

Il Telerilevamento per lo studio dei Laghi di Mantova

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Paolo, Pinardi Monica, Matta Erica



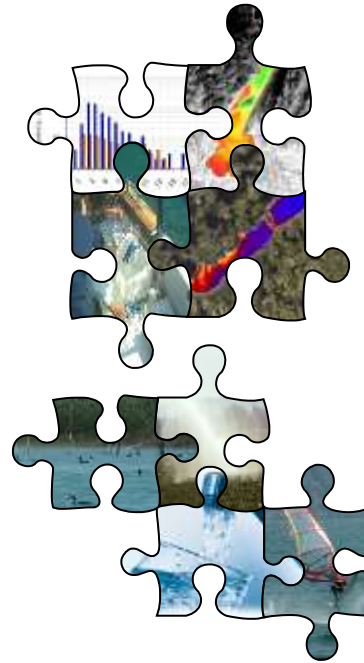
CNR-IREA



SATellite remote sensing for Lake
MONitoring

SALMON è stato un Progetto di Ricerca (1996-1999) finanziato dalla Commissione Europea all'interno del 4° programma quadro (contract ENV4 CT96 0311).

*Da circa 20 anni stiamo facendo
attività di ricerca sul
telerilevamento applicato ai laghi*



Integrazione dei
tradizionali metodi di
monitoraggio con il
Telerilevamento ...

...per fornire dati utili per
la conoscenza e la
salvaguardia della qualità
delle acque lacustri

INFORM

INFORM "Improved monitoring and forecasting of ecological status of European Inland waters by combining Future earth ObseRvation data and Models"

INFORM è un Progetto Collaborativo (2014-2017) finanziato dalla Commissione Europea all'interno del 7° programma quadro (Grant agreement no: 606865).



Il Progetto INFORM



Obiettivo principale del progetto, coordinato dal Flemish institute for technological research (VITO), sarà quello di sviluppare metodologie per il miglioramento dei servizi Copernicus GMES esistenti e per fornire una base per servizi innovativi per lo studio della qualità delle acque interne europee.



Implementazione di algoritmi di versione avanzata per la produzione di mappe satellitari di differenti parametri di qualità dell'acque e integrazione con modelli ecologici per l'analisi dello stato di qualità dei laghi/lagune eutrofici e torbidi europei.



EUAB members

<p>Lisa Menke Advisor Network Water, Rijkswaterstaat</p>	<p>Algislas Stankevicius Head of the Marine Research Department of the Ministry of Environment</p>
<p>Bill Brerly Freshwater Biological Association (FBA)</p>	<p>Thomas Wolf Environmental Agency of Baden-Württemberg (LUBW)</p>
<p>Boudewijn Dierckx International Marine and Dredging Consultants (IMDC)</p>	<p>István Köber Head of Laboratory of Central-Transcarpathian Water Directorate</p>
<p>Alfred Johnny Wiest Group Leader Aquatic Physics (EAWAG)</p>	<p>Marco Barchi Expert ecologist, University of Parma, Life Sciences Department</p>



PM02 meeting
04-05 February 2015
VITO, Belgium



Attività di ricerca sui laghi di MANTOVA

Dal 2007 sono in corso attività di ricerca sui laghi di Mantova, raccolta di dati spettrali in situ sulle acque e sulle macrofite, analisi di immagini satellitari e aviotrasportate

IMMAGINI IPERSPETTRALI AEREE

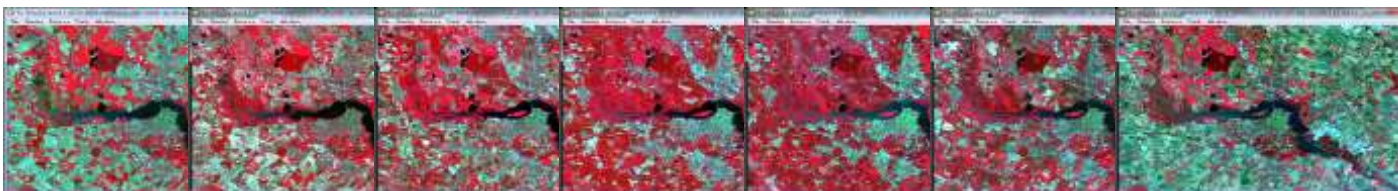


IMMAGINI SATELLITARI ad alta risoluzione



Oltre 20 immagini (5 CHRIS, 3 RAPID-EYE, 5 ALOS, QUICKBIRD ed altri)

IMMAGINI SATELLITARI a media risoluzione

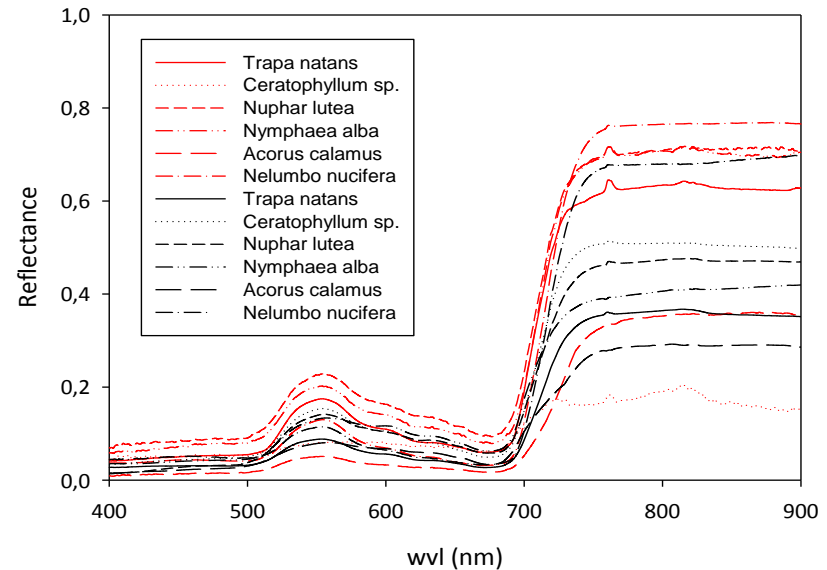
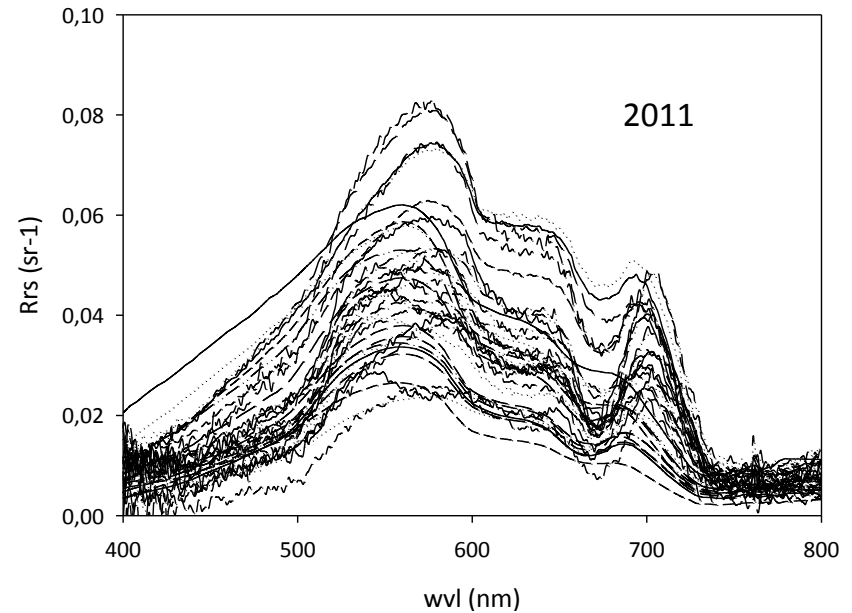
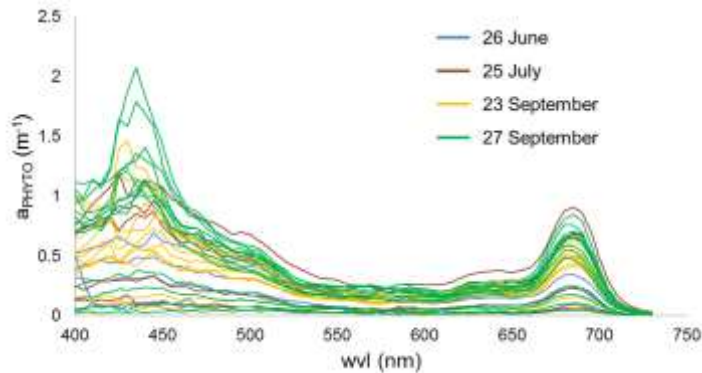


30 anni di archivi del satellite LANDSAT (oltre 100 immagini)

Attività di ricerca sui laghi di MANTOVA

Le attività in situ hanno permesso la caratterizzazione ottica delle acque e della vegetazione acquatica.

Nei 7 anni di ricerca sono state effettuate circa 20 campagne di misura e sono state acquisite oltre 500 firme spettrali di acqua e vegetazione con associati parametri bio-fisici.



	Average	Stdev	Min	Max
Chl-a (mgm^{-3})	53.96	52.50	1.81	213.53
CDOM (m^{-1})	0.70	0.34	0.19	1.39
SPM (gm^{-3})	11.63	7.42	3.36	31.50
SPIM (gm^{-3})	1.83	1.23	0.38	6.12
SPOM (gm^{-3})	5.69	2.44	3.06	11.96
Secchi depth (m)	0.86	0.32	0.40	1.50

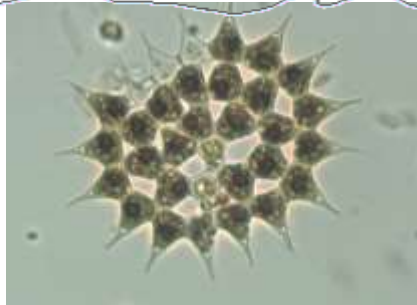
Attività di ricerca sui laghi di MANTOVA

June



Gyrosigma

BACILLARIOPHYCEAE



Pediastrum

CHLOROPHYCEAE



Pseudoanabaena

CYANOPHYCEAE



Scenedesmus

CHLOROPHYCEAE

September



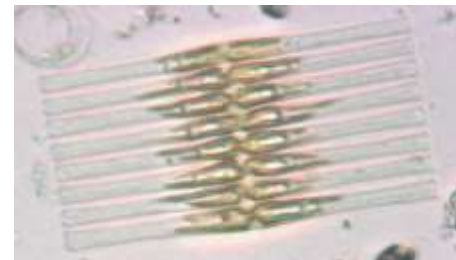
Aulacoseira

BACILLARIOPHYCEAE



Cryptomonas

CRYPTOPHYCEAE



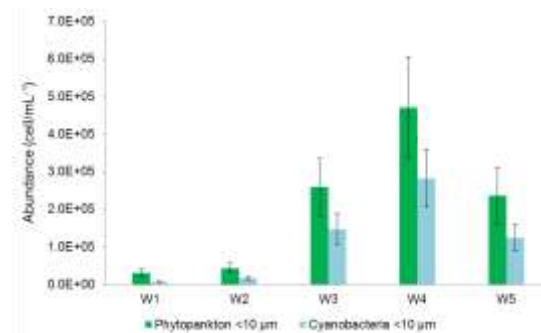
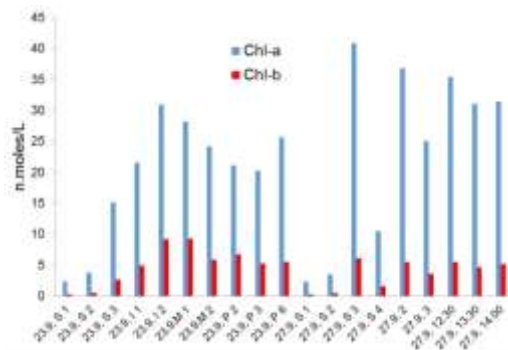
Fragilaria

BACILLARIOPHYCEAE

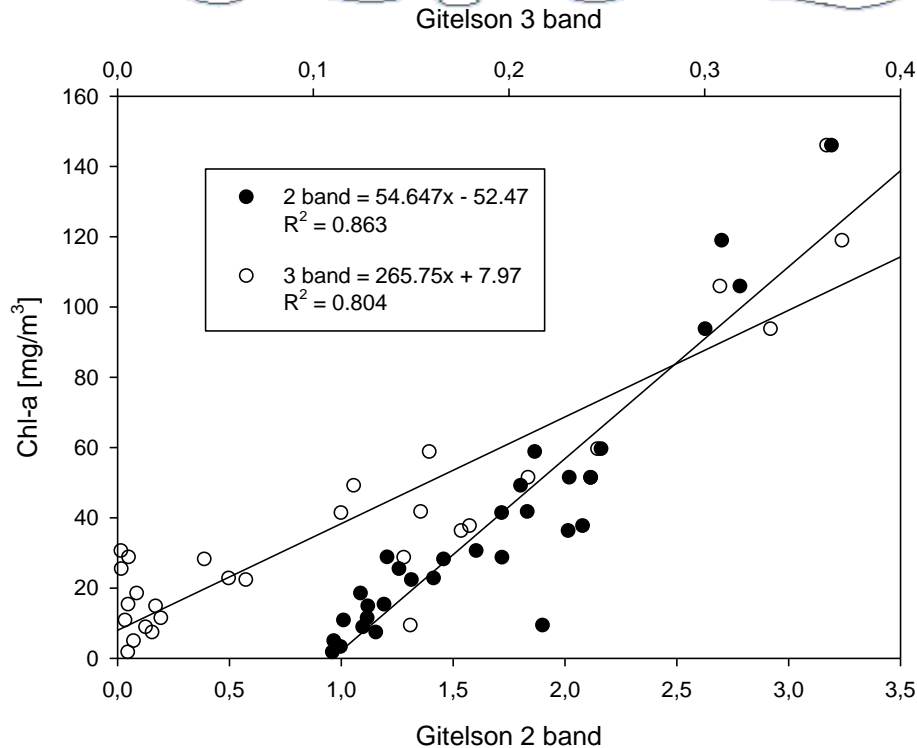


Cyclotella

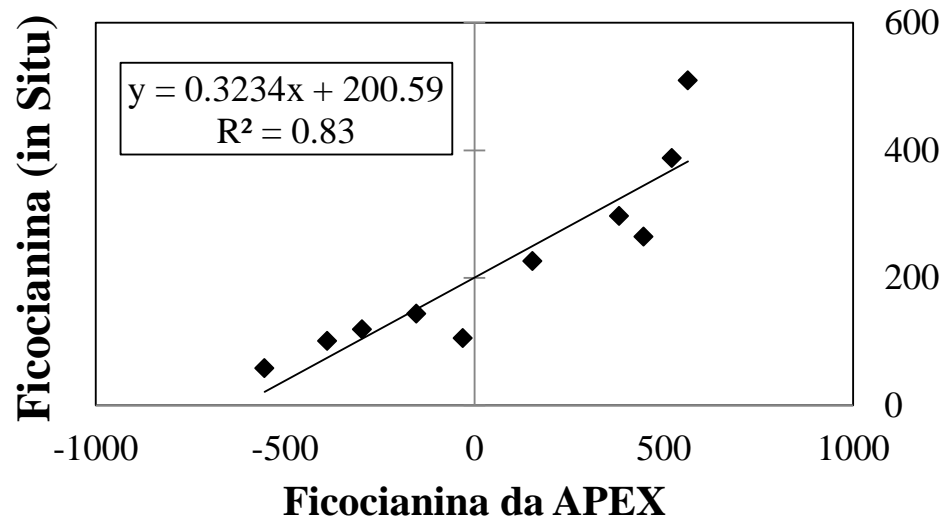
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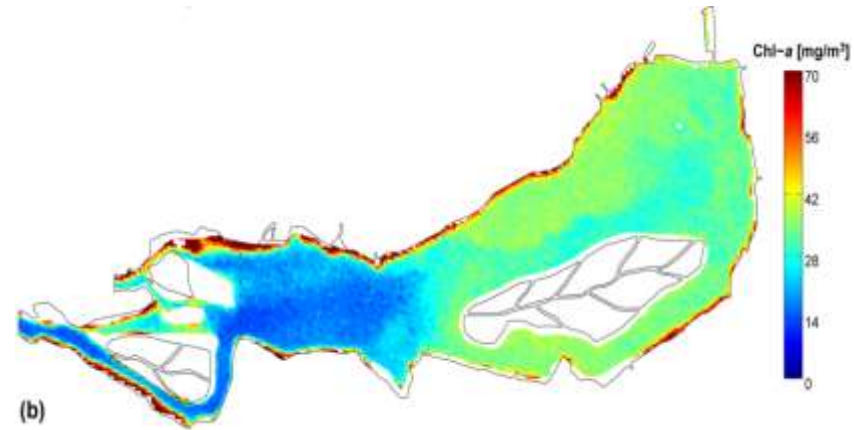
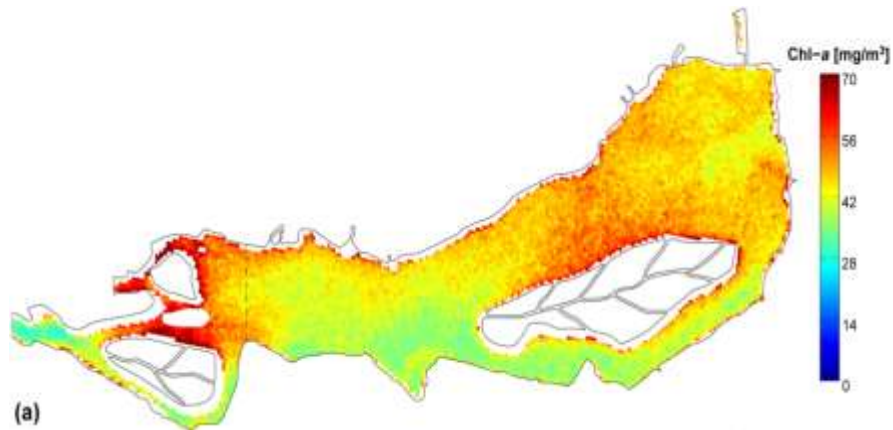
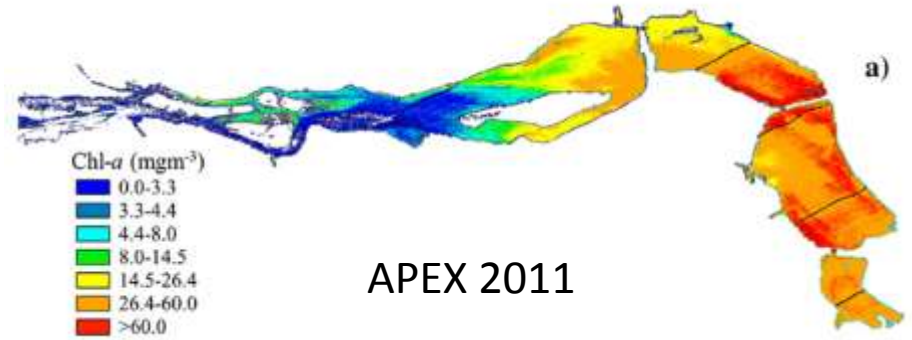
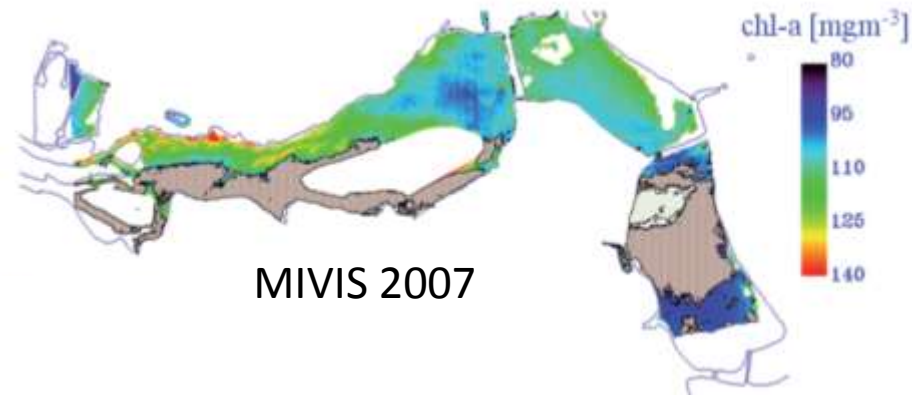
Attività di ricerca sui laghi di MANTOVA



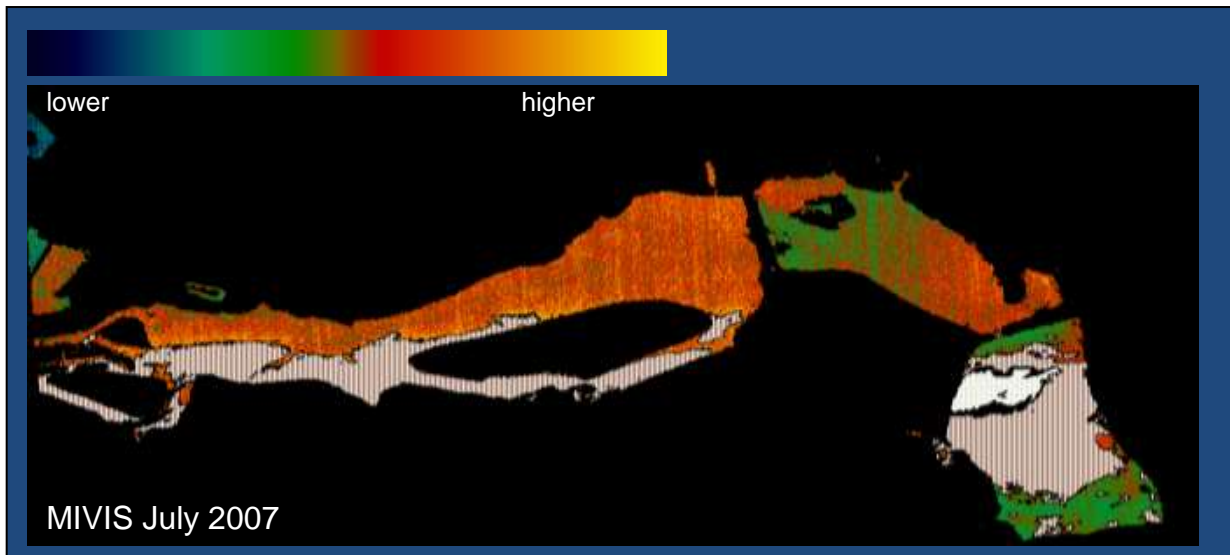
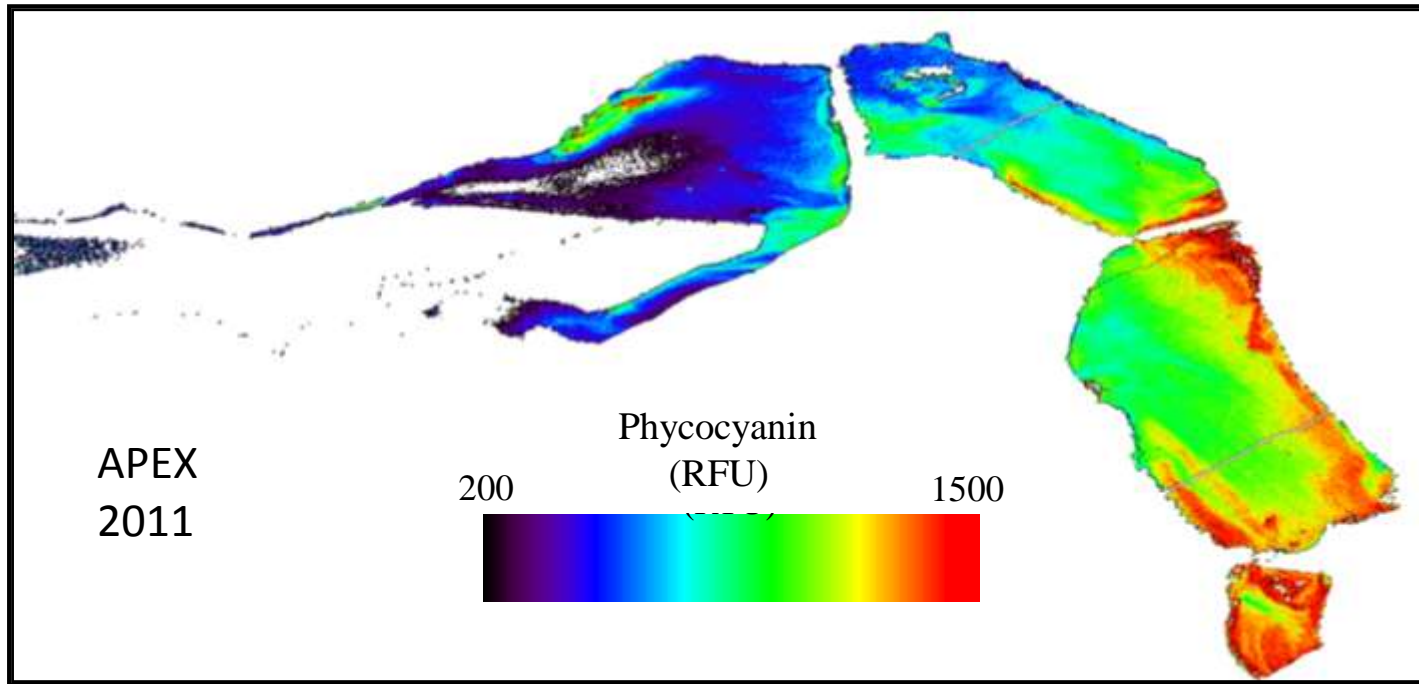
$r^2 = 0.92$ ($p < 0.0001$),
 $r\text{RMSE} = 16.3\%$,
MAE of 3.61,
average in situ data of $36.8 \text{ mg}/\text{m}^3$
estimated average data of $34.3 \text{ mg}/\text{m}^3$



Prodotti della ricerca: Mappe di Chl-a



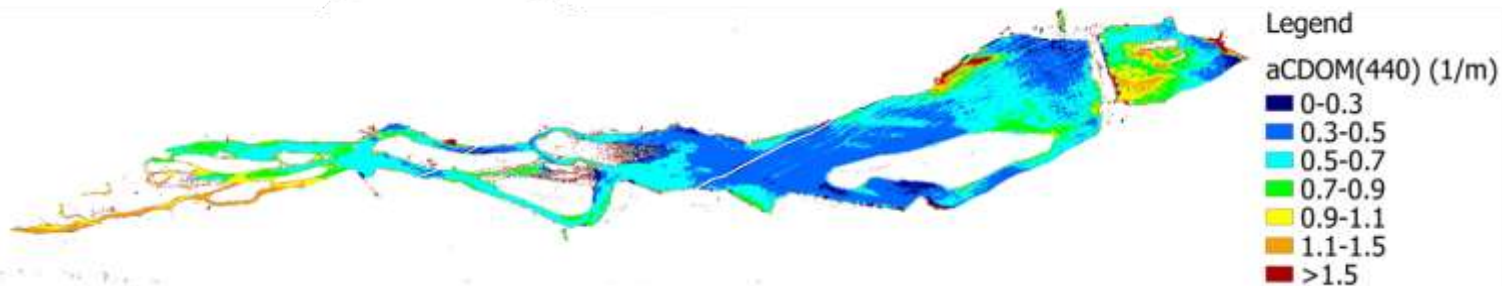
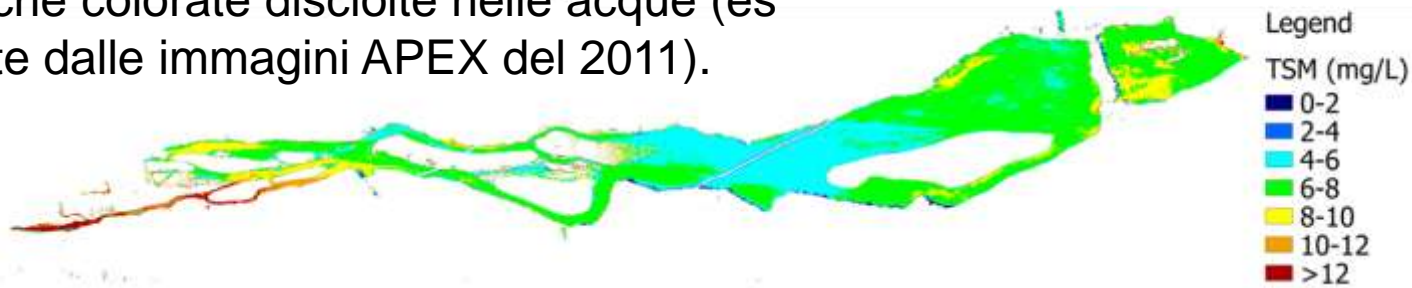
Prodotti della ricerca: Mappe di Cianobatteri



Mappe di
cianobatteri

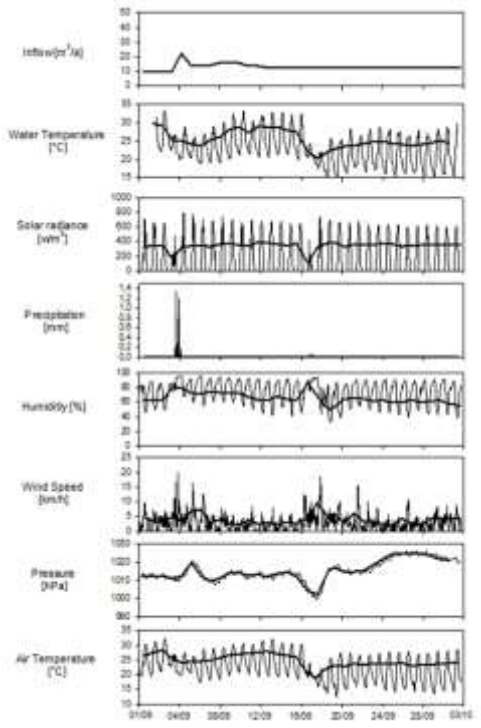
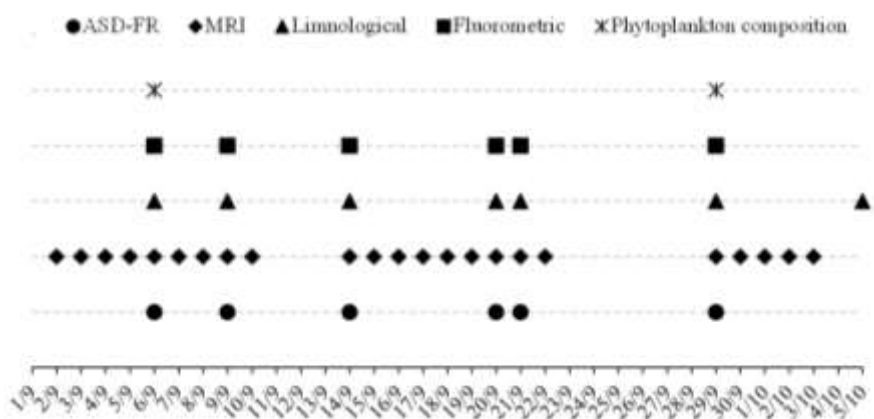
Prodotti della ricerca: altri prodotti

Mappe di solidi sospesi totali e di sostanze organiche colorate disciolte nelle acque (es. ottenute dalle immagini APEX del 2011).

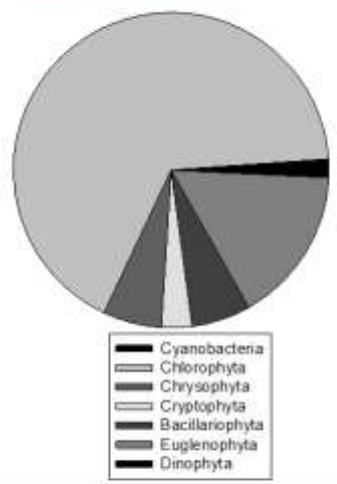


Mappe di temperatura superficiale delle acque (es. ottenute dall'immagine MIVIS del 2008).

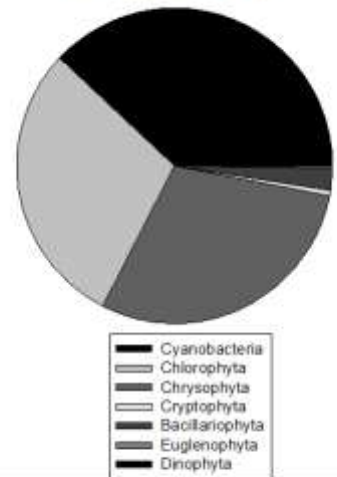
Analysis of intra- and inter-daily chlorophyll-a dynamics in Mantua Superior Lake with spectroradiometric continuous measures



Biomass (mm³/m³)

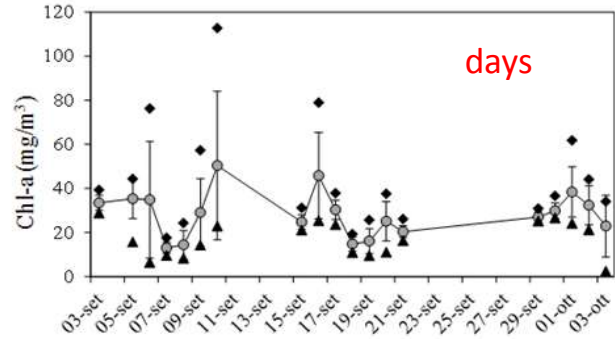
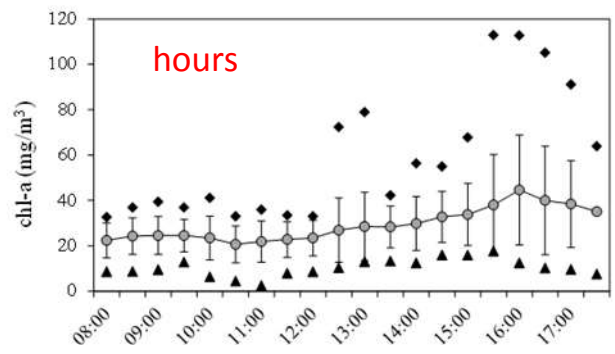
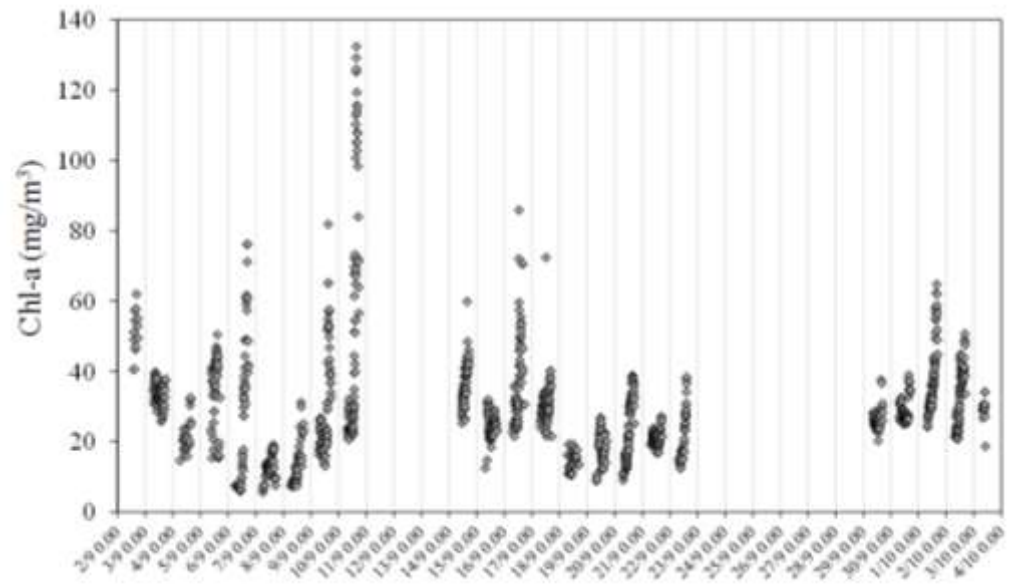


Density (ind/ml)

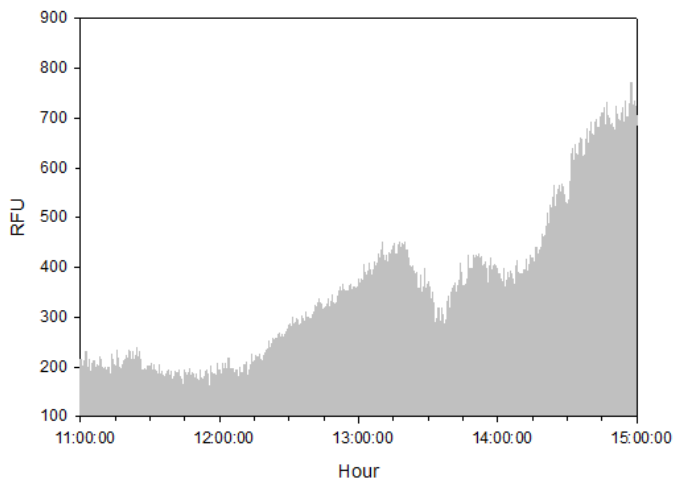
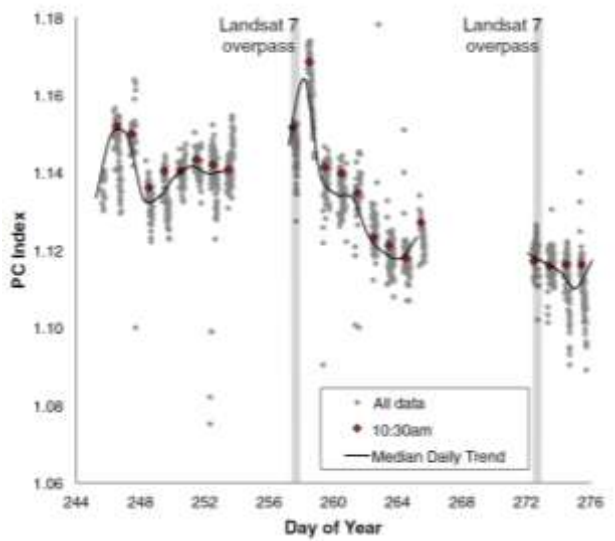


Pandorina morum; *Phacus tortus*; *Oochromonas* sp.; *Planktolyngbya limnetica*

Analysis of intra- and inter-daily chlorophyll-a dynamics in Mantua Superior Lake with spectroradiometric continuous measures

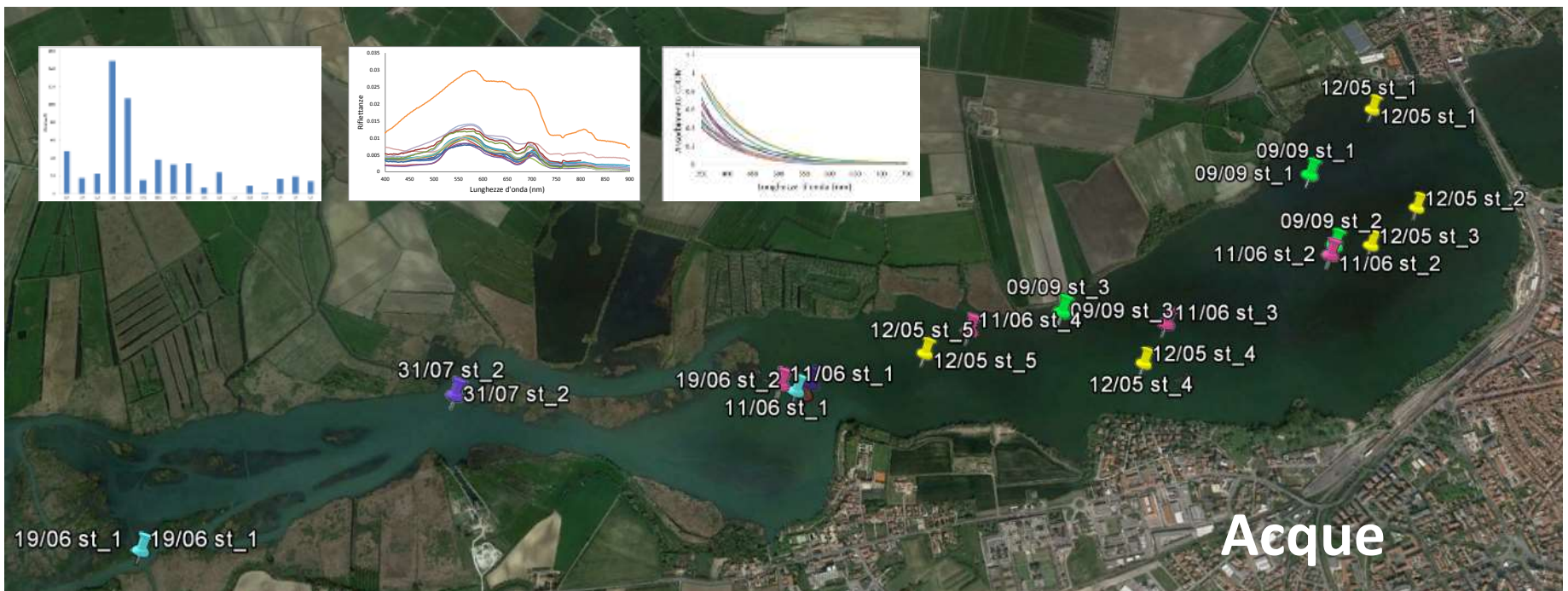
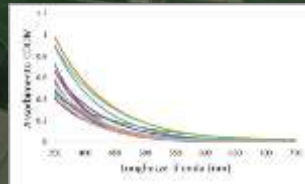
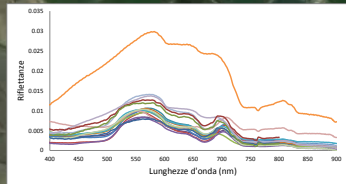


Ficocianine



Macrofite

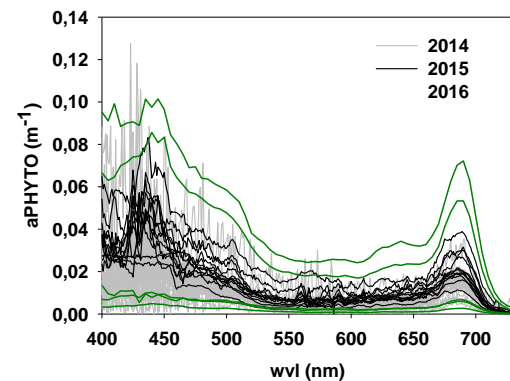
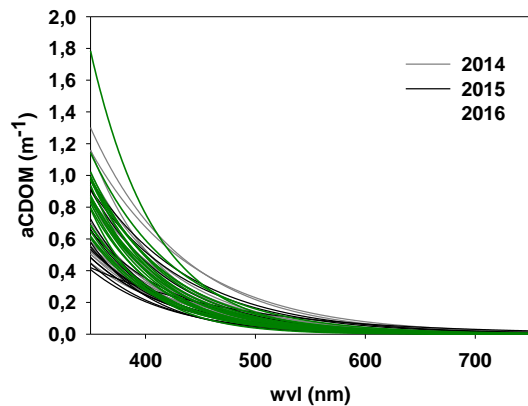
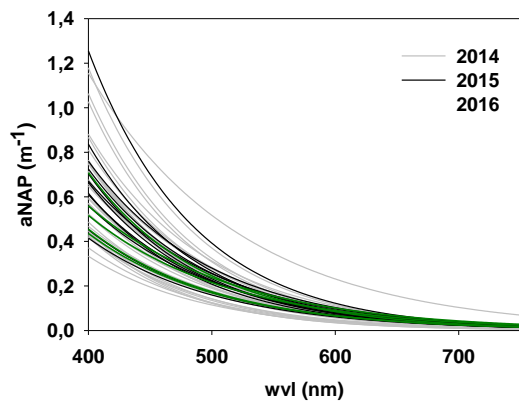
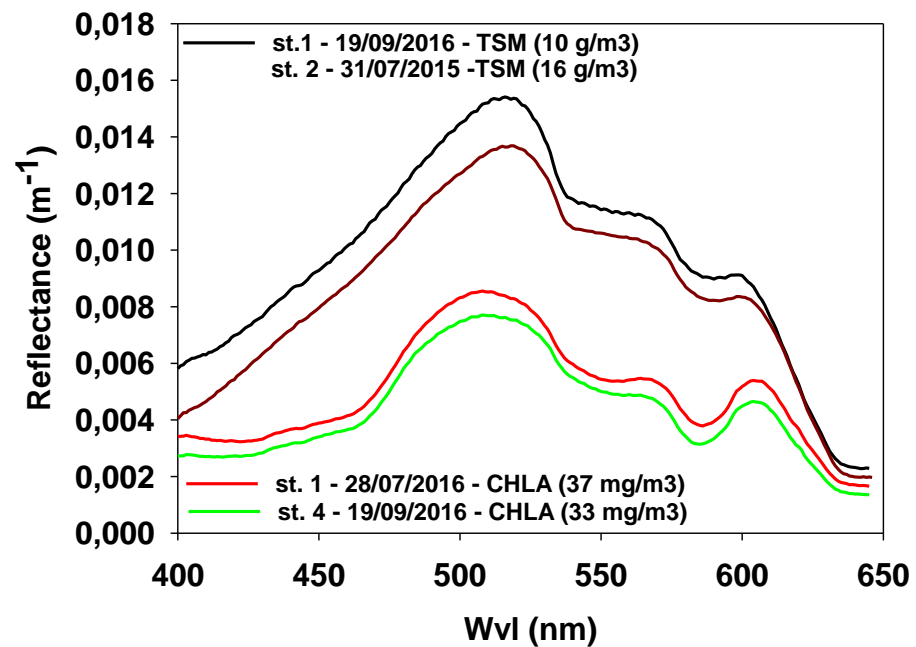
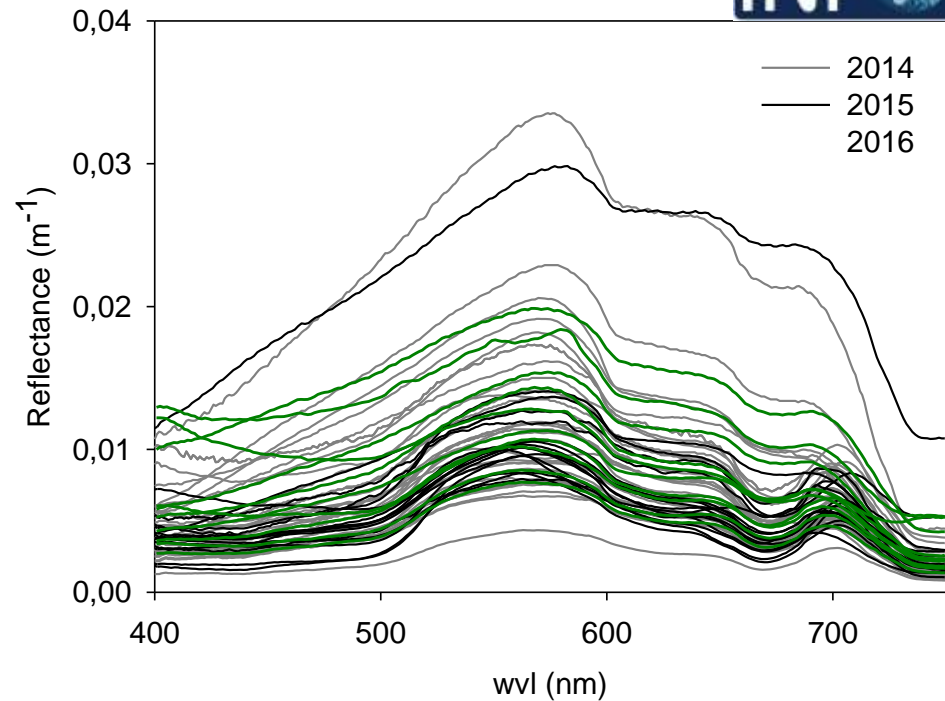
2015



Acque

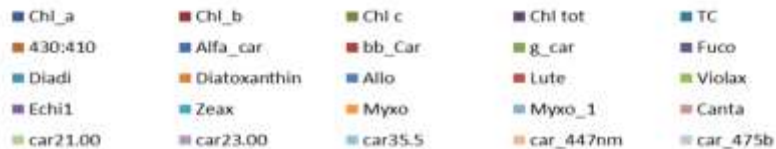
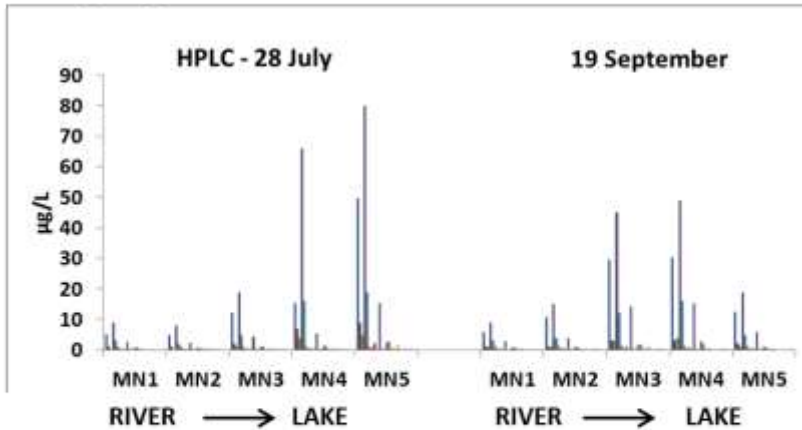
Field campaigns 2016



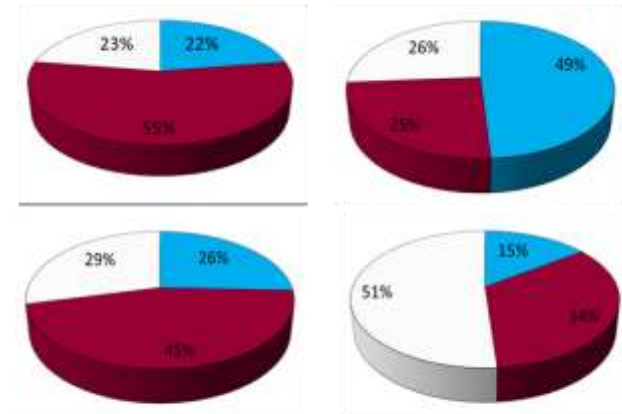


		Secchi Disk	T	Conductivity	O2	Chl-a	TSM	SPOM	SPIM
		cm	°C	µS cm-1	% sat	µg/L	mg/L	%	%
08/06/2016	avg (±sd)	93 (±8)	23.4 (±1.7)	399 (±38)	82 (±5)	16.7 (±6.9)	7.8 (±0.5)	68 (±12)	32 (±12)
	range	85-100	21.4-24.7	360-435	78-88	12.1-24.7	7.2-8.1	59-81	19-41
21/06/2016	avg (±sd)	90 (±8)	23.7 (±3.9)	348 (±6)	118 (±35)	18.3 (±12.6)	11.0 (±4.2)	67 (±29)	33 (±29)
	range	80-100	20.9-26.4	343-352	93-142	6.9-35.6	7.9-17.1	36-100	0-64
11/07/2016	avg (±sd)	73 (±10)	29.2 (±0.2)	228 (±9)	315 (±46)	48.1 (±14.1)	17.7 (±8.9)	62 (±25)	38 (±25)
	range	65-85	29.1-29.4	219-236	261-344	34.9-62.9	10.0-27.4	35-85	15-65
28/07/2016	avg (±sd)	98 (±19)	26.1 (±0.4)	274 (±17)	103 (±33)	18.7 (±15.9)	8.0 (±2.5)	49 (±21)	51 (±21)
	range	70-120	25.7-26.5	244-286	69-138	5.4-36.7	5.2-10.1	18-73	27-82
19/09/2016	avg (±sd)	84 (±5)	21.7 (±0.4)	291 (±2)	79 (±11)	18.2 (±11.7)	7.9 (±2.9)	60 (±26)	40 (±26)
	range	80-90	21.1-22.1	288-292	70-93	5.9-32.5	3.0-10.1	36-100	0-64

Phytoplankton

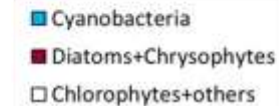


Phyto counts - % Biomass



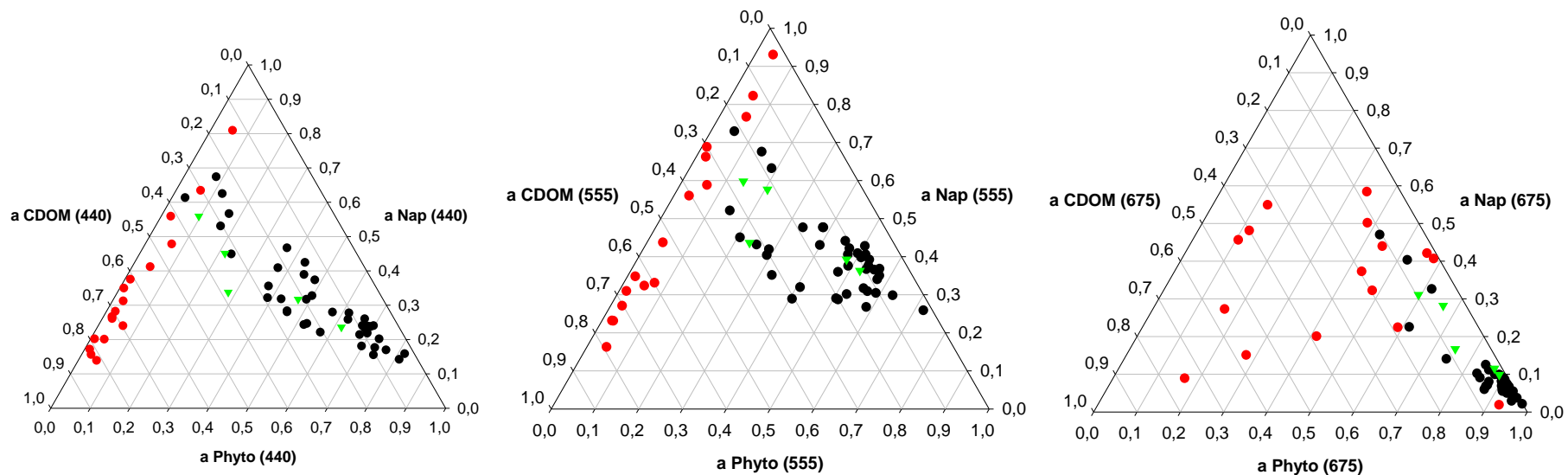
28/07 - MN 2

28/07 - MN 3



28/07

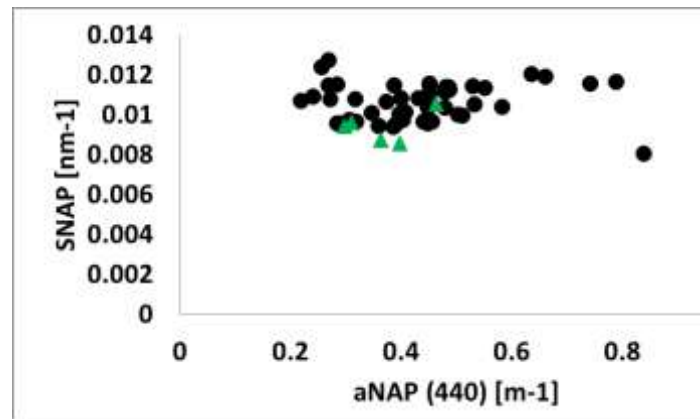
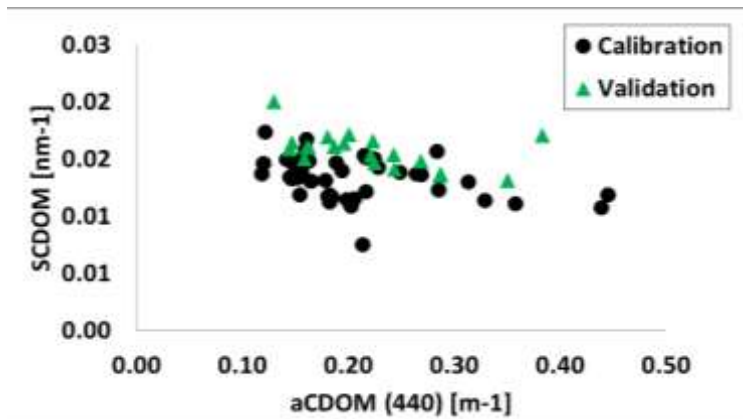
19/09



- Calibration
- Archive
- ▼ Validation

Calibration:
2014-2015

Validation: 2016



Area di studio – Macrofite analizzate

Castagna d'acqua
(*Trapa natans*)



Ninfea gialla
(*Nuphar lutea*)



Azzolla
(*Azzolla caroliniana*)



Ceratofillo
(*Ceratophyllum demersum*)



Fiore di loto
(*Nelumbo nucifera*)

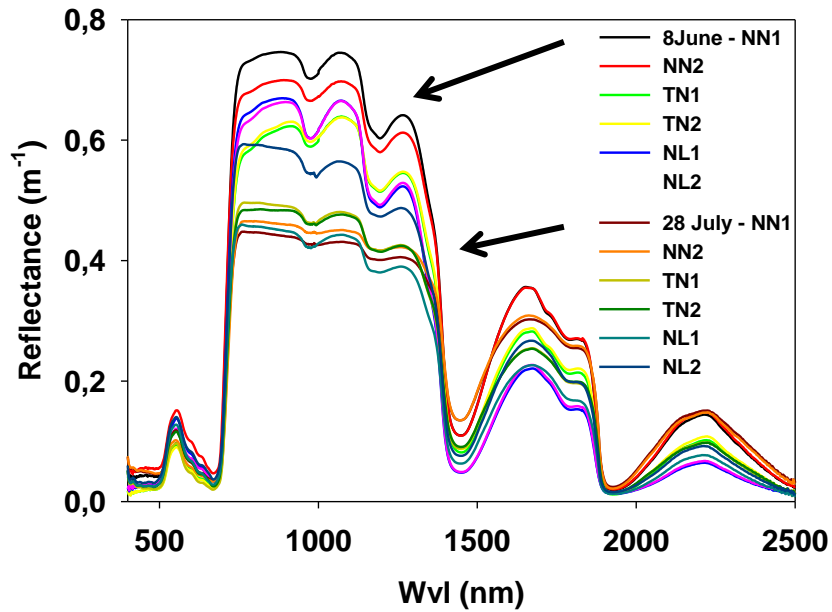


Cannuccia di palude
(*Phragmites australis*)



Macrofite 2016

Firme spettrali foglia



NN = *Nelumbo nucifera*

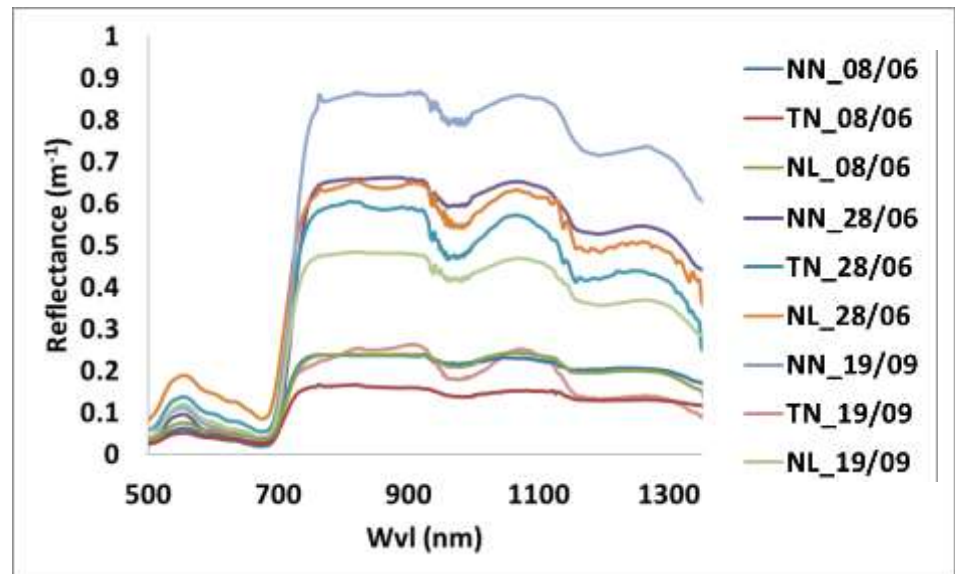


TN = *Trapa natans*



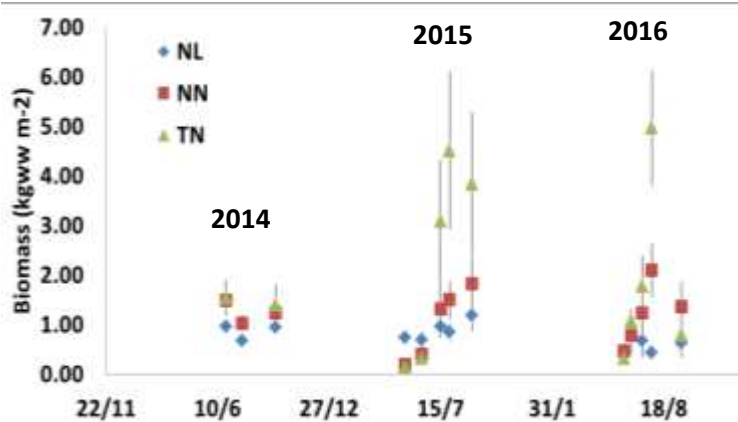
NL = *Nuphar lutea*

Firme spettrali canopy

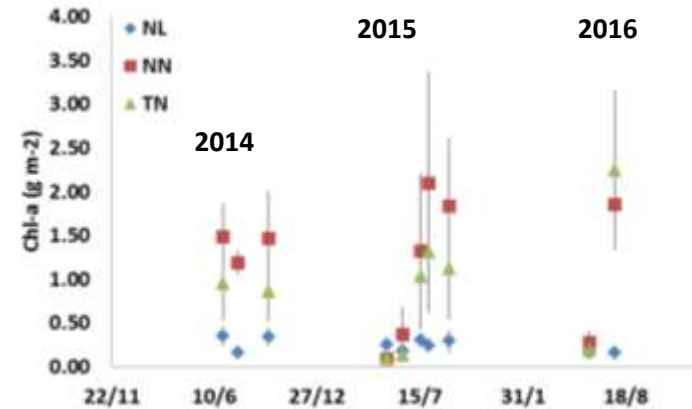


Macrofite 2016

Variazioni stagionali/annuali



Pigmenti fogliari



Biomassa

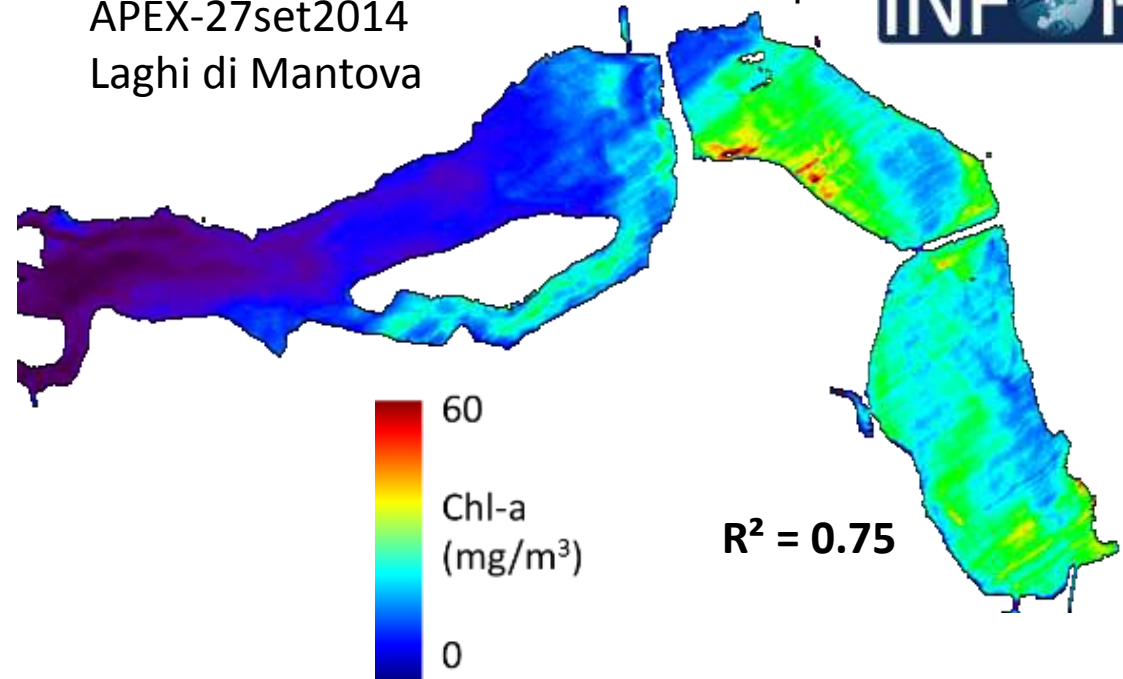
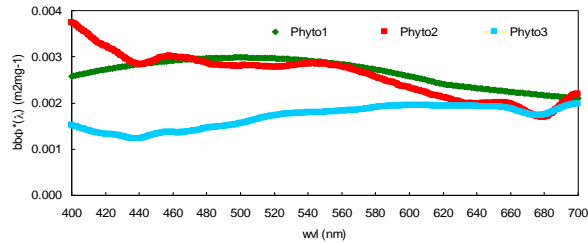
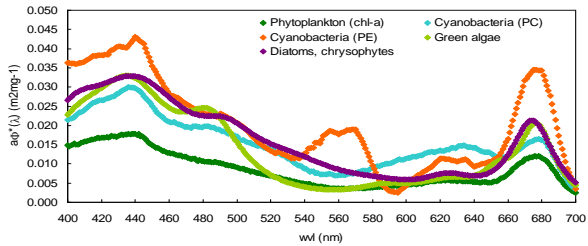
NL = *Nuphar lutea*
NN = *Nelumbo nucifera*
TN = *Trapa natans*

Date	Species	fC (%)		LAI (m ² m ⁻²)		Water content (%)		Biomass (kg _{ww} m ⁻²)		Chl-a (g m ⁻²)		CAR (g m ⁻²)	
		mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
08/06/2016	NL	65.8%	4.7%	0.85	0.08	84%	2%	0.44	0.05	0.16	0.03	0.12	0.01
11/07/2016	NL	88.4%	1.4%	0.85	0.18	83%	4%	0.68	0.34	-	-	-	-
27/07/2016	NL	87.9%	0.6%	1.00	0.00	85%	1%	0.43	0.13	0.16	0.06	0.12	0.04
19/09/2016	NL	75.3%	4.8%	1.02	0.03	81%	2%	0.617	0.20	-	-	-	-
08/06/2016	NN	80.5%	7.8%	0.85	0.09	83%	8%	0.46	0.15	0.28	0.14	0.19	0.09
21/06/2016	NN	94.4%	1.2%	1.35	0.04	83%	3%	0.79	0.39	-	-	-	-
11/07/2016	NN	96.7%	0.6%	1.64	0.01	78%	7%	1.24	0.52	-	-	-	-
27/07/2016	NN	97.4%	0.1%	1.66	0.01	85%	3%	2.10	0.54	1.85	0.37	1.25	0.52
19/09/2016	NN	97.5%	-	1.66	-	82%	4%	1.360	0.51	-	-	-	-
08/06/2016	TN	61.6%	8.6%	0.62	0.08	80%	4%	0.33	0.07	0.19	0.06	0.10	0.03
21/06/2016	TN	84.8%	1.6%	0.92	0.01	88%	2%	1.07	0.24	-	-	-	-
11/07/2016	TN	89.2%	1.9%	0.98	0.02	91%	0%	1.77	0.61	-	-	-	-
27/07/2016	TN	91.4%	2.0%	1.08	0.03	92%	1%	4.97	1.16	2.25	0.91	1.22	0.68
19/09/2016	TN	45.7%	1.3%	0.48	0.01	91%	1%	0.788	0.45	-	-	-	-

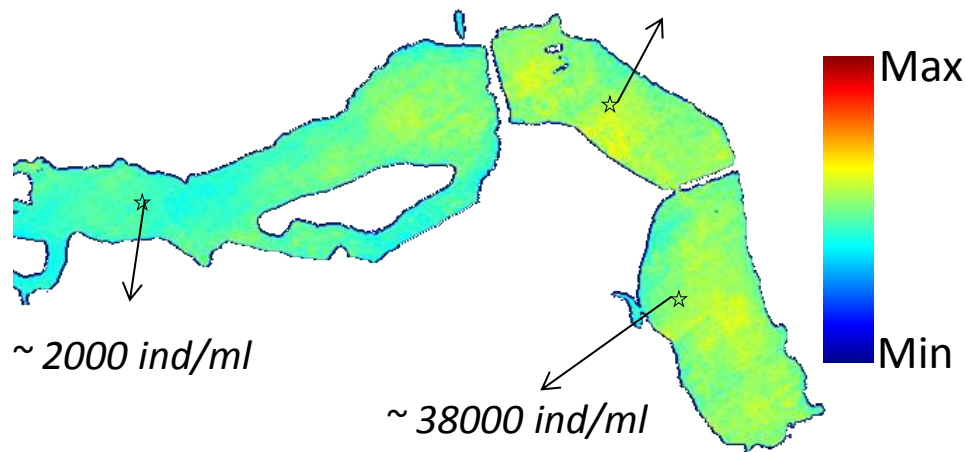
Gruppi fitoplanctonici



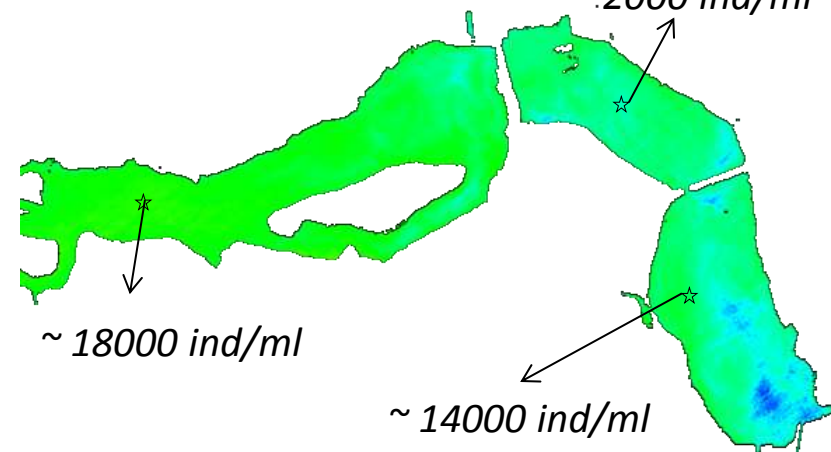
APEX-27set2014
Laghi di Mantova

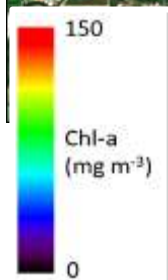
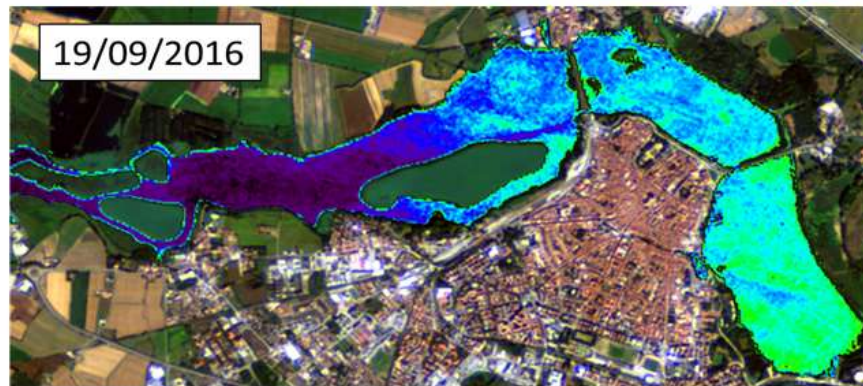
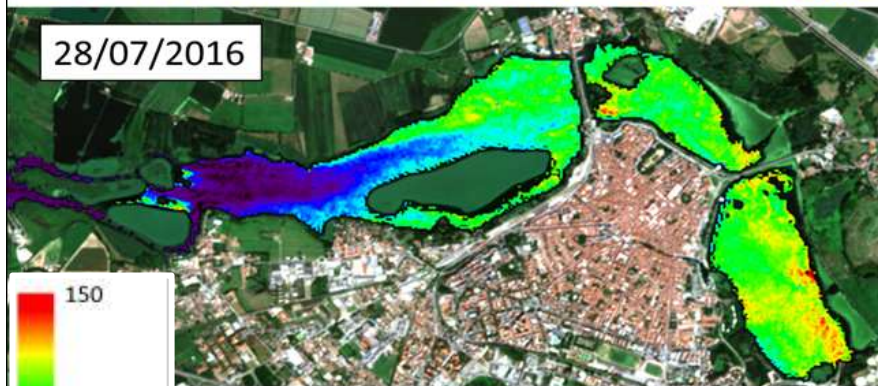
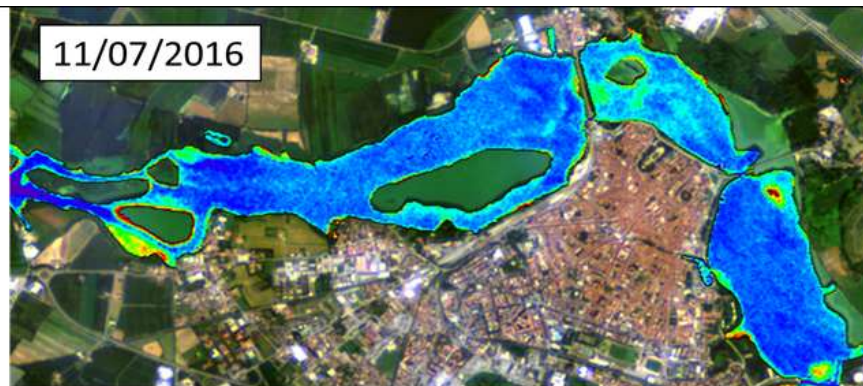
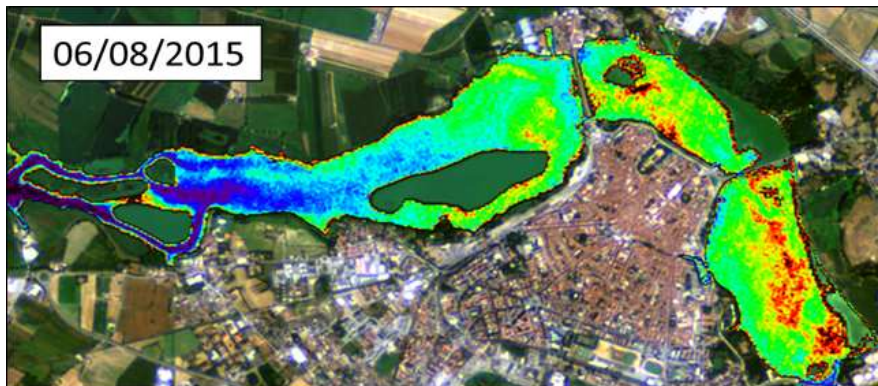


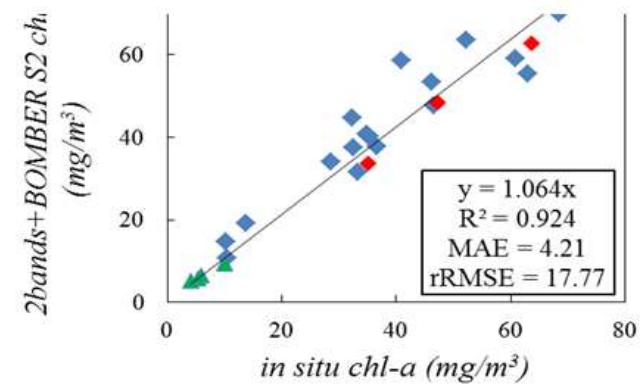
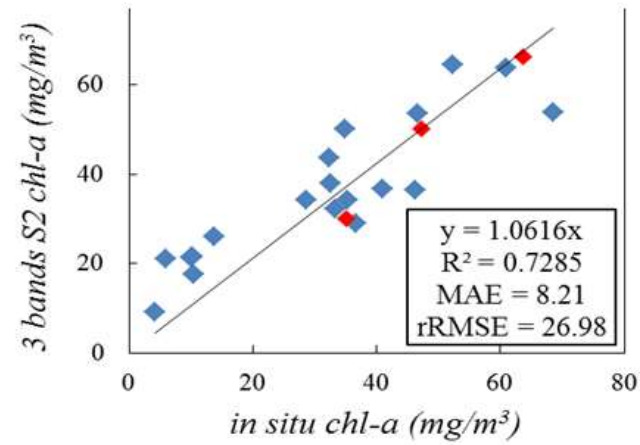
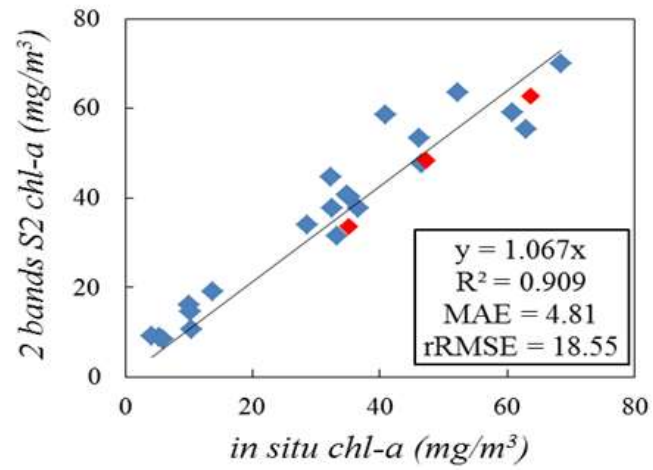
Cianobatteri-ficocianine ~ 57000 ind/ml

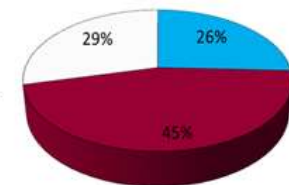
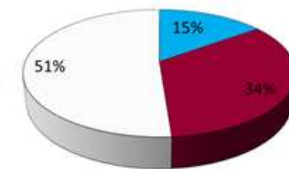
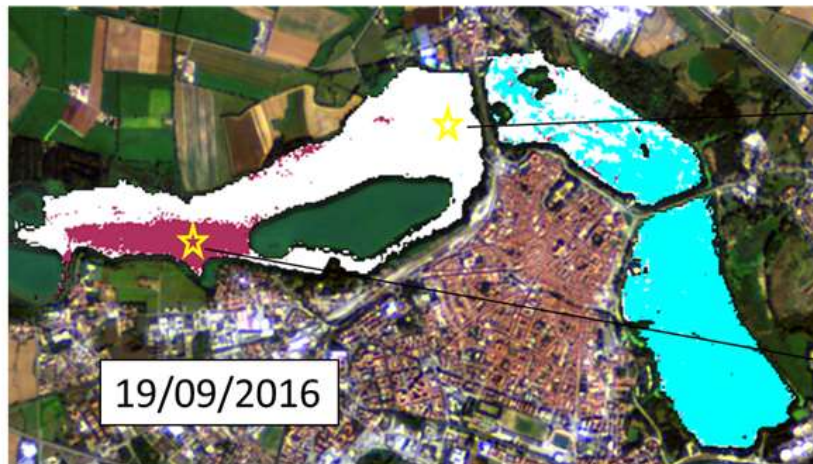
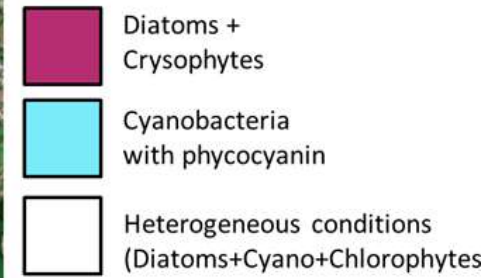
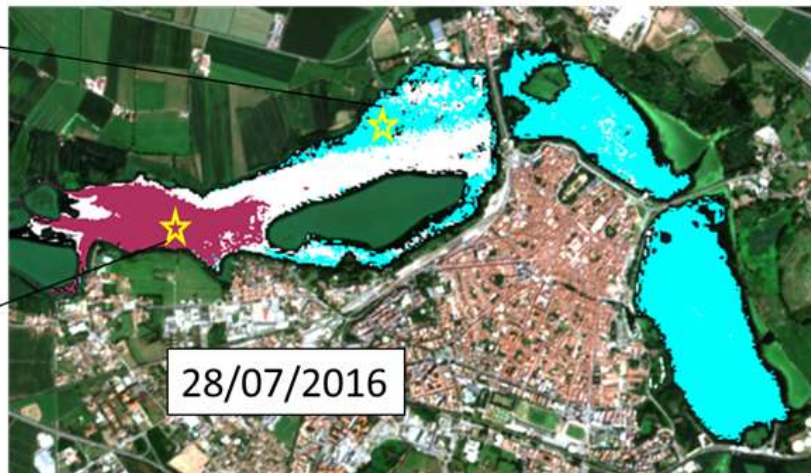
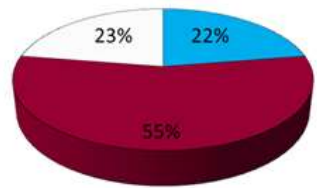
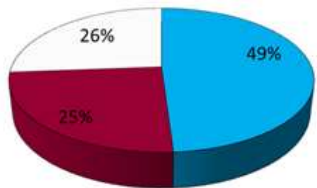


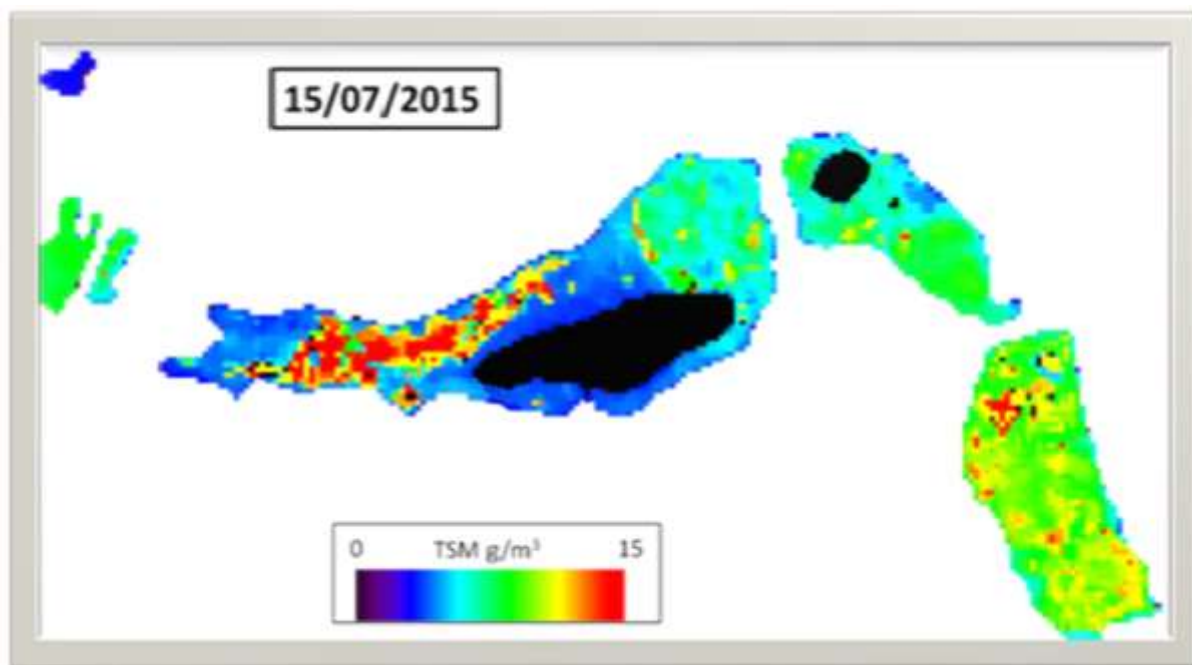
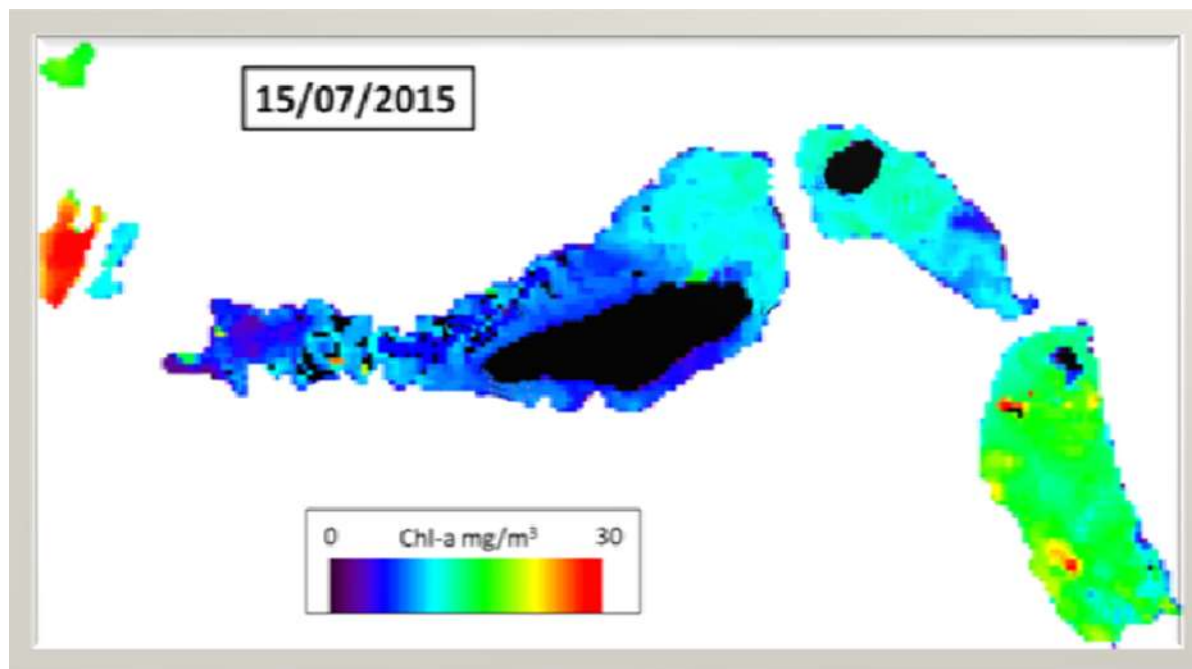
Diatomee-carotenoidi ~ 2000 ind/ml



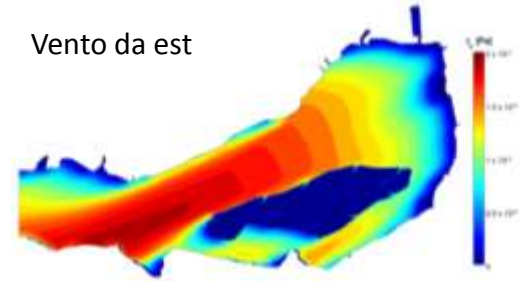








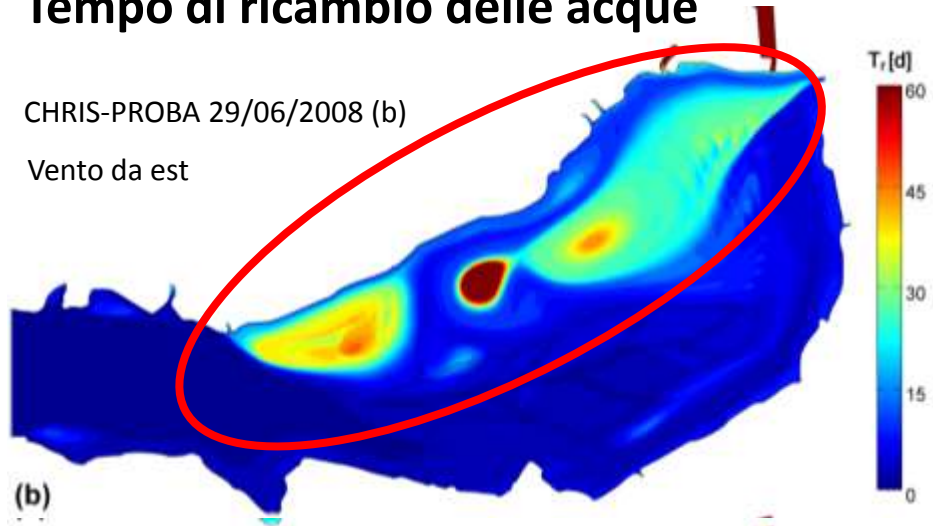
Analisi del fitoplancton combinando tecniche limnologiche e di remote sensing e l'idrodinamica lacustre



Tempo di ricambio delle acque

CHRIS-PROBA 29/06/2008 (b)

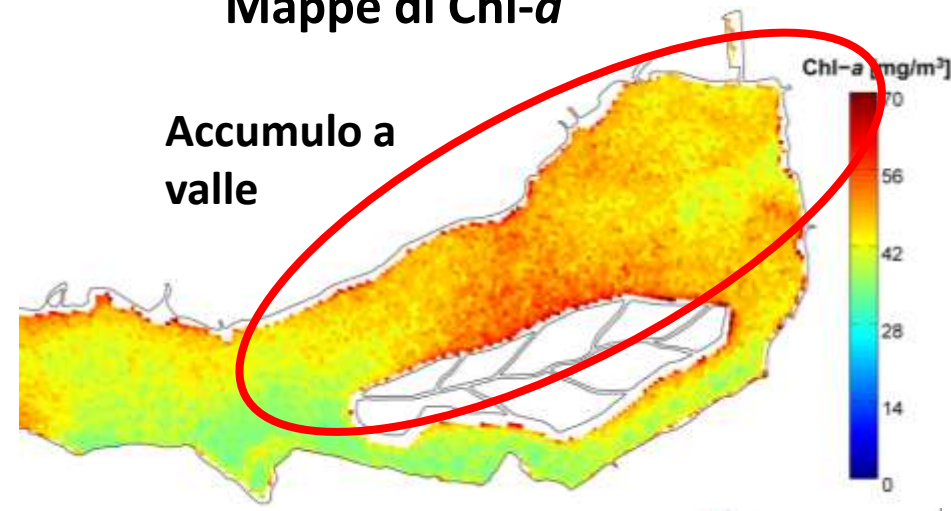
Vento da est



(b)

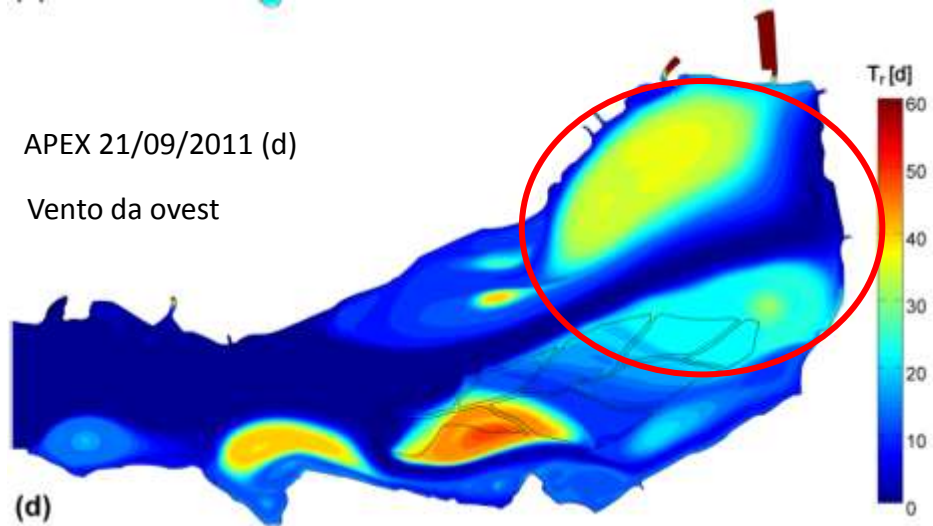
Mappe di Chl- α

Accumulo a valle



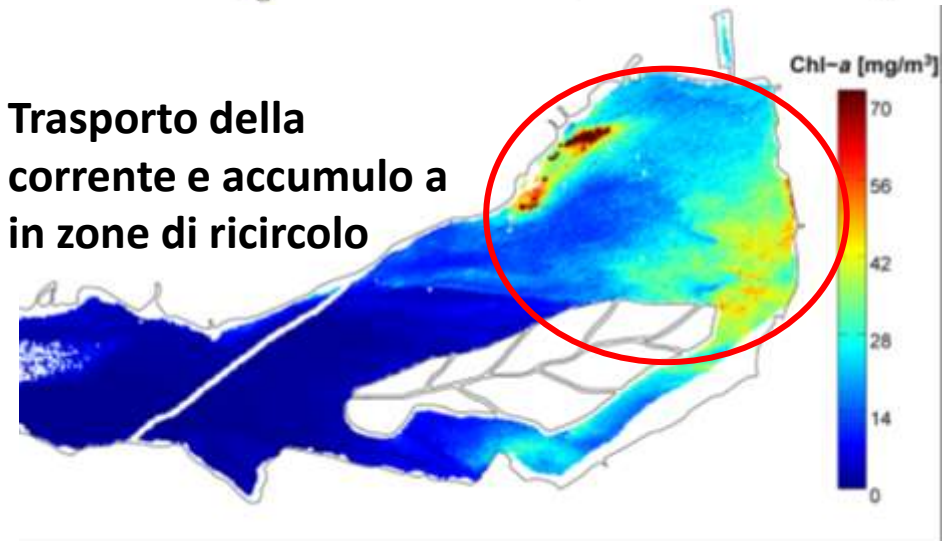
APEX 21/09/2011 (d)

Vento da ovest

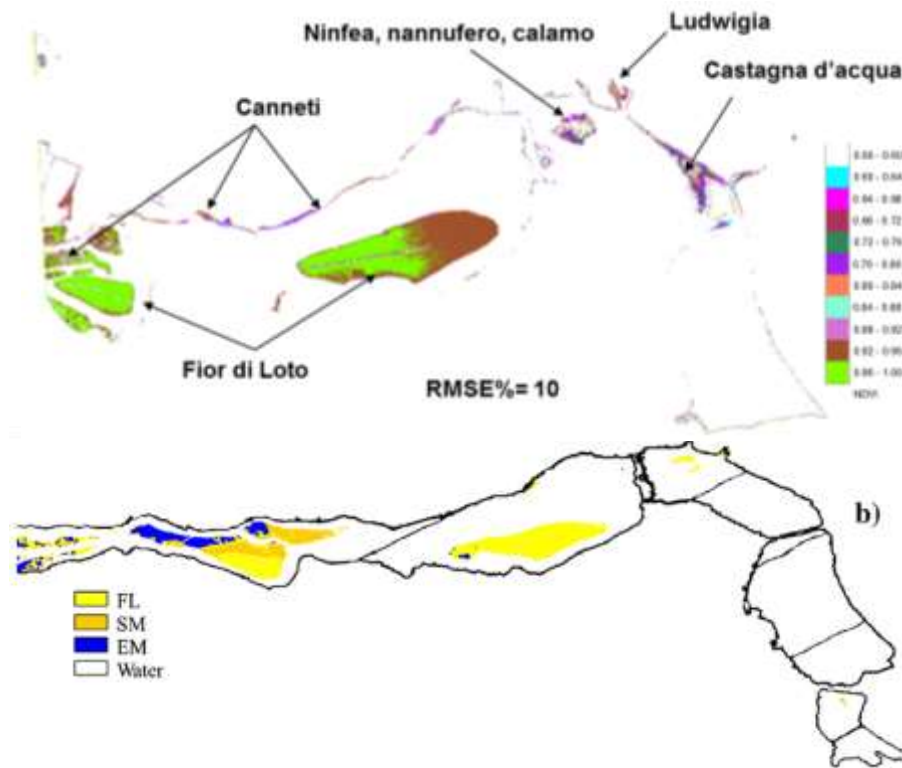


(d)

Trasporto della corrente e accumulo a in zone di ricircolo

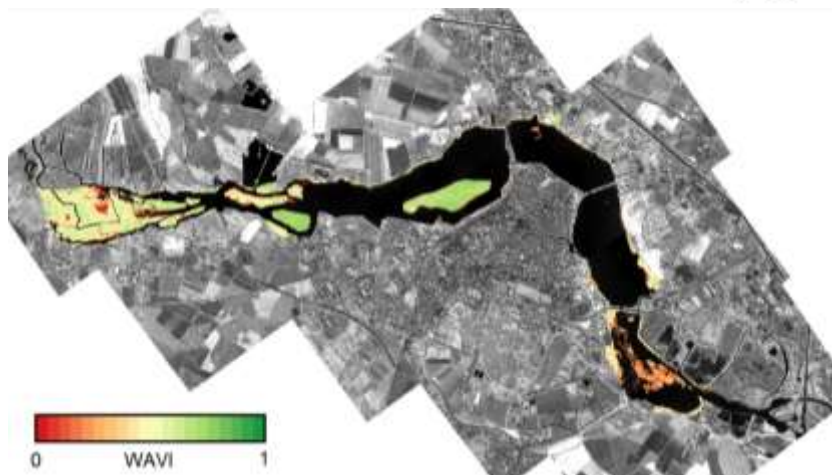


Prodotti della ricerca: Mappe di Macrofite



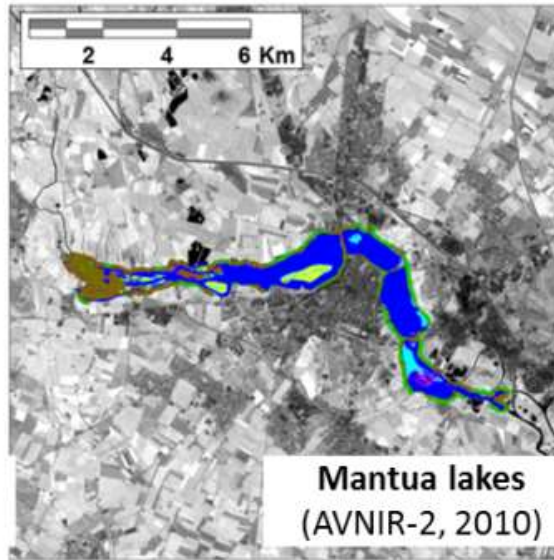
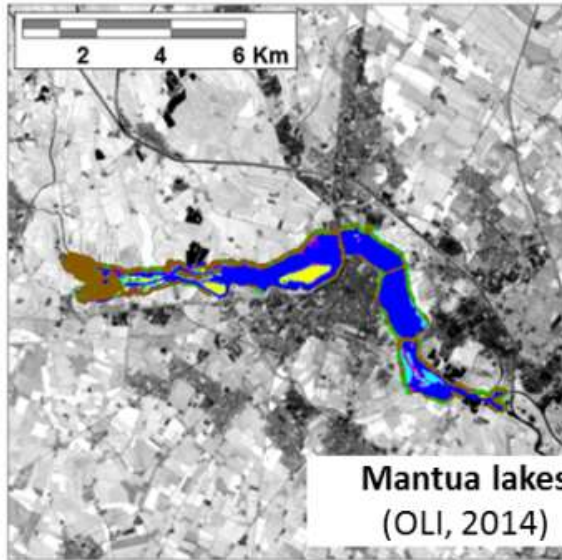
Mappa di indici di stato di densità delle vegetazione (es. ottenuto da immagine MIVIS del 2007).

Mappa di gruppi di macrofite (es. ottenuto da immagine APEX del 2011).



Mappa di indici di BIOMASSA (es. ottenuto da immagine APEX del 2014).

Prodotti della ricerca: Mappe di Macrofite









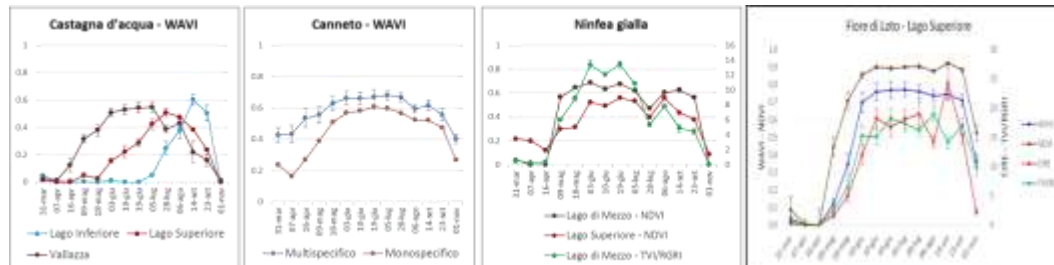
Classificazione delle macrofite basata su andamenti fenologici multistagionali

Class color

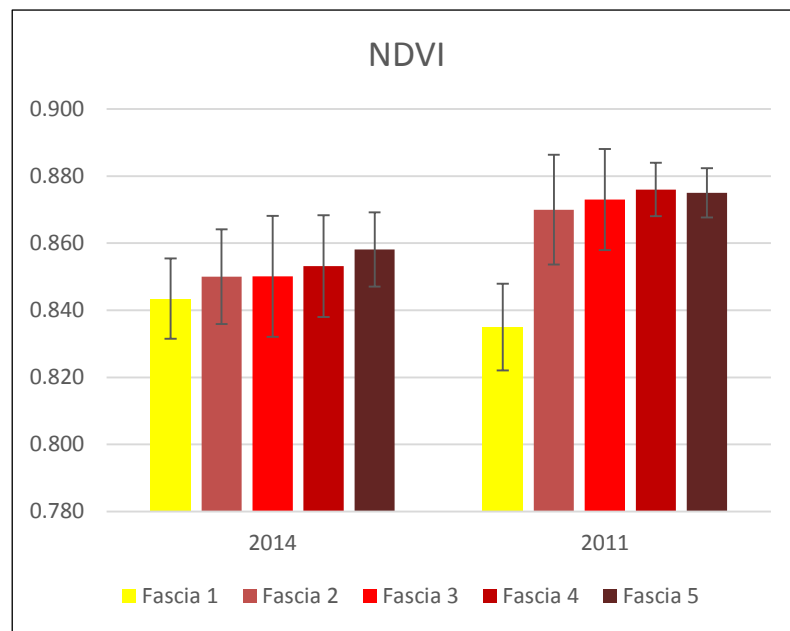
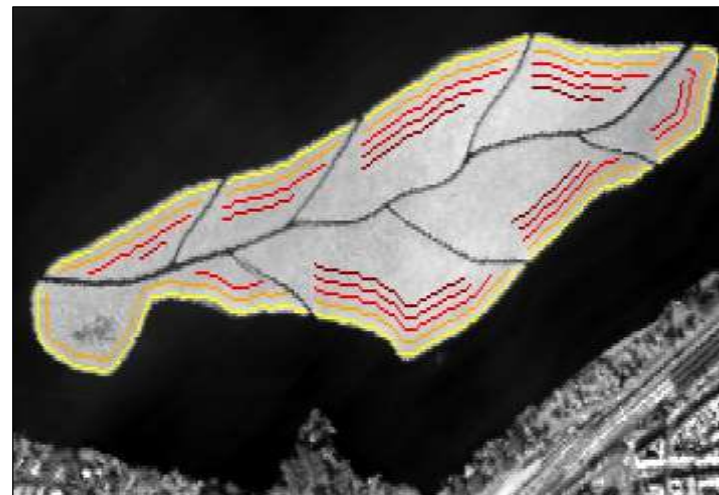
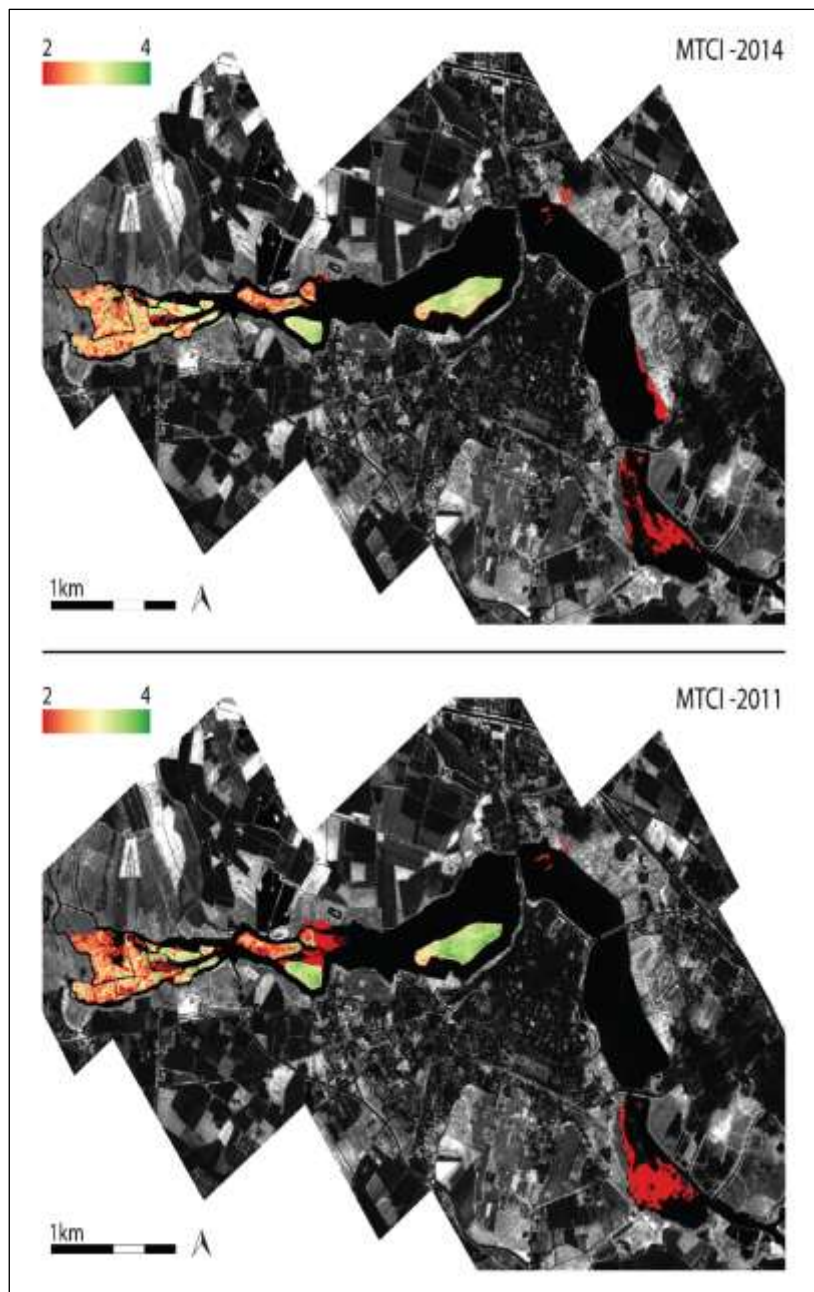
Class ID

Class description

						
	SF	FL	EM	EH	TV	OW
	Floating-Submerged association	Floating macrophytes	Emergent macrophytes	Emergent helophytes	Terrestrial vegetation	Open water



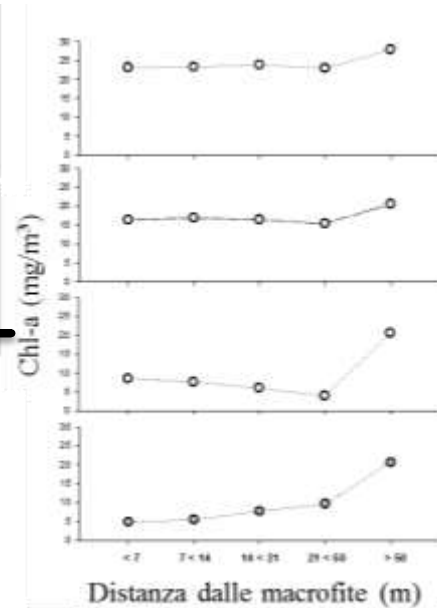
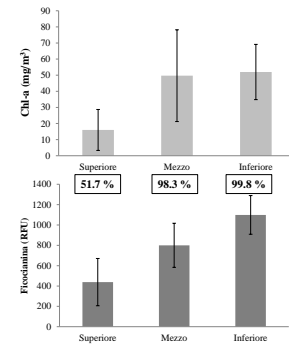
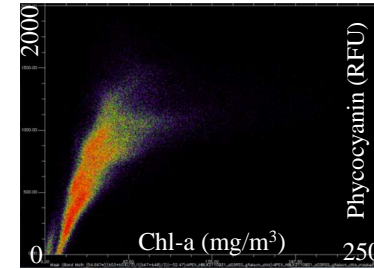
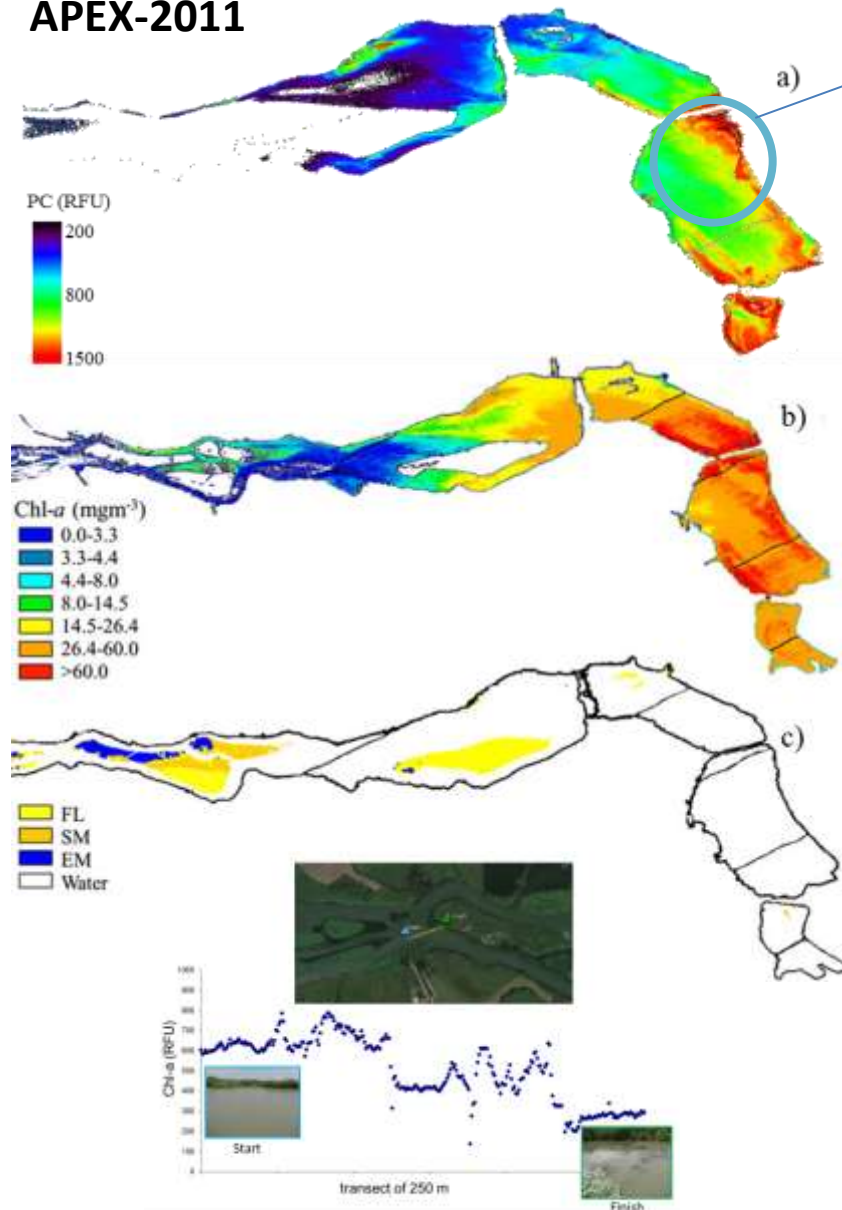
Risultati - Analisi spaziale APEX



Analisi della coesistenza dei produttori primari

Zona con elevata presenza di cianobatteri

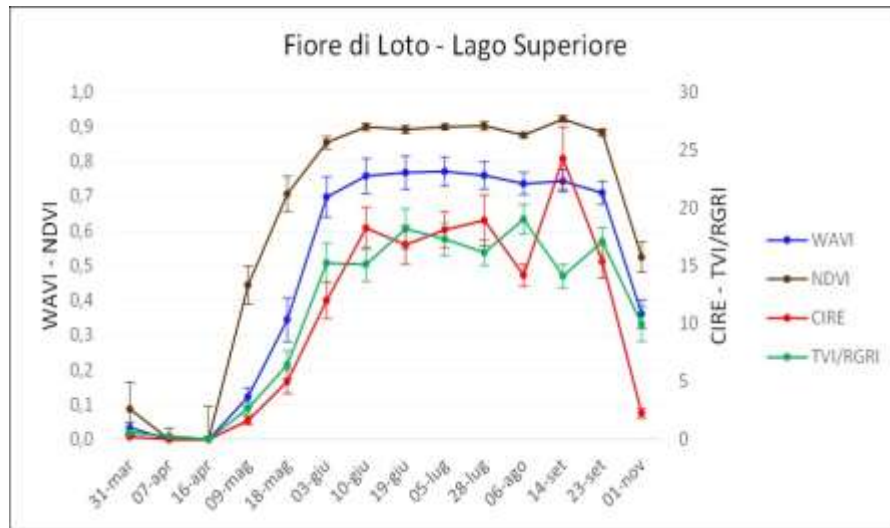
APEX-2011



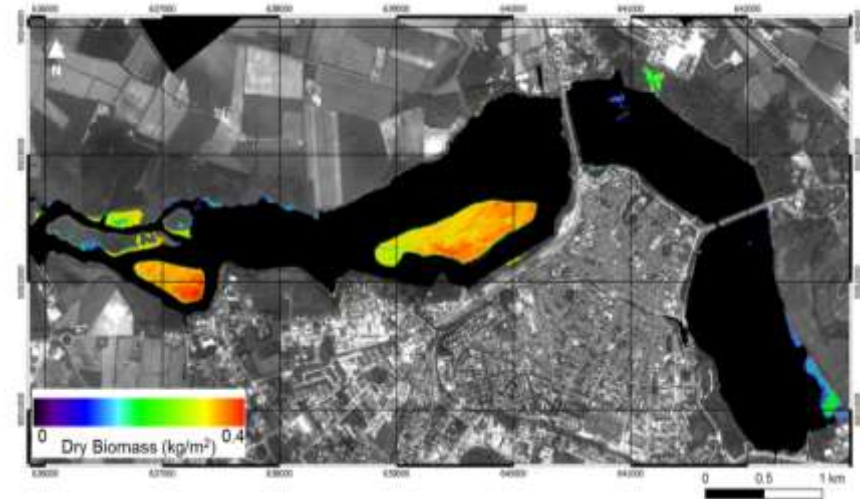
La presenza di ben strutturate associazioni di macrofite riduce le conc. di Chl-a e di cianobatteri nelle zone più vicine alle macrofite rispetto a quelle più lontane.

Obiettivo: sviluppare e fornire prodotti orientati agli utenti per il monitoraggio e la previsione della qualità delle acque interne

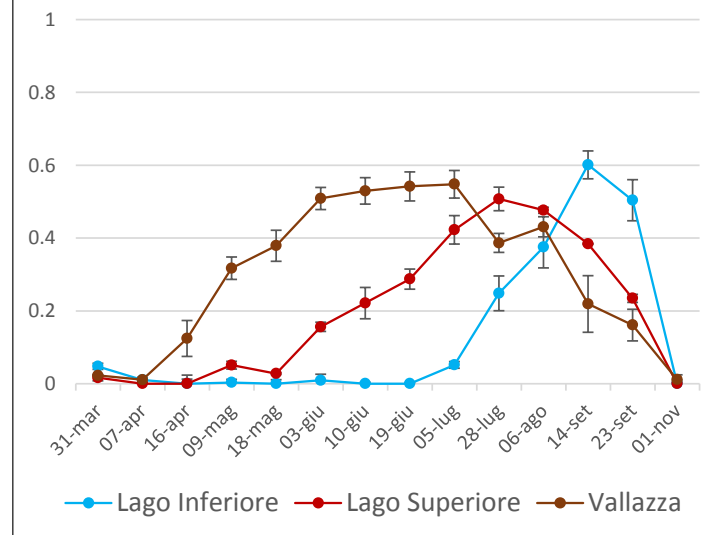
Analisi fenologica stagionale

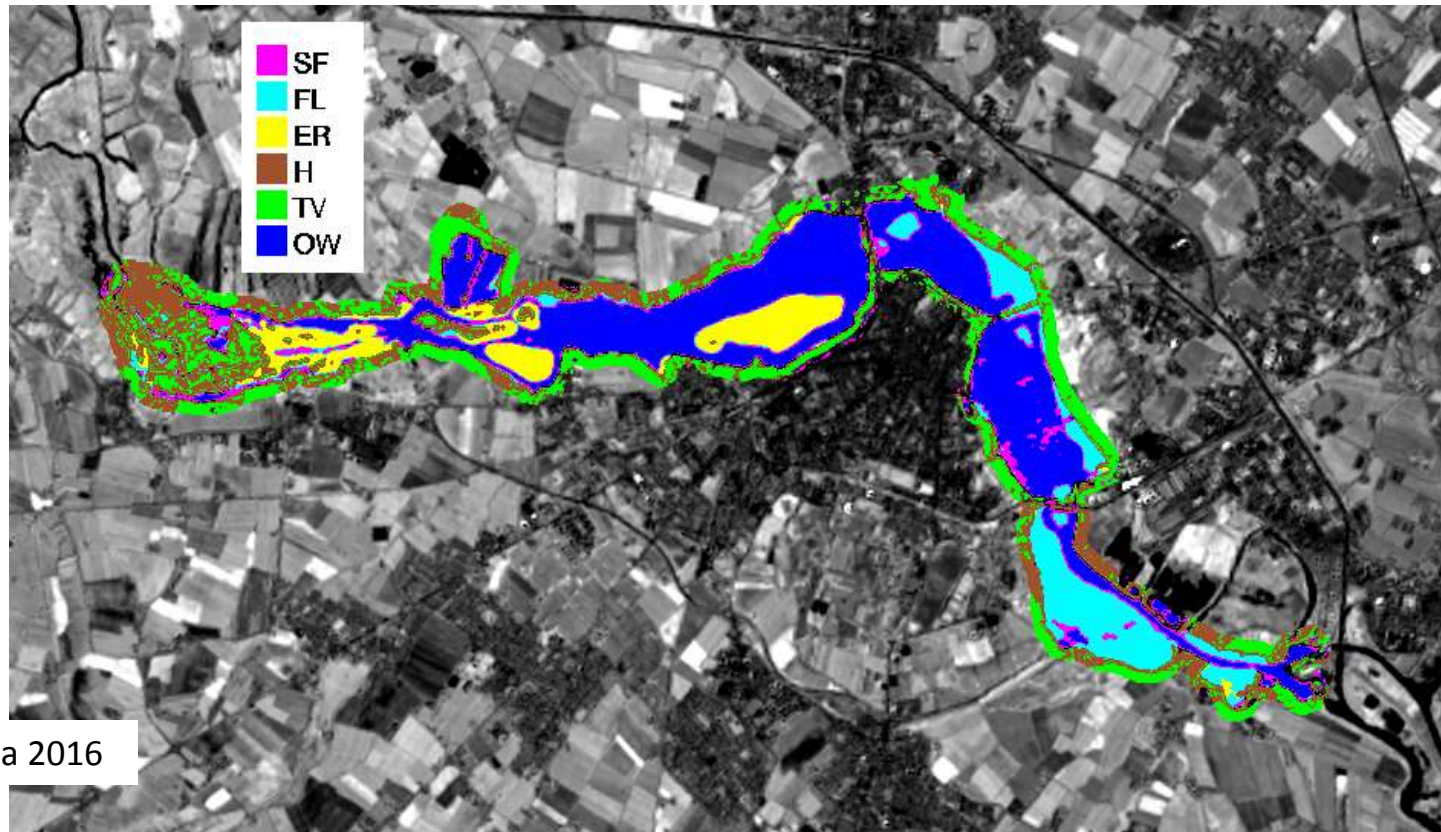


Mappa di Biomassa



Castagna d'acqua - WAVI



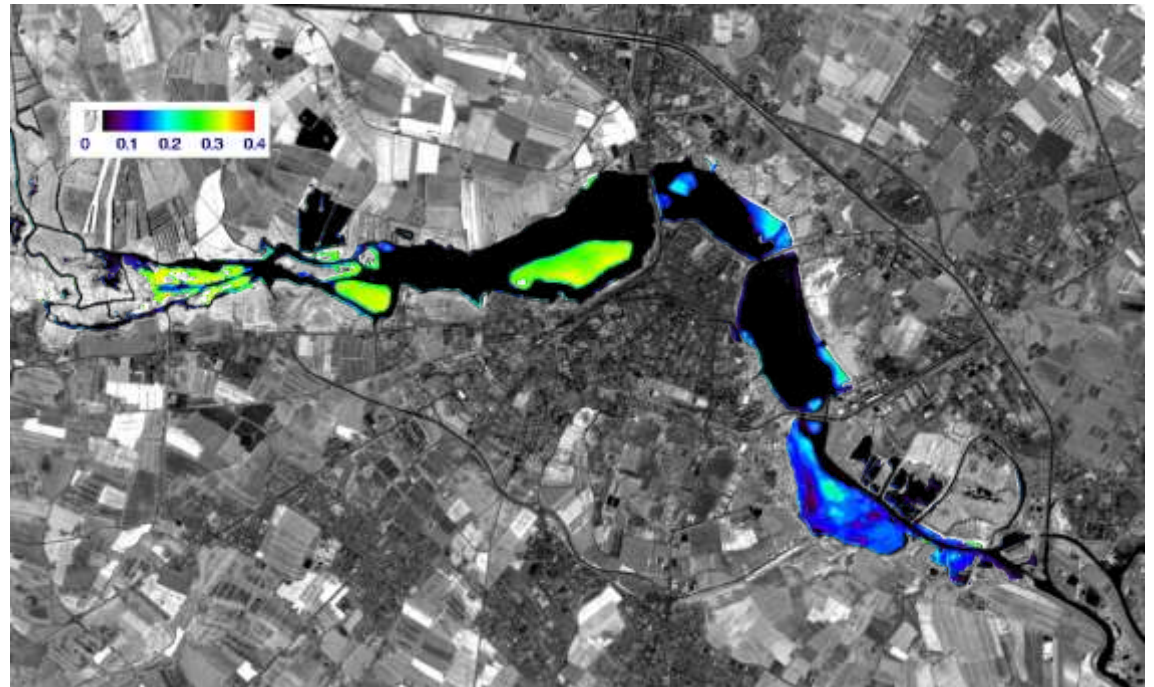
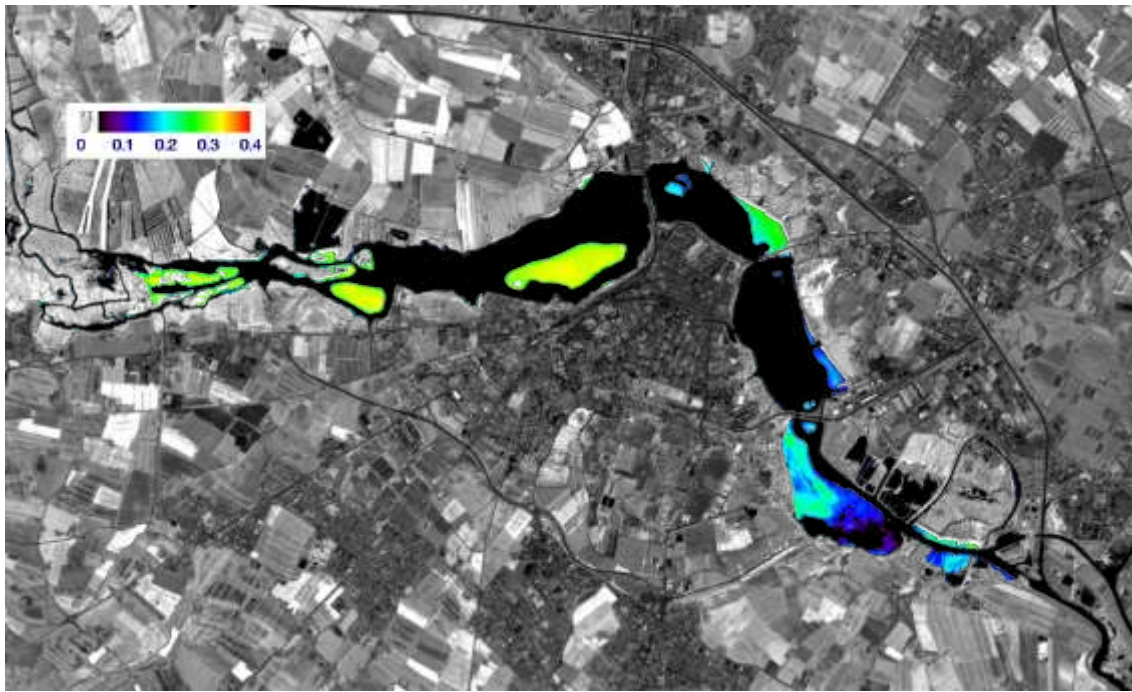


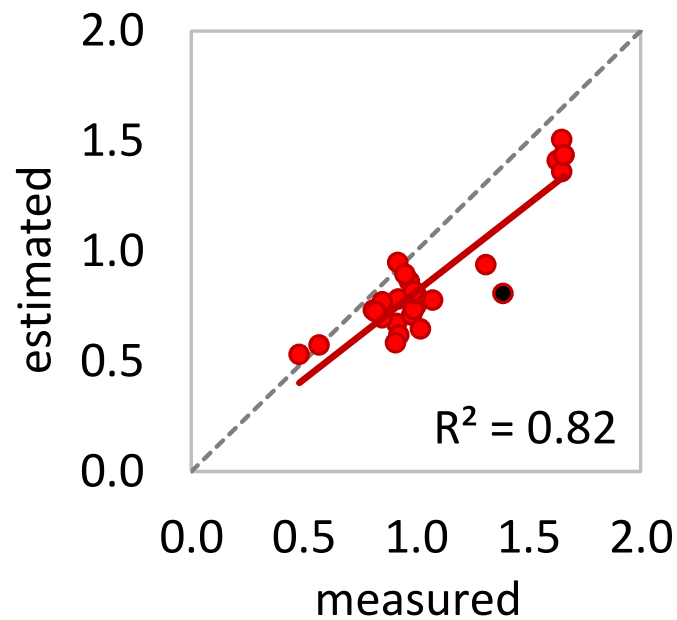
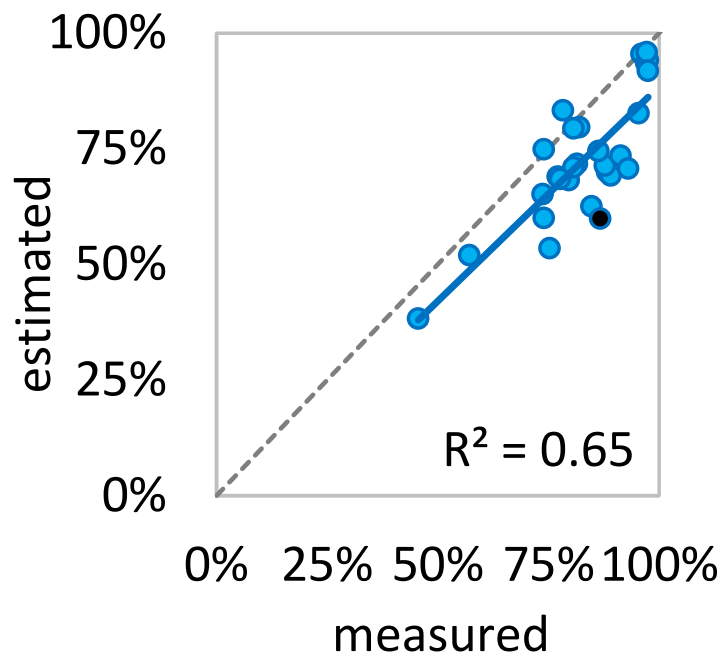
Validazione (2016 data):

Accuratezza totale= 92%

Errore relativo 15-20% per SF, H e TV

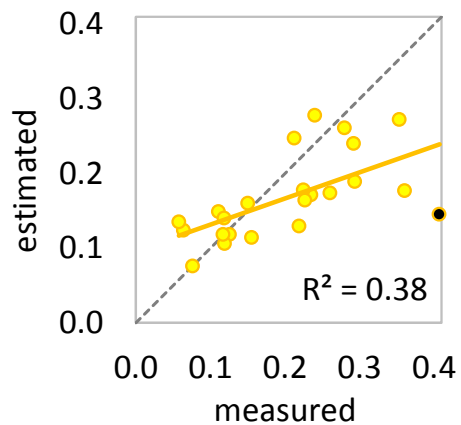
Errore relativo <5% per FL, ER e OW





fC (%)

LAI ($\text{m}^2 \text{m}^{-2}$)



AW biom (kg m^{-2})

Analisi storica delle variazioni spaziali delle isole di fior di loto

Data	Satellite-Sensore	Fior di Loto Isola 1 (m ²)	Fior di Loto Isola 2 (m ²)	pixel size (m)
14/08/1977	Landsat-MSS#	227200	50400	60x60
11/07/1987	Landsat-TM	451800	90900	30x30
05/08/1999	Landsat-TM	502200	104400	30x30
30/07/2003	Landsat-TM	801000	175500	30x30
15/07/2015	Landsat-TM	480000	170000	30x30



Senza gestione attiva le macrofite occuperebbero l'intera superficie dei laghi

Monitoraggio su superfici ampie con tecniche appropriate (TELERILEVAMENTO)

