.17*NDVIs+7.17, R^2=0.46
	Landsat	NEE	-26.03*NDVI-4.76, R^2=0.80	-73.81*MNDWI-15, R^2=0.69
	Proba-V		-19.35*NDVIs+3.13, R^2=0.59	-18.49*NDVIs+7, R^2=0.62
Daily	Landsat	GPP	(-0.044*NDVI+0.004)*PAR, R^2=0.91	-29.05*MNDWI-3, R^2=0.69
	Proba-V		(-0.033*NDVIs)*PAR, R^2=0.80	(-0.0238*NDVI)*PAR, R^2=0.60
	Landsat	NEE	-10.72*LSWI-0.57, R^2=0.38	-12.34*LSWI, R^2=0.86
	Proba-V		-6.81*NDVIs+2.61, R^2=0.36	-7.97*NDVI-88, R^2=0.59

Model	VI source	Flux	Midday	Daily
1	Landsat	NEE	exp(4.031*EVI-0.133)+2, R^2=0.75	-exp(-0.694*EVI-0.694)+2, R^2=0.57
	Proba-V		p(3.234*NDVIrw-0.119)+2.1, R^2=0.68	-exp(-16*NDVIrw-0.209)+2.1, R^2=0.41
	Landsat	GPP	-4.924*EVI-0.817, R^2=0.76	-9.598*EVI-2.023, R^2=0.69
	Proba-V		-5.558*NDVIrw-1.219, R^2=0.73	-4.874*NDVIrw-2.319, R^2=0.66
2	Landsat	GPP	-0.03*EVI*Ws*Ta*Rg, R^2=0.79	-0.063*EVI*Ws*Ta*Rg, R^2=0.85



Results

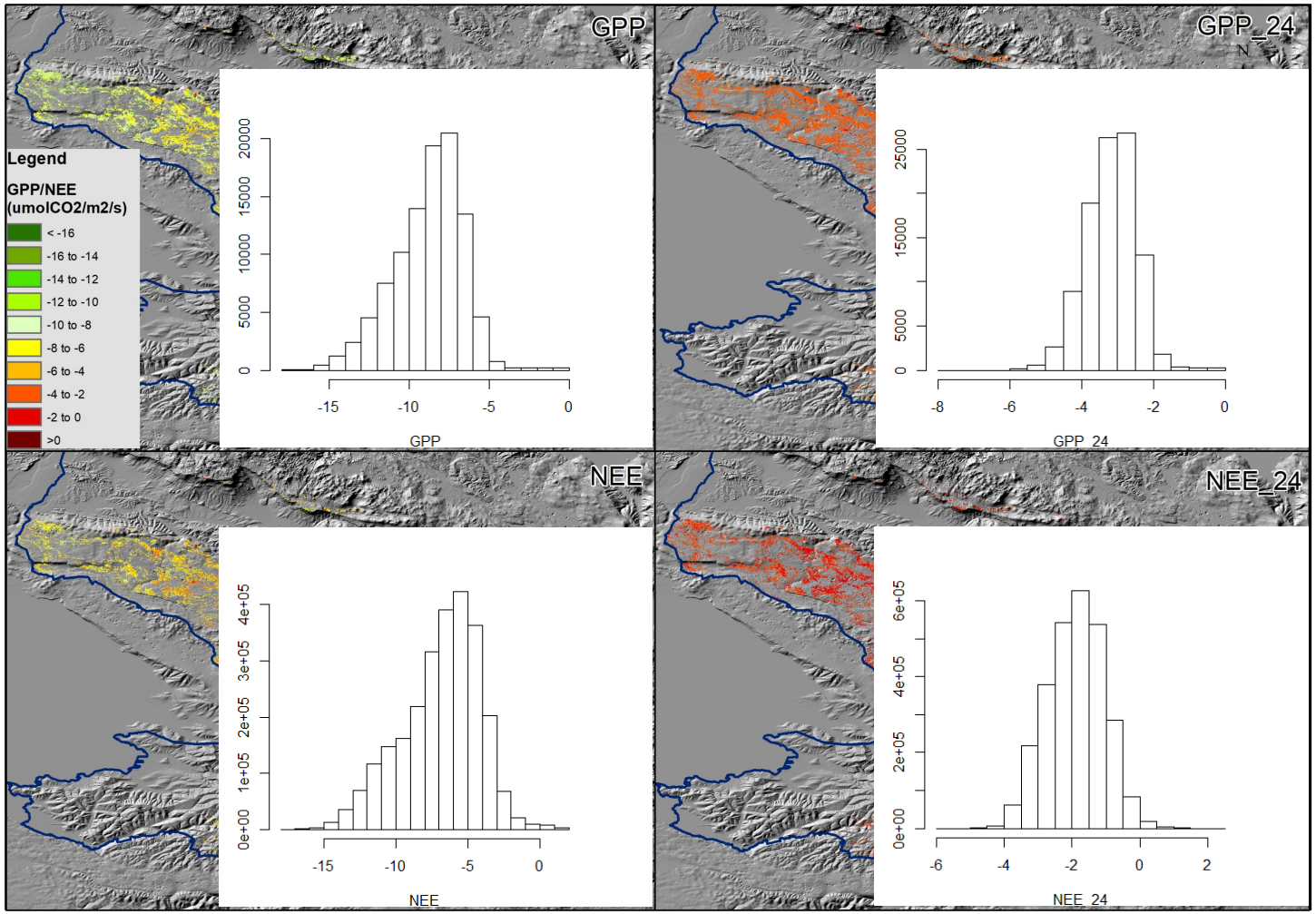
GPP/NEE estimates (15th-30th 09/2018)



- Less difference between midday and daily GPP values compared to NEE
- No visual spatial trend to point out?

Results

GPP/NEE estimates (15th-30th 09/2018)



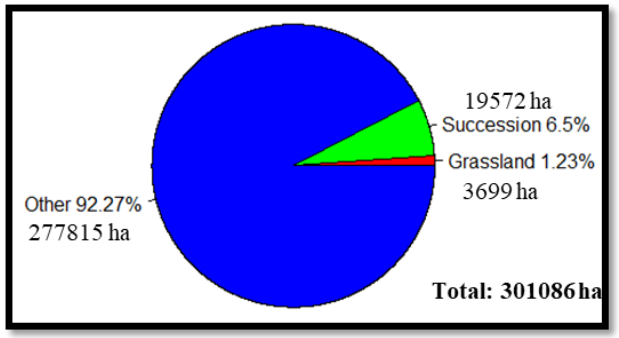
- Less difference between midday and daily GPP values compared to NEE

Results

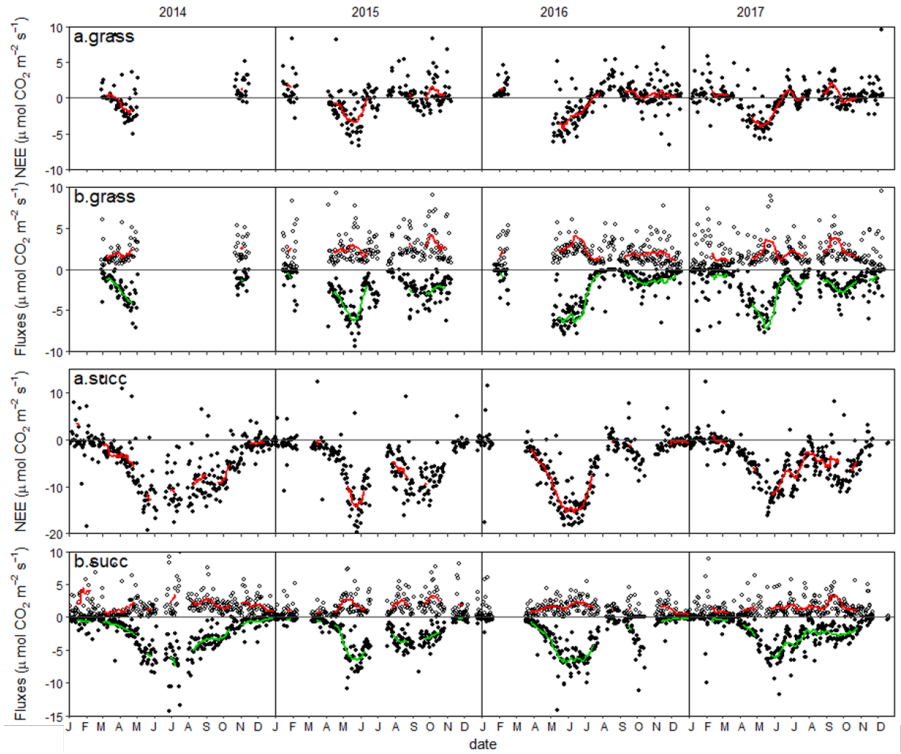
GPP/NEE estimates (15th-30th 09/2018)

Flux estimates for 2018/09/15-2018/09/30

	(gC.m-2)		(ktC)	
	Grassland	Succession	Grassland	Succession
GPP	-39.02	-28.74	-1.443	-5.626
NEE	-36.25	-20.62	-1.341	-4.035
GPP_24	-61.76	-51.14	-2.285	-10.009
NEE_24	-33.04	-31.05	-1.222	-6.077



Proportion of grassland and succession



Conclusions

To take away

- (GPP or NEE) ~ VIs, different types of model, 2 types of aggregation of fluxes (midday/daily), in a karst grassland and mid-succession

Grassland

✓ Split growing season (VPD = 1500) ➔ better results

✓ NDVI ➔ best for greening phase, LSWI and MNDWI ➔ best for dry phase

Mid-succession

✓ Single growing season

✓ EVI ➔ best VI throughout the growing season

Conclusions

Limitations

- ✓ Satellite images: Clouds?
- ✓ Number of EC towers: problem of representativeness??

Conclusions

Open Access | Article

Estimation of Carbon Fluxes from Eddy Covariance Data and Satellite-Derived Vegetation Indices in a Karst Grassland (Podgorski Kras, Slovenia)

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Remote Sens. **2019**, *11*(6), 649; https://doi.org/10.3390/rs11060649

Received: 19 January 2019 / Revised: 12 March 2019 / Accepted: 13 March 2019 / Published: 16 March 2019

(This article belongs to the Special Issue Remote Sensing of Primary Productivity)

Transferability of methods / results?

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THANK YOU

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