Support Information

The role of vegetation on urban atmosphere of three European cities. Part 2: Evaluation of vegetation impact on air pollutant concentrations and depositions

Table S1. FARM and CMAQ CTMs domains used for simulations from continental to urban scale.

	Geographic area	Grid Dimension (points) lon x lat	Horizontal resolution(km)	Meteorological model	Anthropogenic Emission inventory
			FARM		
D1 (EU)	Europe	468 x 421	15 x 10	IFS 2015 (DSC-9674 Permission to use IFS data)	CAMS-REGAP_v2.2.1 for 2015 (TNO)
D2 (NI)	North of Italy	140 x 100	4 x 4	WRF data (D'Isidoro&Mircea et al., 2023).	National emission inventory distributed by ISPRA (Italian Institute for Environmental Protection and Research) (ISPRA, 2018)
Bologna (BO)	Bologna Municipality	50 x 50	1 x 1	WRF data (D'Isidoro&Mircea et al., 2023)	Emission inventory at municipal level provided by ARPA Emilia Romagna
Milan (MI)	Milan Municipality	60 x 60	1 x 1	WRF data (D'Isidoro&Mircea et al., 2023)	Emission inventory at municipal level provided by ARPA Lombardy
			CMAQ		
D1	Europe	187 x 176	27 x 27	WRF data (D'Isidoro&Mircea et al., 2023)	CAMS-REGAP_v2.2.1 for 2015
D2	Iberian Peninsula	131 x 99	9 x 9	WRF data (D'Isidoro&Mircea et al., 2023)	National Emission Inventory (MITECO, 2019)
D3	Spain central area	60 x 60	3 x 3	WRF data (D'Isidoro&Mircea et al., 2023)	National Emission Inventory (MITECO, 2019)
Madrid (MD)	Greater Madrid area	136 x 144	1 x 1	WRF data (D'Isidoro&Mircea et al., 2023).	local emission inventory of the Madrid City (AM, 2019)

Table S2. FARM and CMAQ validation of VEG simulations from continental to urban scale.

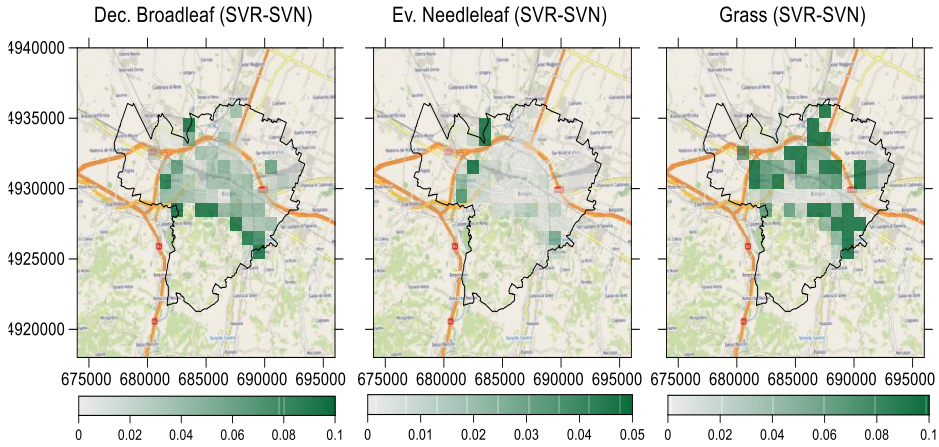
FARM scores*		**EU Jan/Jul**	**NI Jan/Jul**	**BO Jan/Jul**	**MI Jan/Jul**	**MD Jan/Jul**
O_3	bias	-8.05/-3.45	0.73/-14.3	-1.65/-21.5	-1.91/-24.0	0.75/-29.5
	rmse	17.8/23.9	16.4/30.6	12.1/31.0	14.5/36.6	17.3/39.7
	corr	0.70/0.76	0.56/0.79	0.61/0.83	0.61/0.83	0.75/0.72
NO_2	bias	-3.69/-1.01	-11.3/-3.5	3.83/1.51	-7.7/-1.16	-22.1/-7.31
	rmse	11.6/7.65	18.5/8.82	17.3/11.3	21.8/12.1	36.1/22.8
	corr	0.57/0.44	0.51/0.48	0.45/0.62	0.5/0.47	0.73/0.56
PM10	bias	-4.61/-7.45	-11.9/-12.9	-7.7/-12.6	-12.0/-14.2	-4.3/-11.3
	rmse	13.0/11.3	22.2/14.4	19.1/13.6	26.7/16.2	15.8/17.2
	corr	0.34/0.46	0.40/0.44	0.48/0.53	0.39/0.51	0.57/0.30

* the statistical scores were computed with R software. Bias and rmse are expressed in mg/m^3 and corr is adimensional.

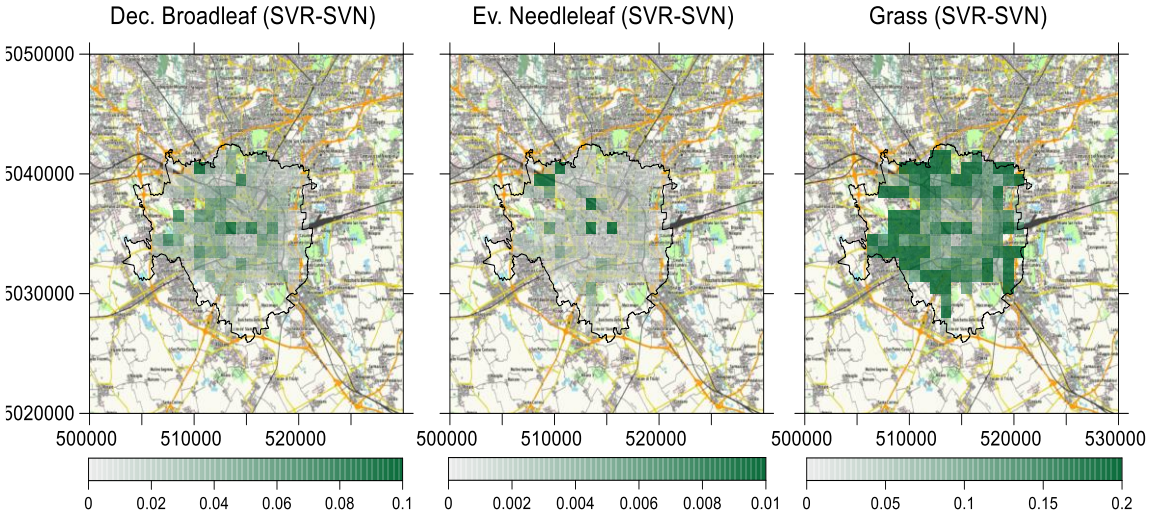
Table S3. Ranking of the 20 most relevant species in terms of percent of the total area covered by trees. Colours identify same species in different cities.

Milano		Bologna		Madrid	
Name	Percent of total tree cover	Name	Percent of total tree cover	*Name*	Percent of total tree cover
Platanus acerifolia	11.43	*Celtis australis*	13.31	*Platanus*	17.78
Celtis australis	8.71	*Platanus acerifolia*	13.06	*Ulmus pumila*	13.74
Platanus	5.86	*Tilia*	7.66	*Pinus pinea*	9.03
Ulmus	5.64	*Populus nigra*	6.43	*Sophora japonica*	8.05
Tilia	3.91	*Aesculus hippocastanum*	5.58	*Robinia pseudoacacia*	5.08
Quercus rubra	3.82	*Populus alba*	4.83	*Acer negundo*	3.24
Acer platanoides	3.20	*Cedrus deodara*	4.13	*Aesculus hippocastanum*	2.71
Robinia pseudoacacia	2.94	*Quercus robur*	2.38	*Pinus halepensis*	2.51
Acer negundo	2.60	*Sophora japonica*	2.22	*Platanus hybrida*	2.09
Populus nigra	2.53	*Acer campestre*	2.07	*Ulmus*	2.02
Acer saccharinum	2.50	*Tilia platyphyllos*	2.04	*Celtis australis*	1.96

Aesculus hippocastanum	2.36	*Fraxinus excelsior*	1.92	*Gleditsia triacanthos*	1.85
Ulmus pumila	2.31	*Fraxinus oxycarpa*	1.85	*Cedrus deodara*	1.77
Celtis	2.20	*Cedrus atlantica*	1.81	*Populus alba*	1.67
Cedrus atlantica	2.04	*Populus canescens*	1.74	*Platanus orientalis*	1.49
Sophora japonica	1.90	*Robinia pseudoacacia*	1.63	*Prunus cerasus*	1.43
Acer pseudoplatanus	1.87	*Fraxinus*	1.55	*Ligustrum lucidum*	1.38
Platanus hybrida	1.71	*Pinus pinea*	1.40	*Melia azedarach*	1.32



(a)



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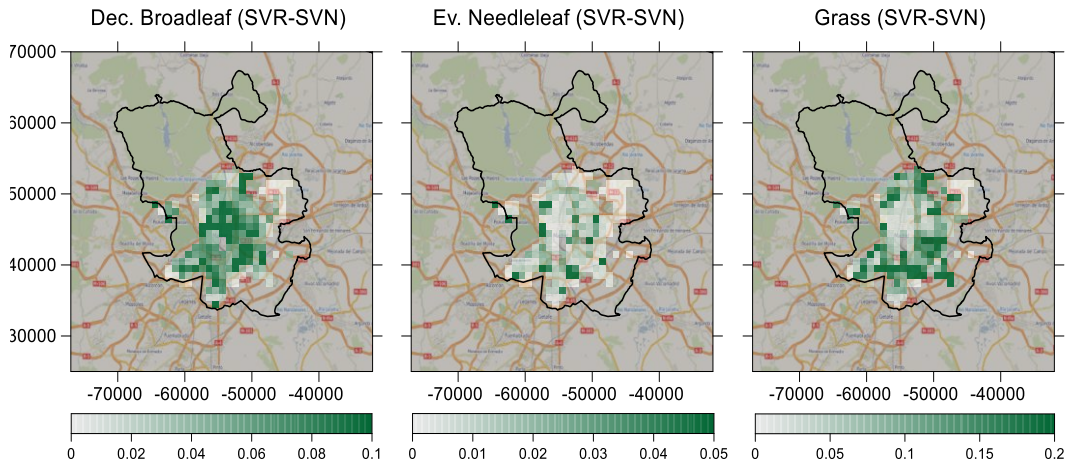
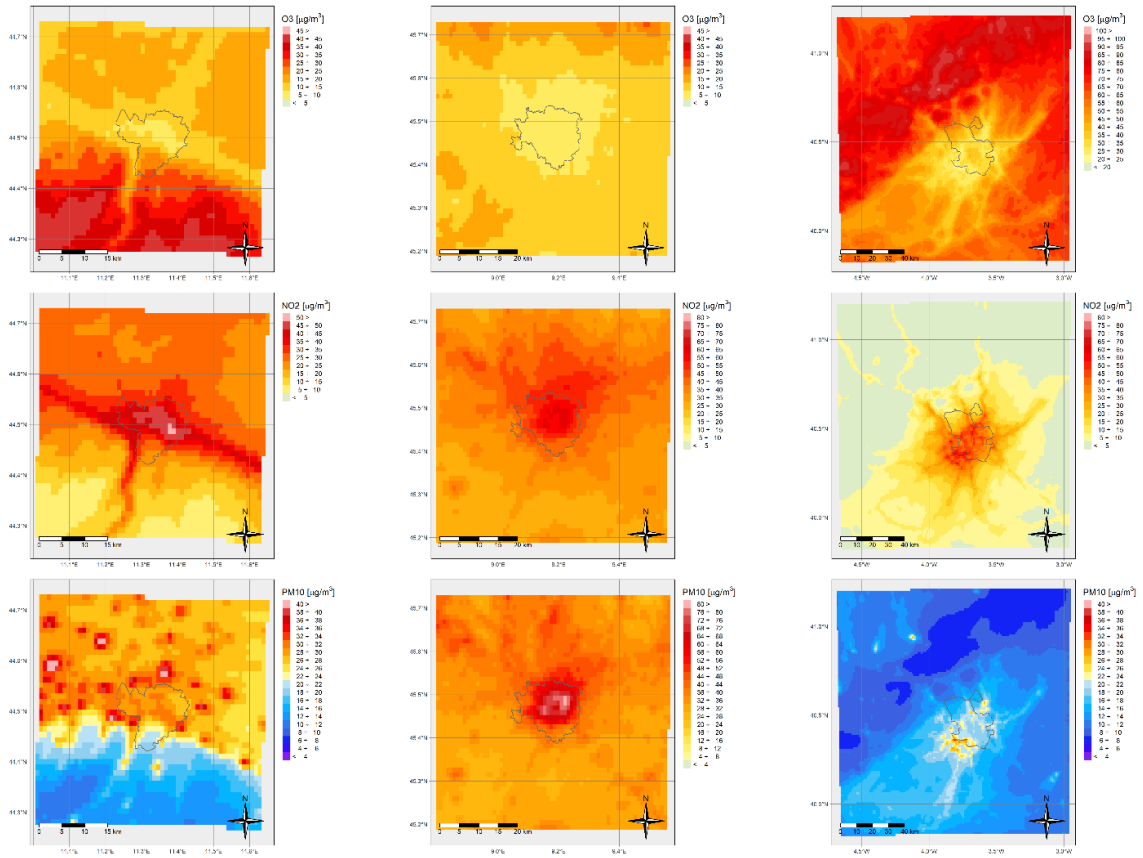
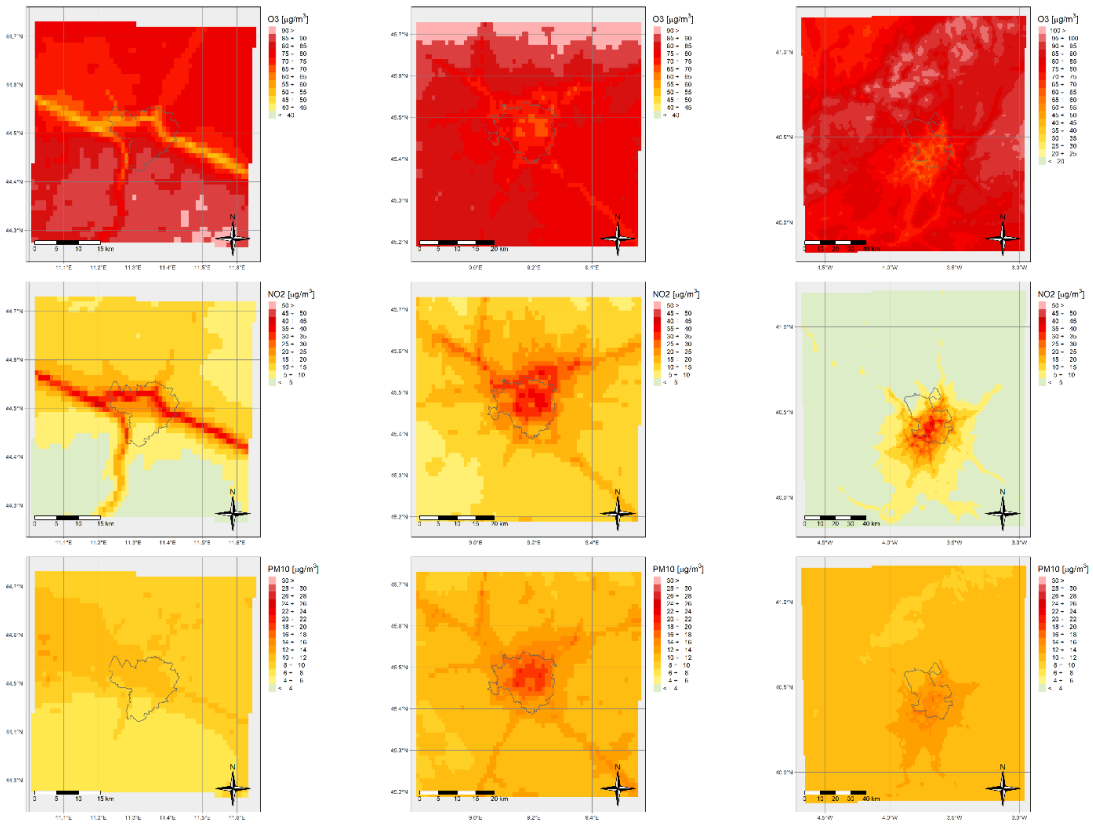


(c)

Figure S1. Fractional land cover maps of deciduous broadleaf species (left), evergreen needleleaf evergreen species (centre) and grass (right panel) over Bologna urban area (black contour). Maps are obtained as difference of vegetation cover characterising VEG and NOVEG scenarios. Pixel dimension is 1 km^2. Colour scales are different to make the maps of different vegetation classes. visible.(a)Bologna, (b)Milano, (c)Madrid.



(a)



(b)

Figure S2. Monthly averages of air concentrations (mg/m^3) (VEG) for O_3 (upper panel), NO_2 (middle panel) and PM10 (bottom panel) in Bologna (left column), Milan (central column) and Madrid (right column) (a)January 2015, (b)July.

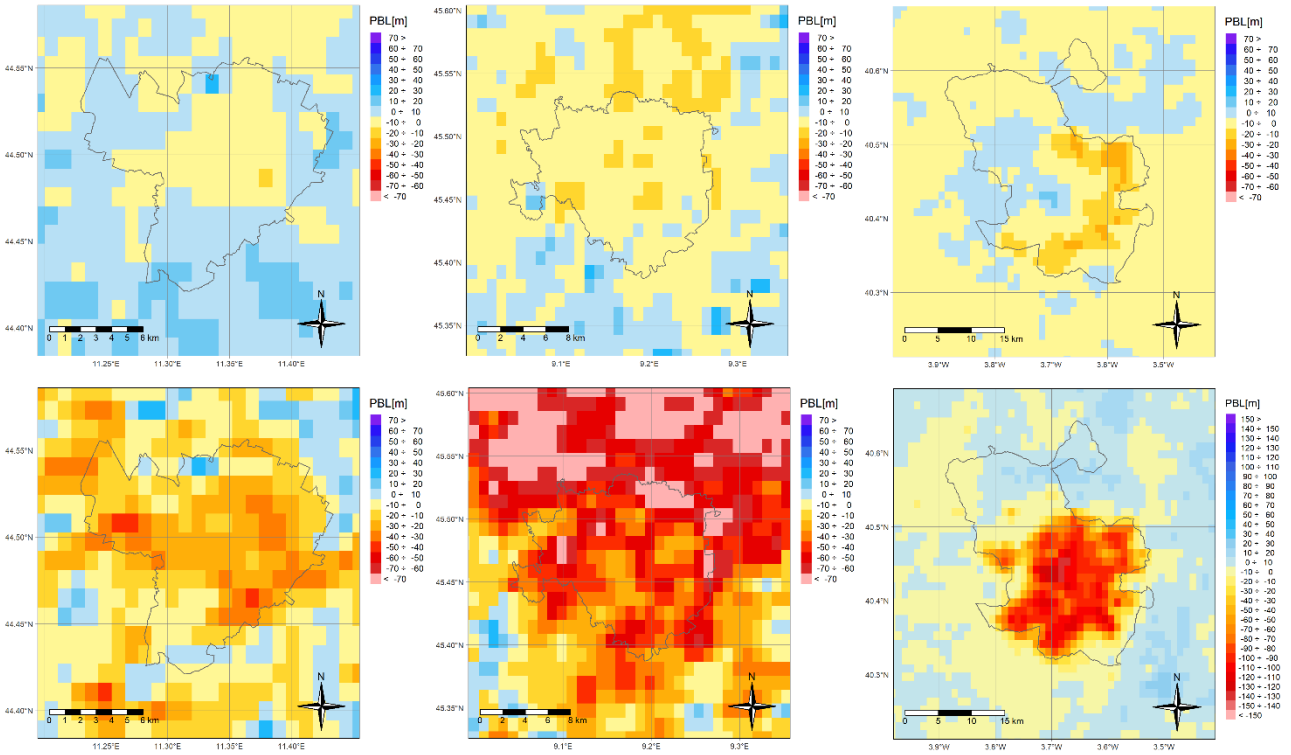


Figure S3. Monthly averages of differences (VEG-NOVEG) of planetary boundary layer (PBL) height (m) for January (upper panel) and July (bottom panel) in Bologna (left column), Milan (central column) and Madrid (right column).

Figure S4. Description of multiple graphs with daily cycle of O_3, NO_2 and PM10 concentrations differences (VEG-NOVEG) (mg/m^3) and deposition differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the municipalities

City		O3	NO2	PM10
Bologna	**Conc**	S4ac1	S4ac2	S4ac3
	Dep	S4ad1	S4ad2	S4ad3
Milan	**Conc**	S4bc1	S4bc2	S4bc3
	Dep	S4bd1	S4bd2	S4bd3
Madrid	**Conc**	S4cc1	S4cc2	S4cc3
	Dep	S4cd1	S4cd2	S4cd3

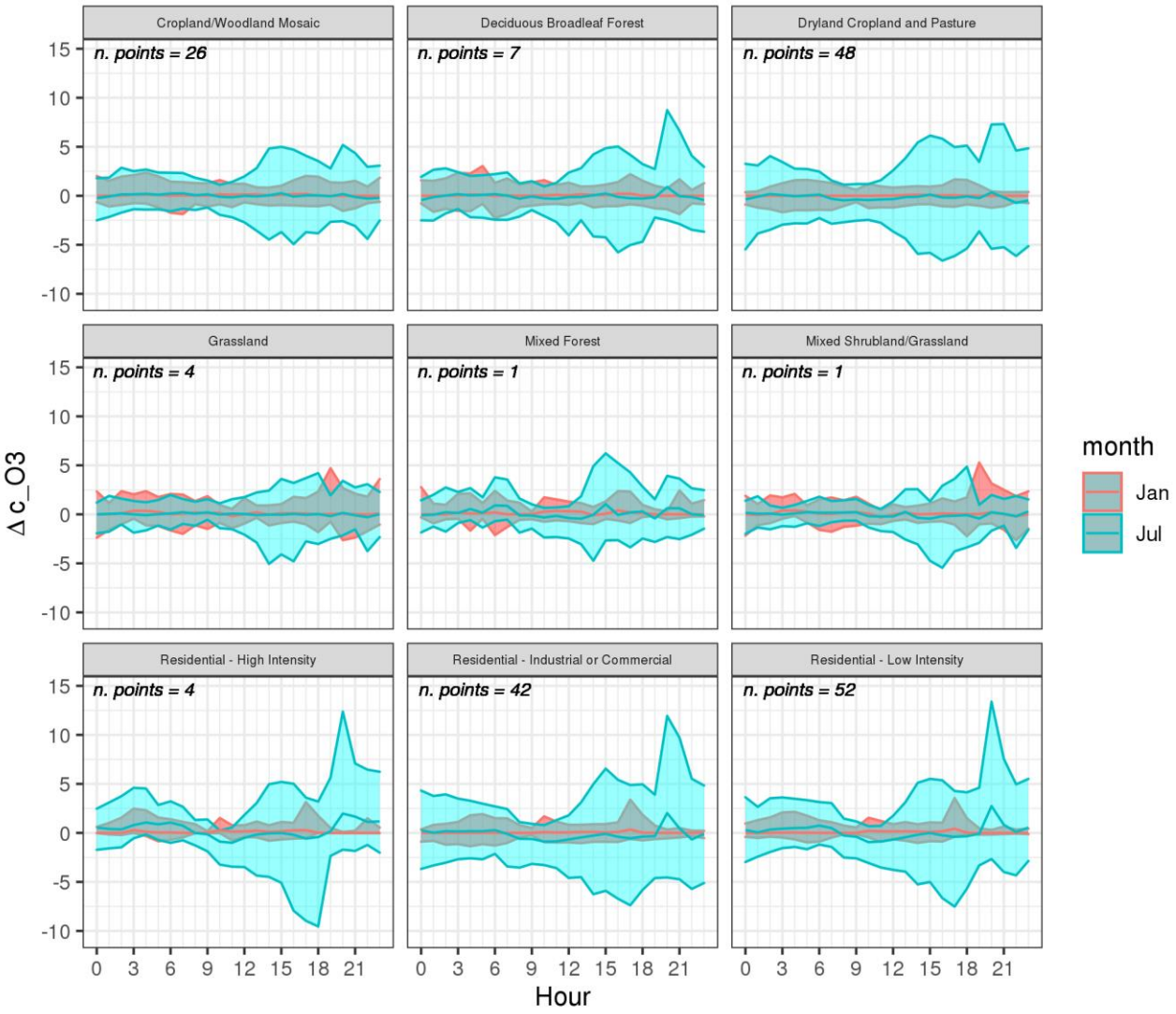


Figure S4ac1. Daily cycle of O_3 concentrations differences (VEG-NOVEG) (mg/m^3) as a function of land-use, considering only grid points inside the Bologna municipality. Medians are shown as lines and shaded area covers the interval 10^{th} to 90^{th} percentiles. Cyan and red colours refer to July and January, respectively.

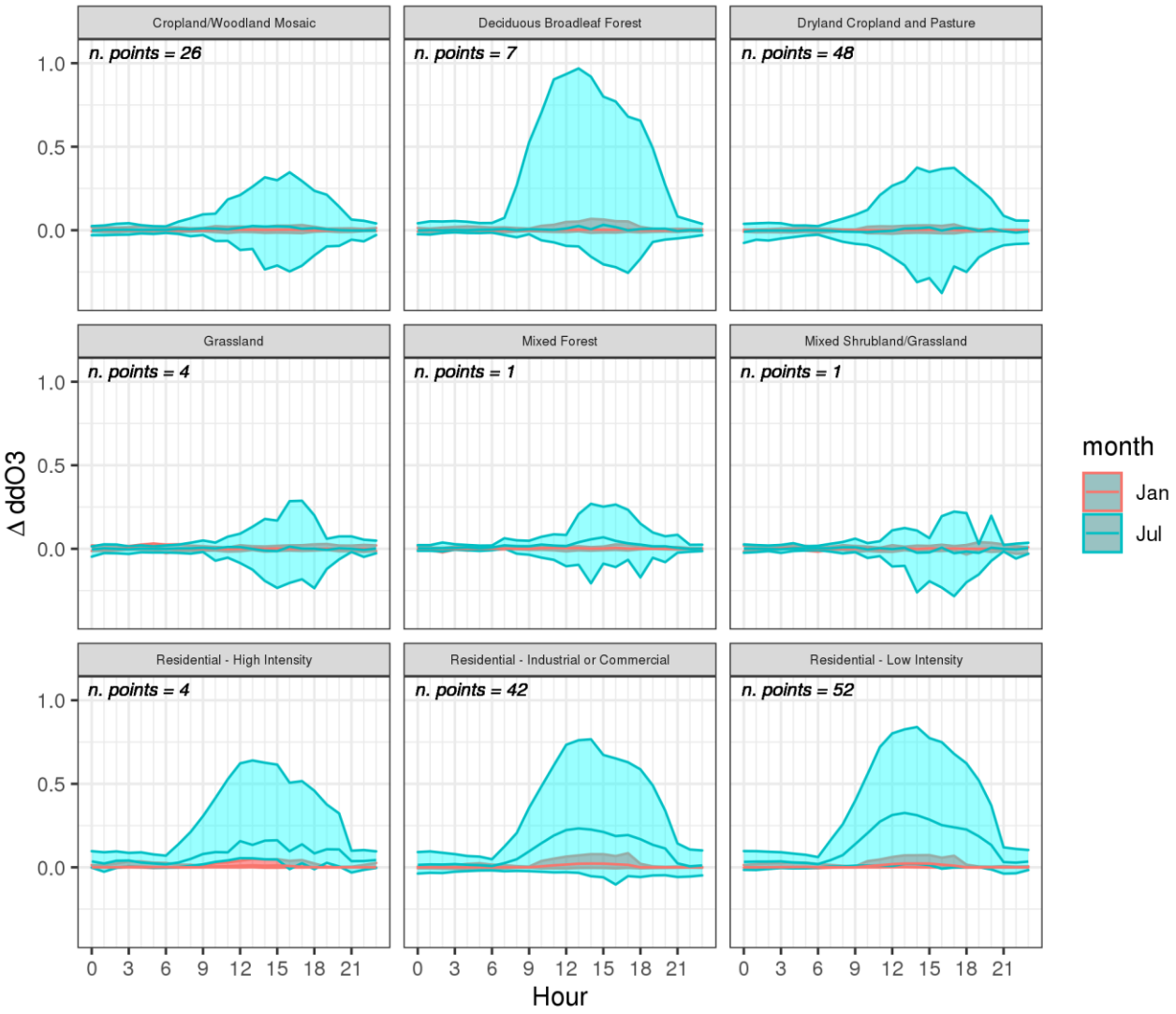


Figure S4ad1. Daily cycle of O_3 deposition differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the Bologna municipality. Medians are shown as lines and shaded area covers the interval 10th to 90th percentiles. Cyan and red colours refer to July and January, respectively.

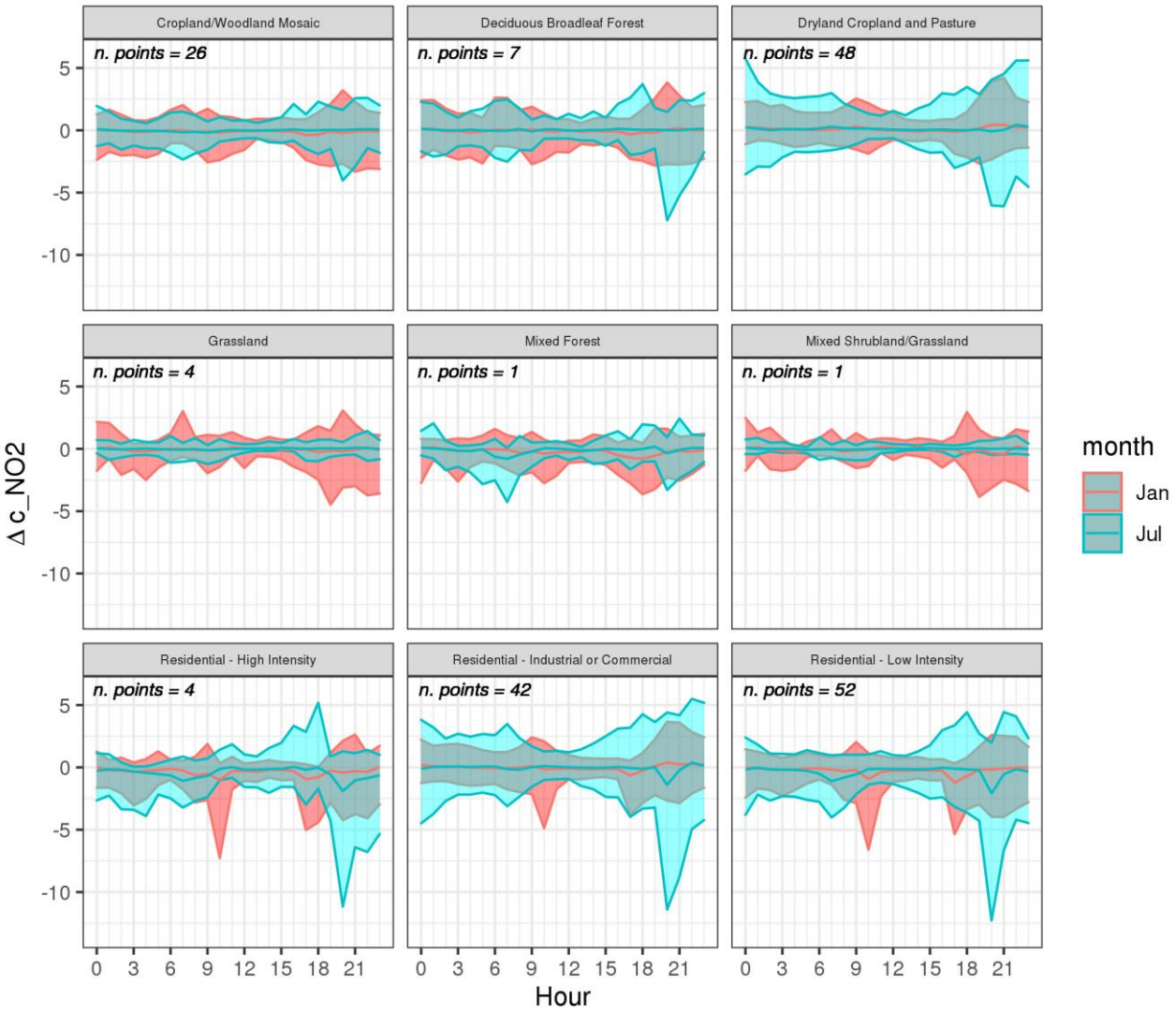


Figure S4ac2. Daily cycle of NO_2 concentrations differences (VEG-NOVEG) (mg/m^3) as a function of land-use, considering only grid points inside the Bologna municipality. Medians are shown as lines and shaded area covers the interval 10^{th} to 90^{th} percentiles. Cyan and red colours refer to July and January, respectively.

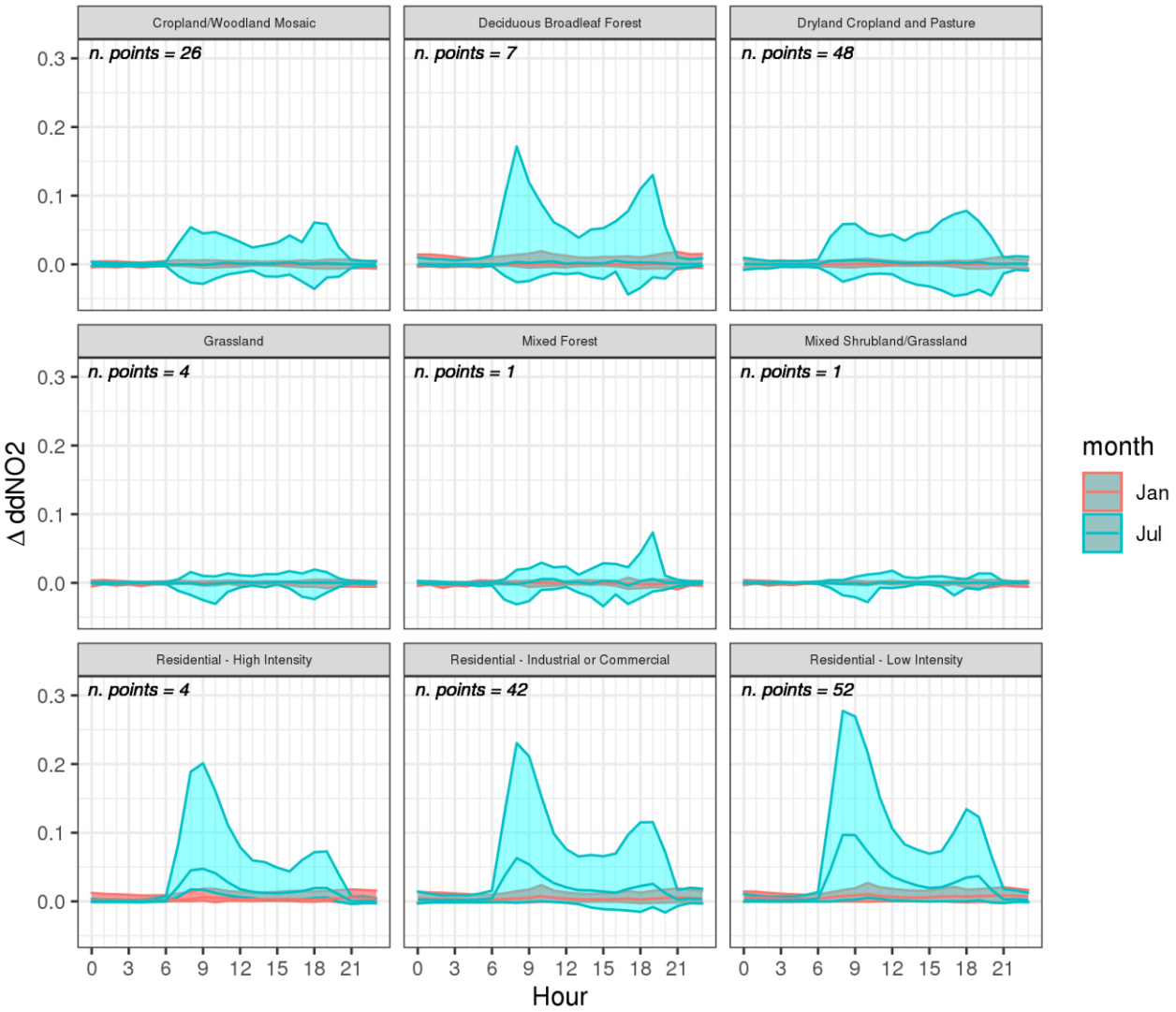


Figure S4ad2. Daily cycle of NO_2 deposition differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the Bologna municipality. Medians are shown as lines and shaded area covers the interval 10^{th} to 90^{th} percentiles. Cyan and red colours refer to July and January, respectively.

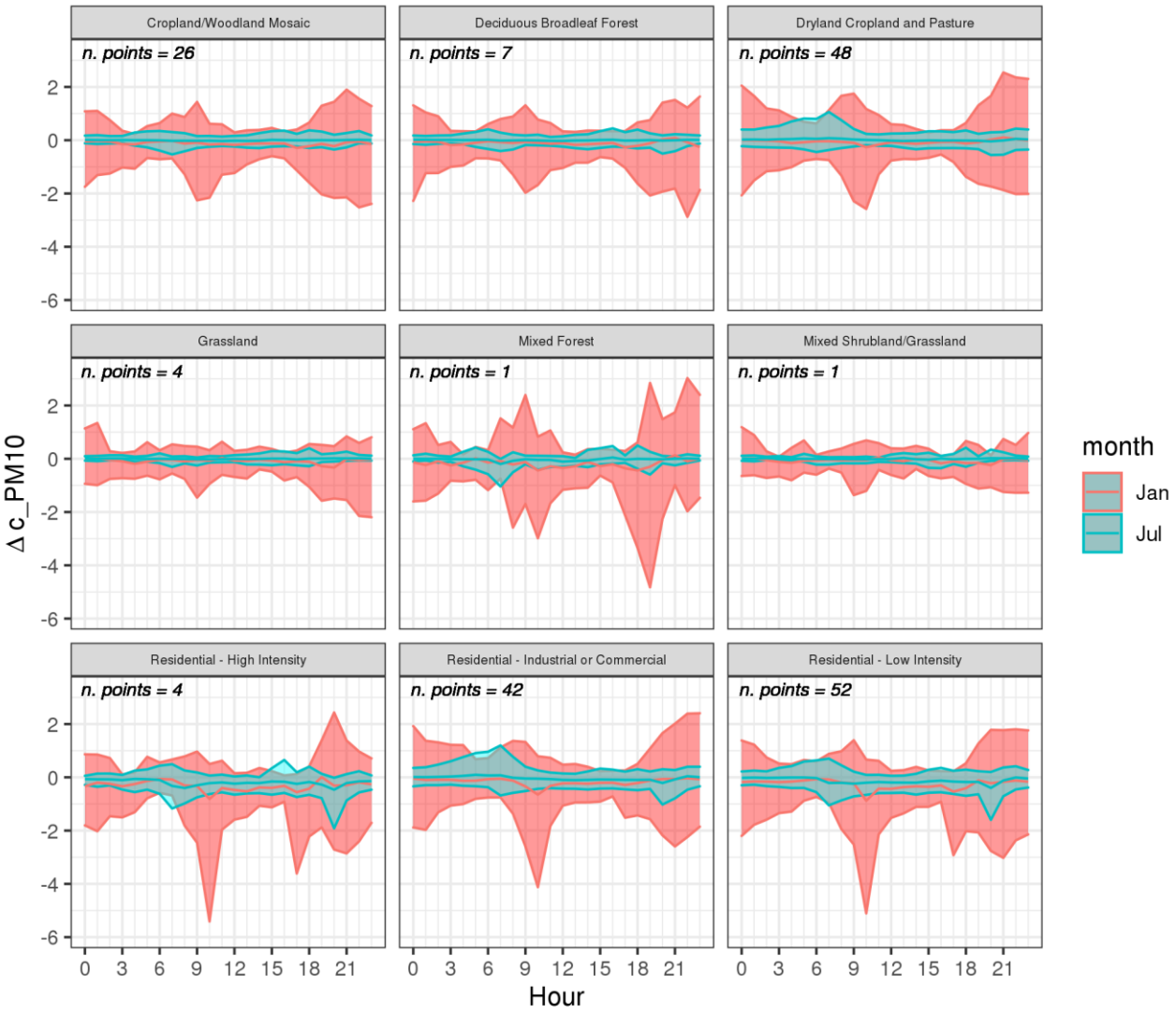


Figure S4ac3. Daily cycle of PM10 concentrations differences (VEG-NOVEG) (mg/m^3) as a function of land-use, considering only grid points inside the Bologna municipality. Medians are shown as lines and shaded area covers the interval 10th to 90th percentiles. Cyan and red colours refer to July and January, respectively.

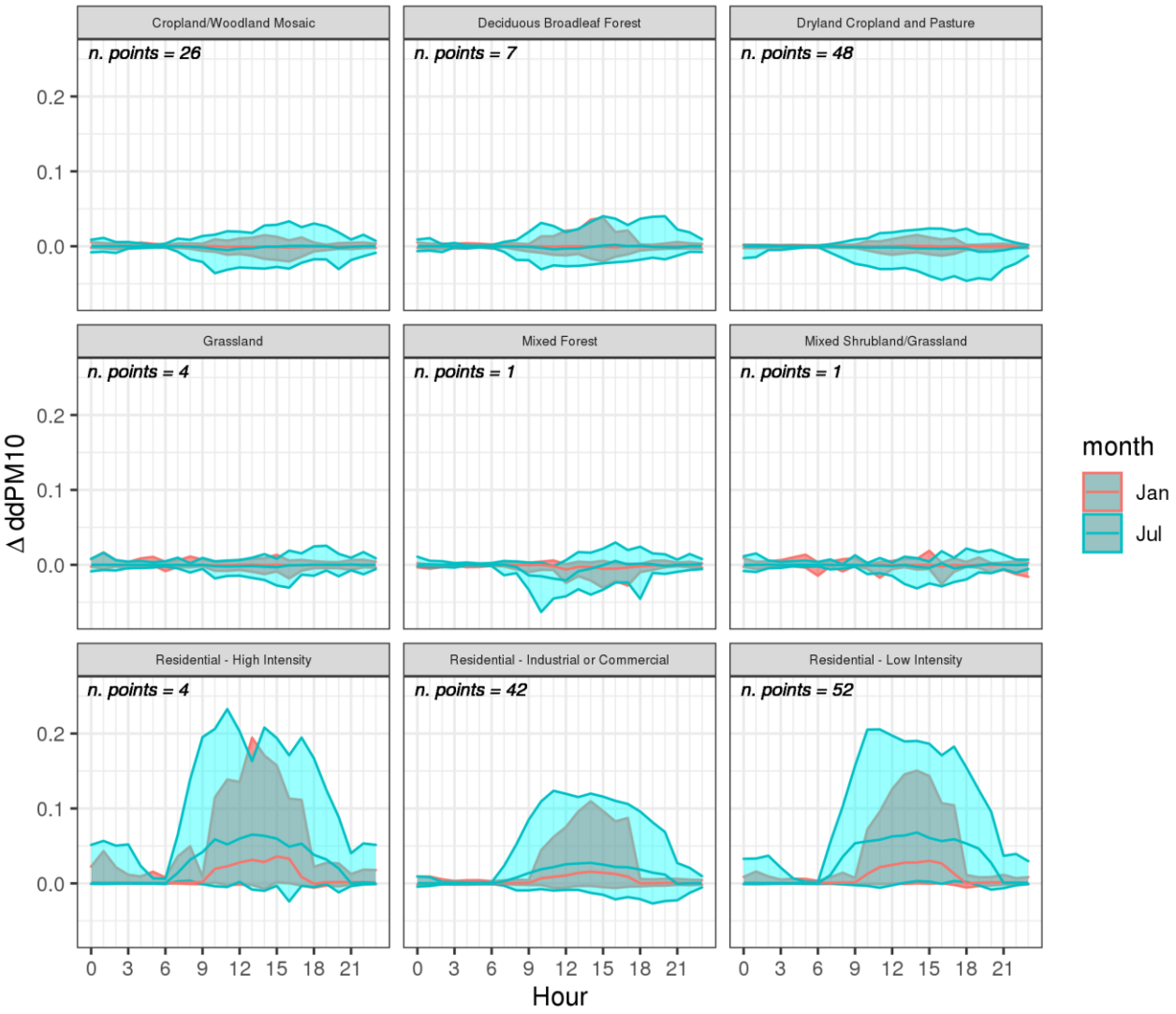


Figure S4ad3. Daily cycle of PM10 deposition differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the Bologna municipality. Medians are shown as lines and shaded area covers the interval 10th to 90th percentiles. Cyan and red colours refer to July and January, respectively.

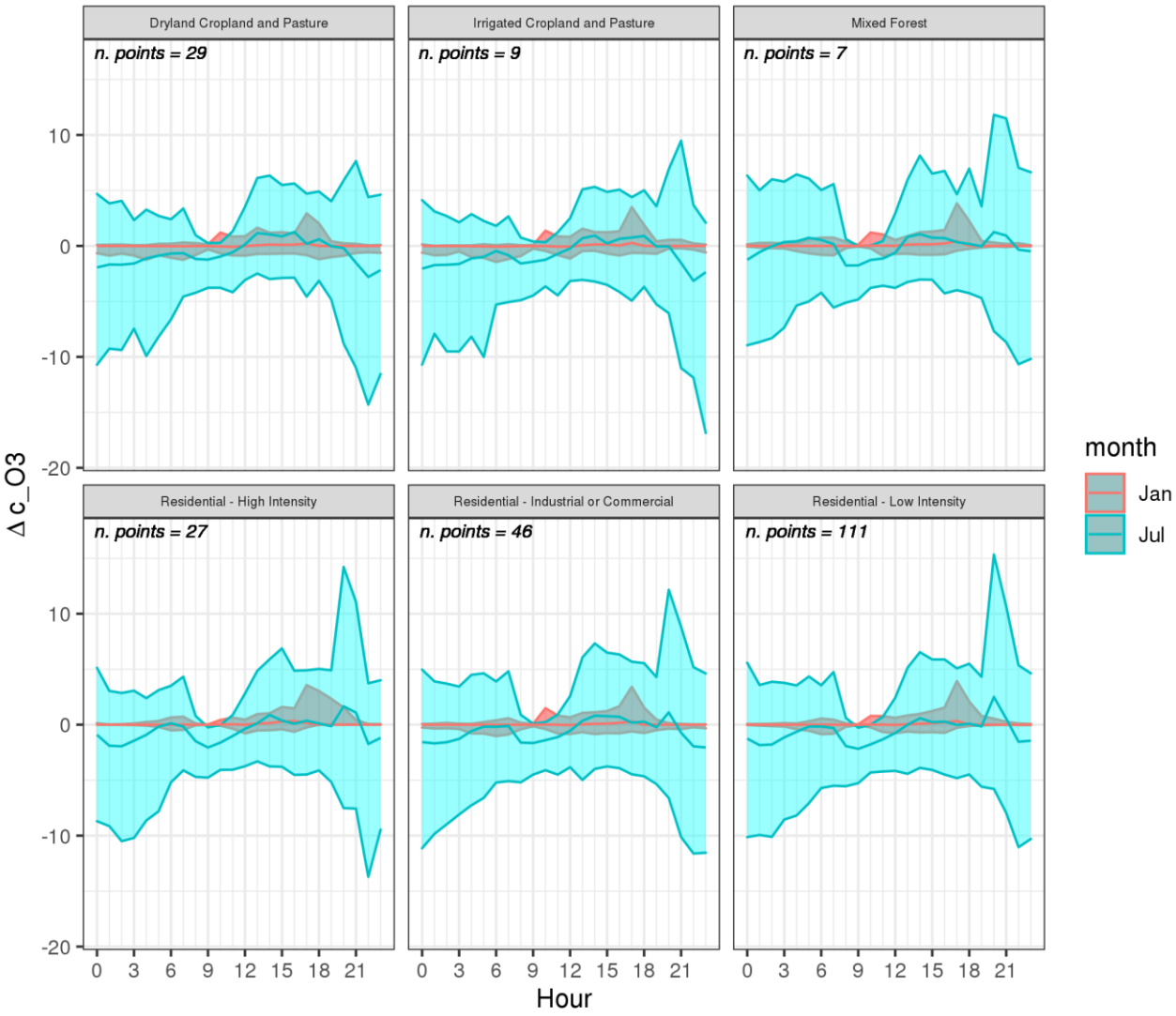


Figure S4bc1. Daily cycle of O_3 concentrations differences (VEG-NOVEG) (mg/m^3) as a function of land-use, considering only grid points inside the Milan municipality. Medians are shown as lines and shaded area covers the interval 10^{th} to 90^{th} percentiles. Cyan and red colours refer to July and January, respectively.

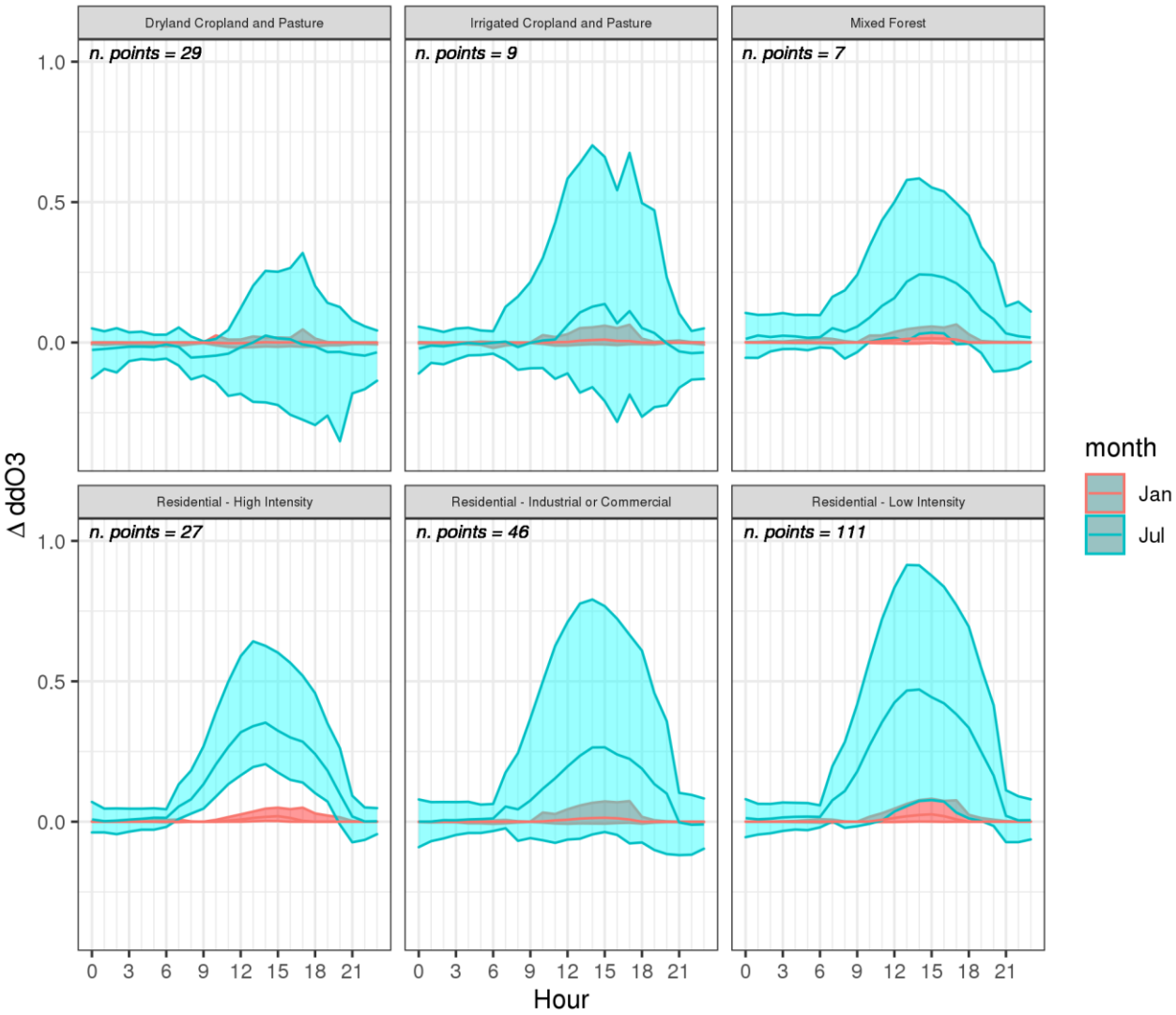


Figure S4bd1. Daily cycle of O_3 deposition differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the Milan municipality. Medians are shown as lines and shaded area covers the interval 10^{th} to 90^{th} percentiles. Cyan and red colours refer to July and January, respectively.

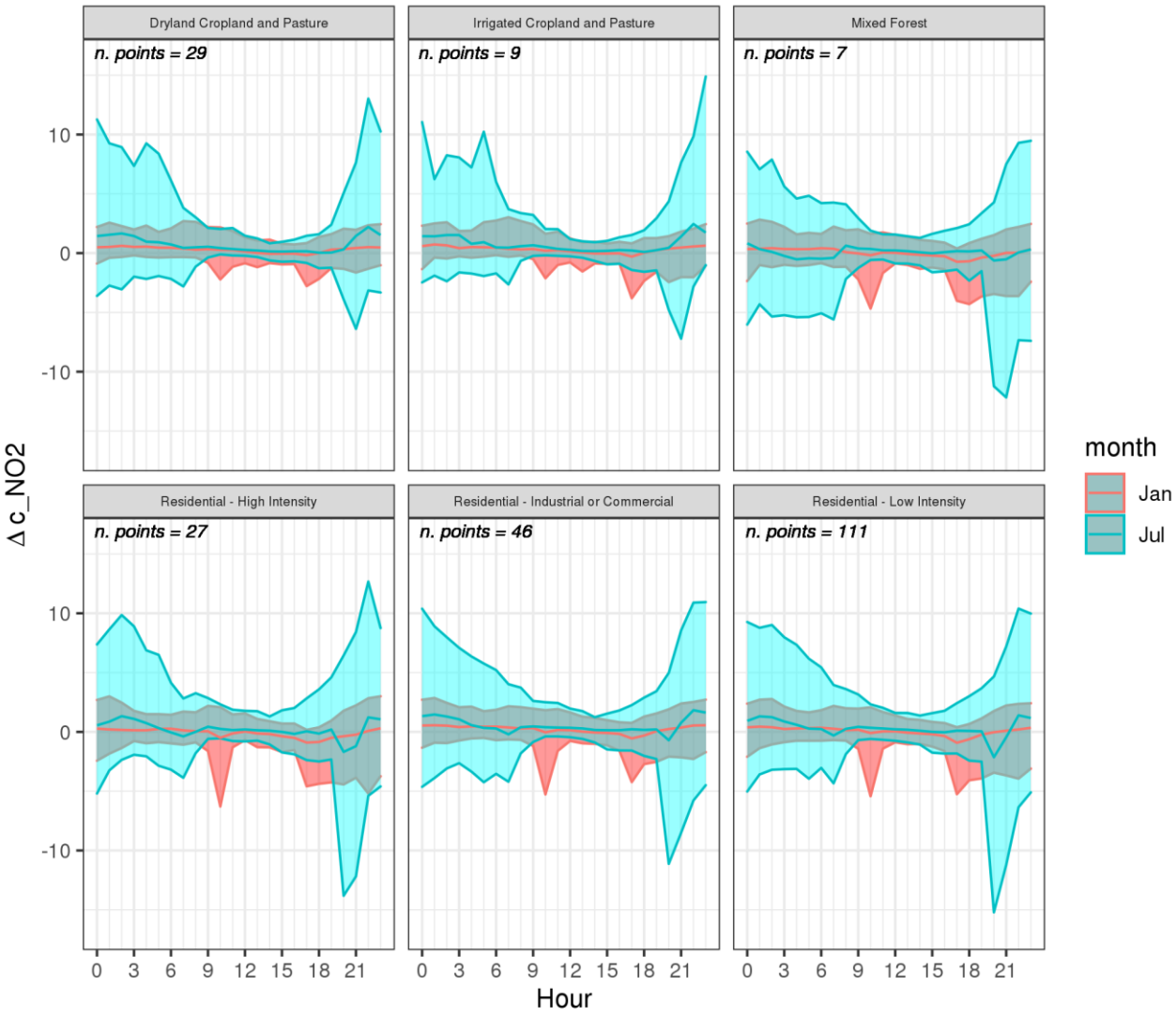


Figure S4bc2. Daily cycle of NO_2 concentrations differences (VEG-NOVEG) (mg/m^3) as a function of land-use, considering only grid points inside the Milan municipality. Medians are shown as lines and shaded area covers the interval 10^{th} to 90^{th} percentiles. Cyan and red colours refer to July and January, respectively.

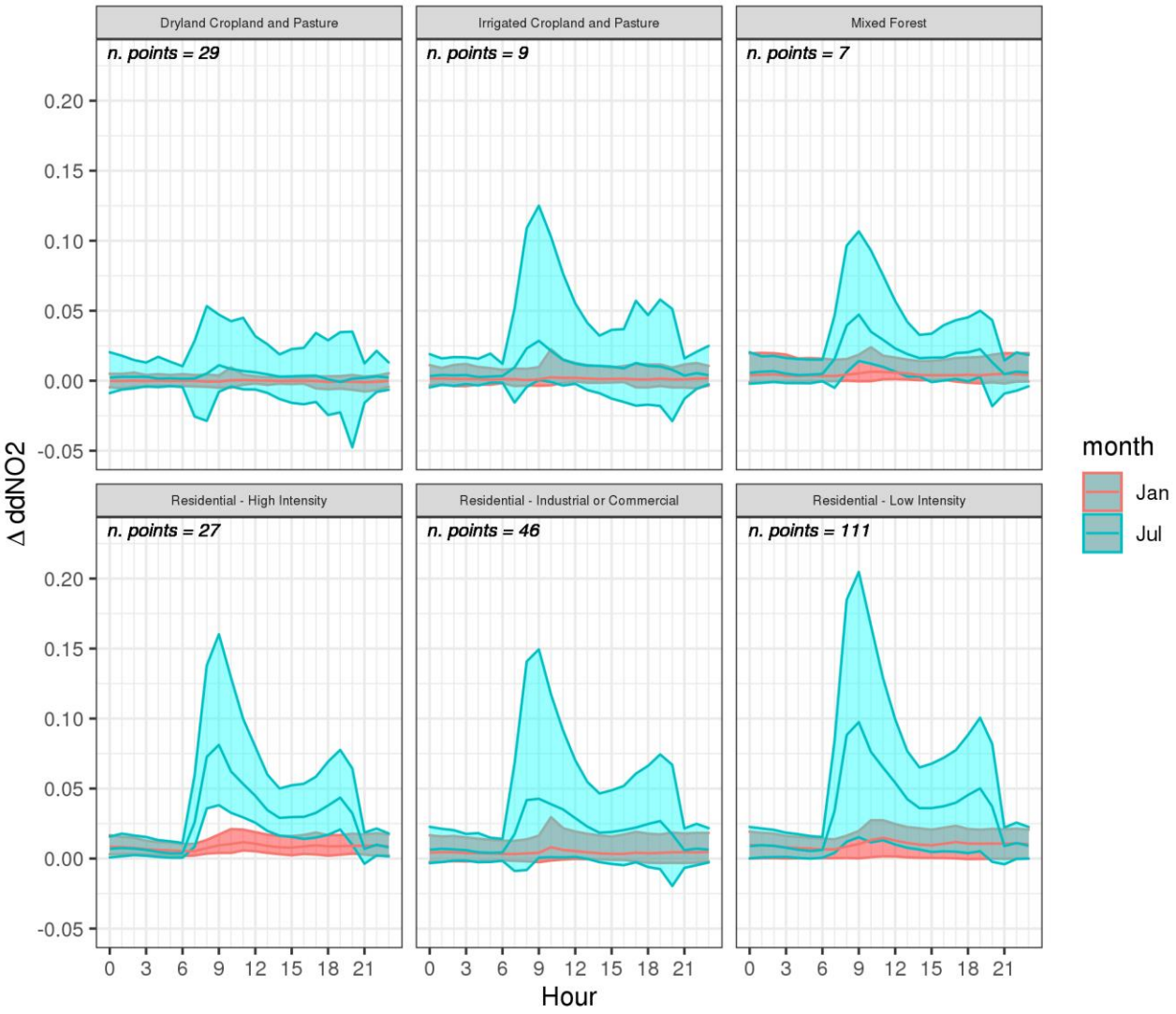


Figure S4bd2. Daily cycle of NO_2 deposition differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the Milan municipality. Medians are shown as lines and shaded area covers the interval 10^{th} to 90^{th} percentiles. Cyan and red colours refer to July and January, respectively.

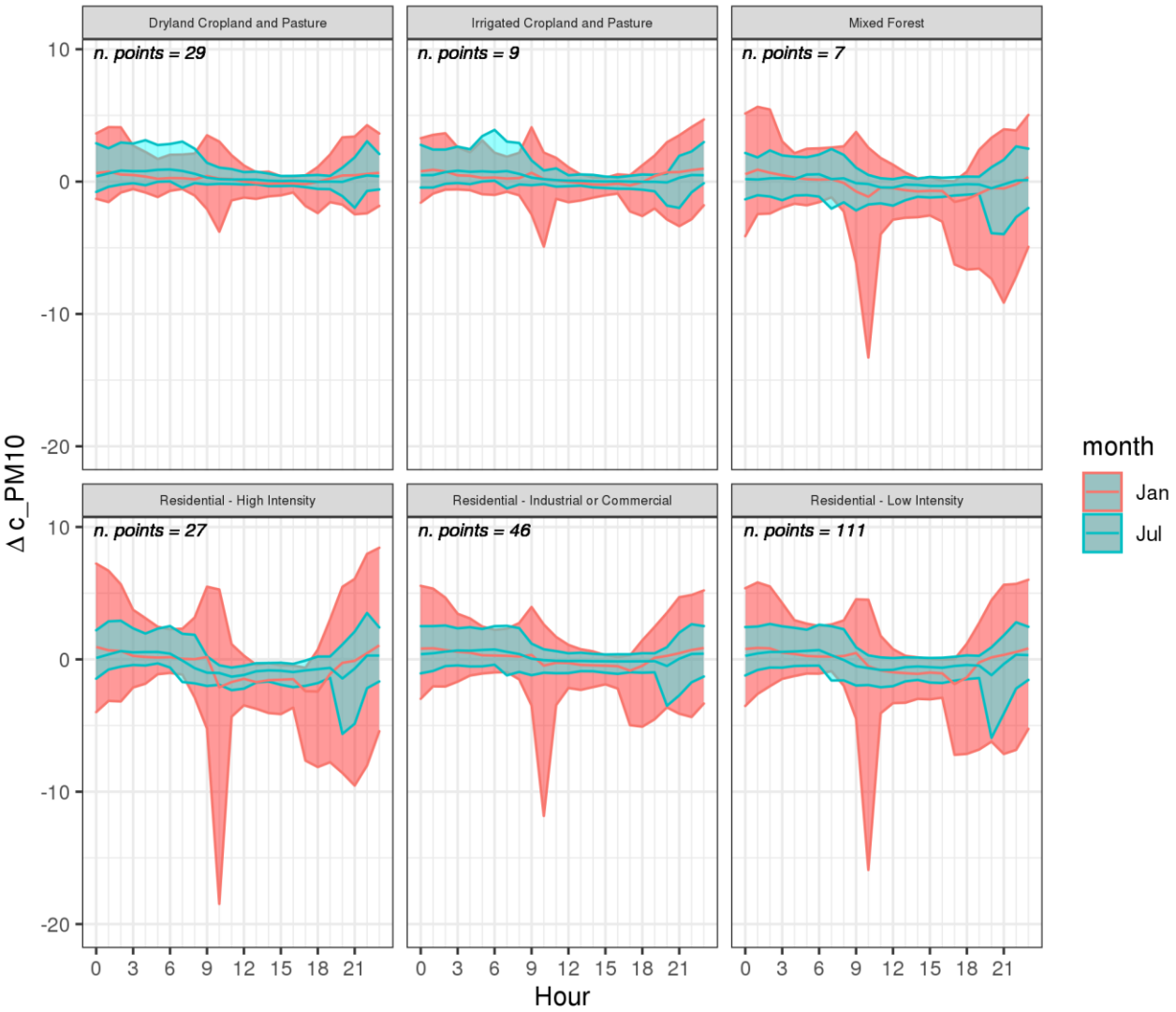


Figure S4bc3. Daily cycle of PM10 concentrations differences (VEG-NOVEG) (mg/m^3) as a function of land-use, considering only grid points inside the Milan municipality. Medians are shown as lines and shaded area covers the interval 10th to 90th percentiles. Cyan and red colours refer to July and January, respectively.

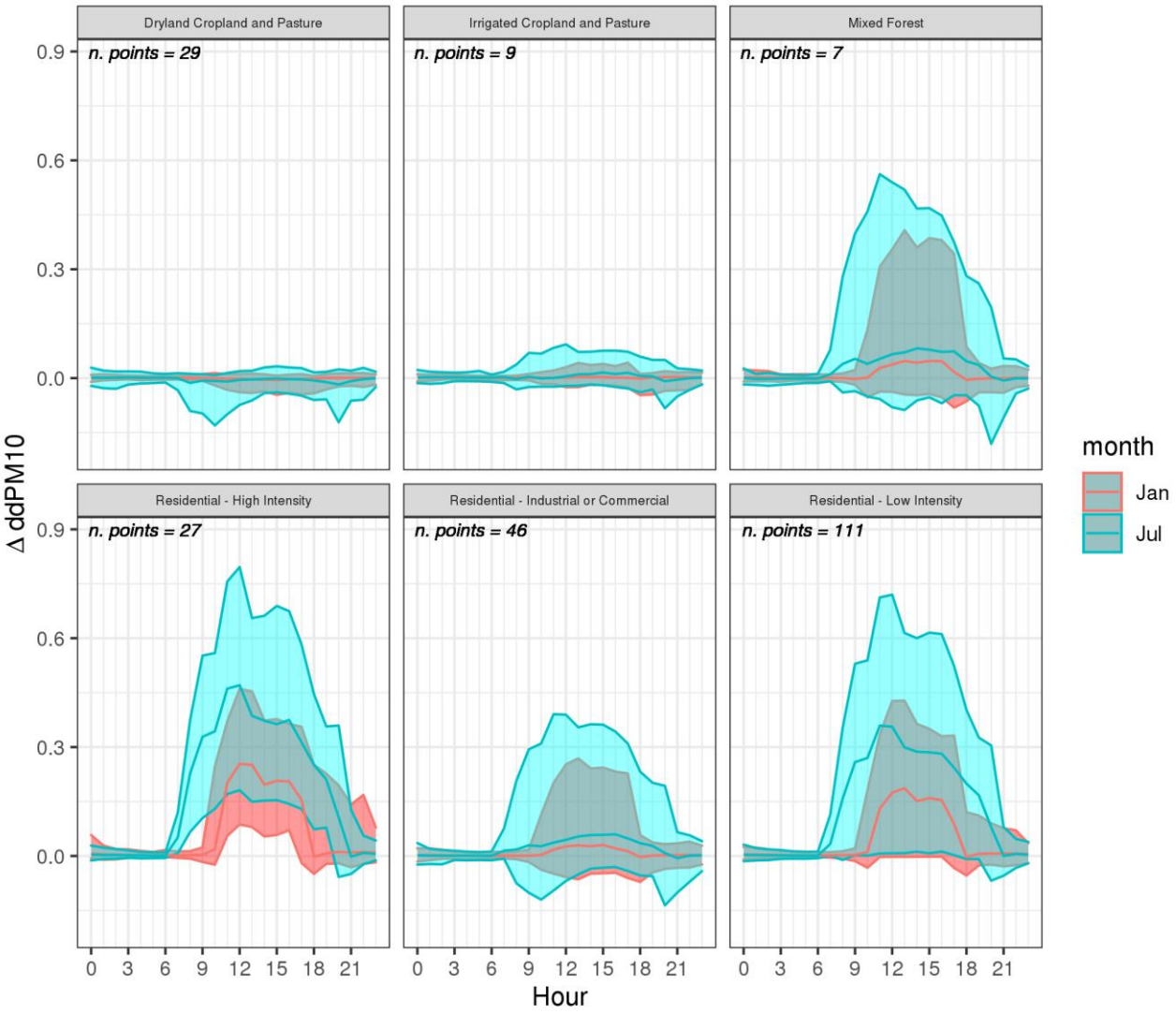


Figure S4bd3. Daily cycle of PM10 deposition differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the Milan municipality. Medians are shown as lines and shaded area covers the interval 10th to 90th percentiles. Cyan and red colours refer to July and January, respectively.

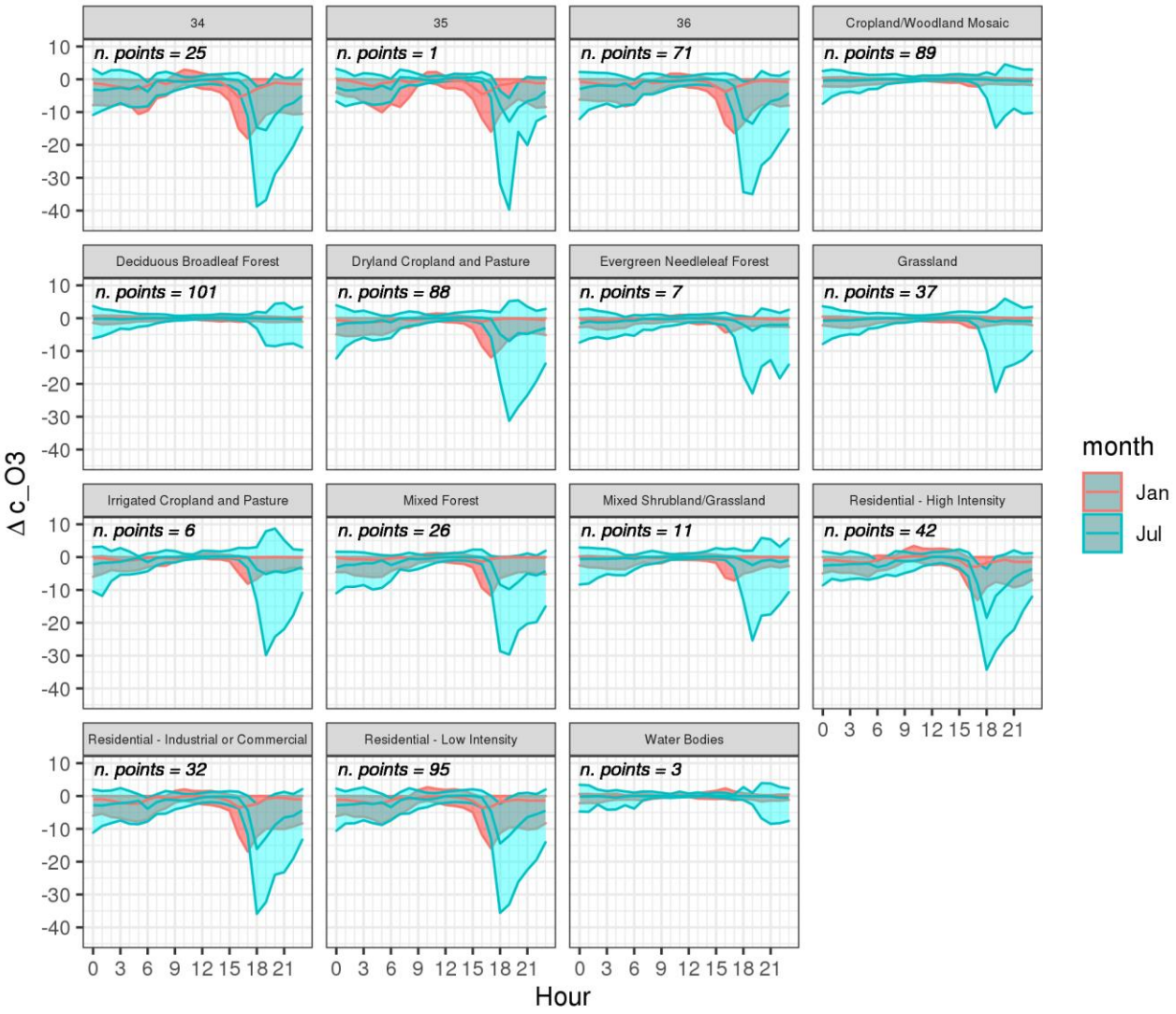


Figure S4cc1. Daily cycle of O_3 concentrations differences (VEG-NOVEG) (mg/m^3) as a function of land-use, considering only grid points inside the Madrid municipality. Medians are shown as lines and shaded area covers the interval 10^{th} to 90^{th} percentiles. Cyan and red colours refer to July and January respectively.

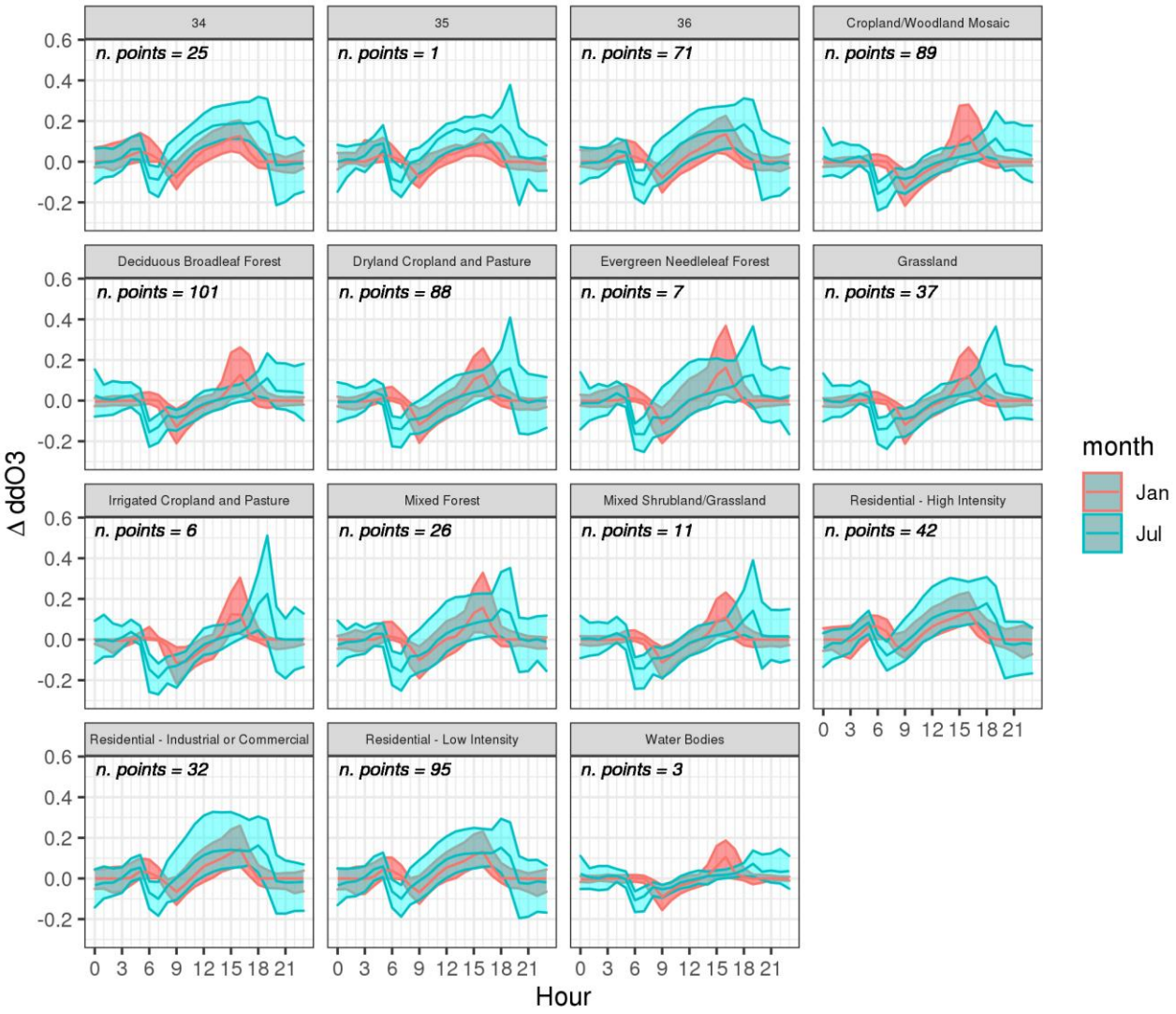


Figure S4cd1. Daily cycle of O_3 deposition differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the Madrid municipality. Medians are shown as lines and shaded area covers the interval 10th to 90th percentiles. Cyan and red colours refer to July and January respectively.

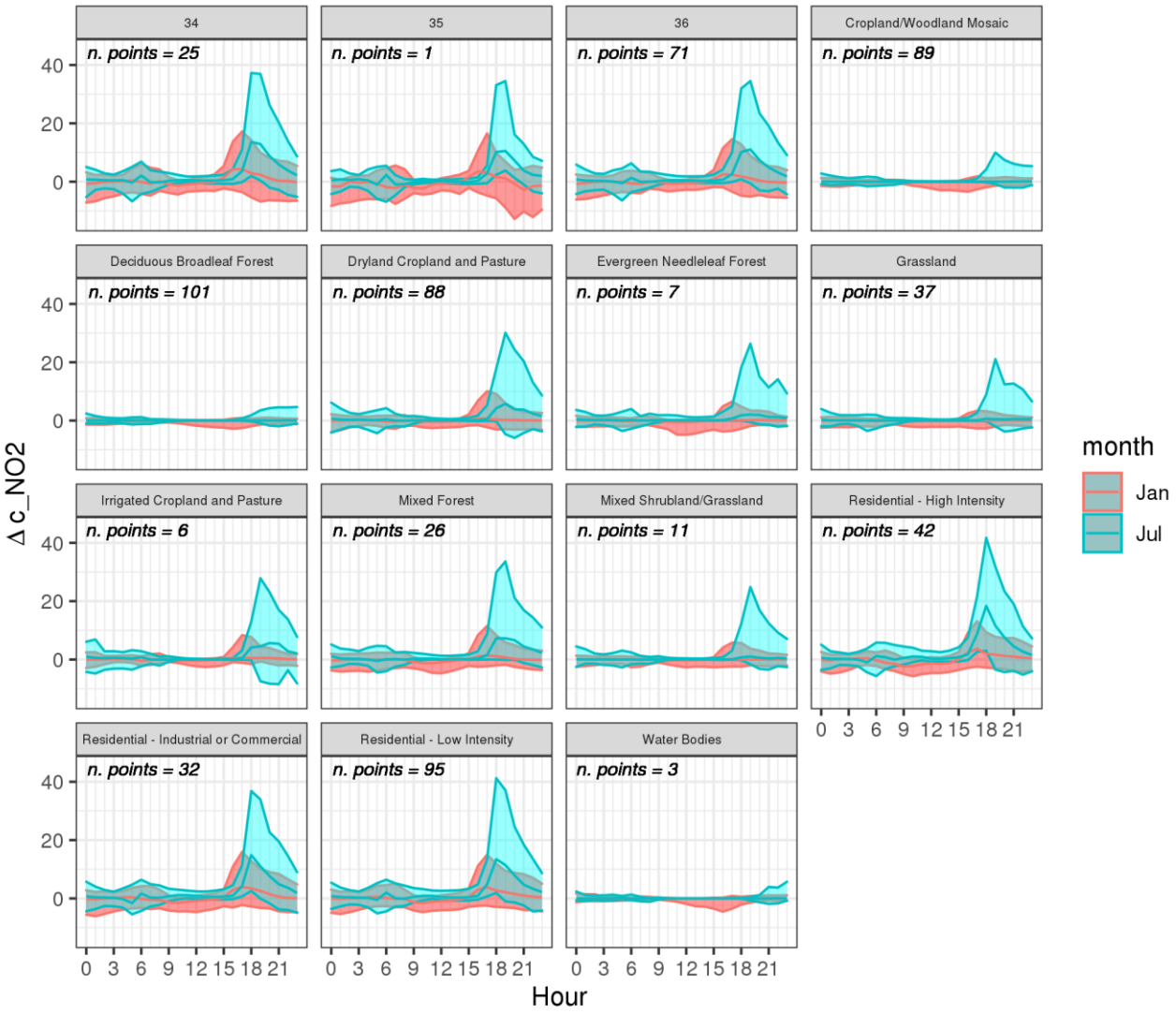


Figure S4cc2. Daily cycle of NO_2 concentrations differences (VEG-NOVEG) (mg/m^3) as a function of land-use, considering only grid points inside the Madrid municipality. Medians are shown as lines and shaded area covers the interval 10^{th} to 90^{th} percentiles. Cyan and red colours refer to July and January respectively.

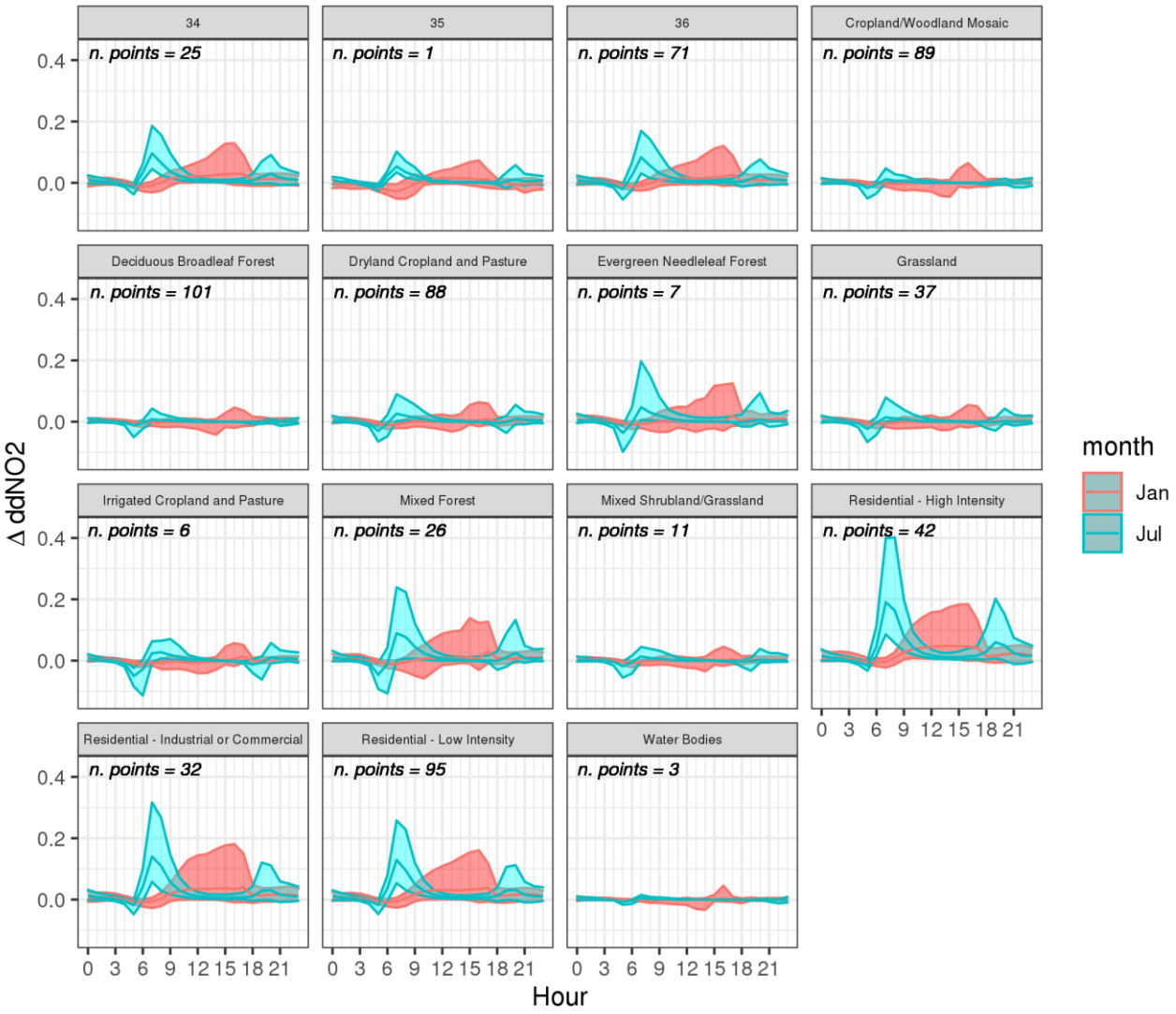


Figure S4cd2. Daily cycle of NO_2 deposition differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the Madrid municipality. Medians are shown as lines and shaded area covers the interval 10^{th} to 90^{th} percentiles. Cyan and red colours refer to July and January respectively.

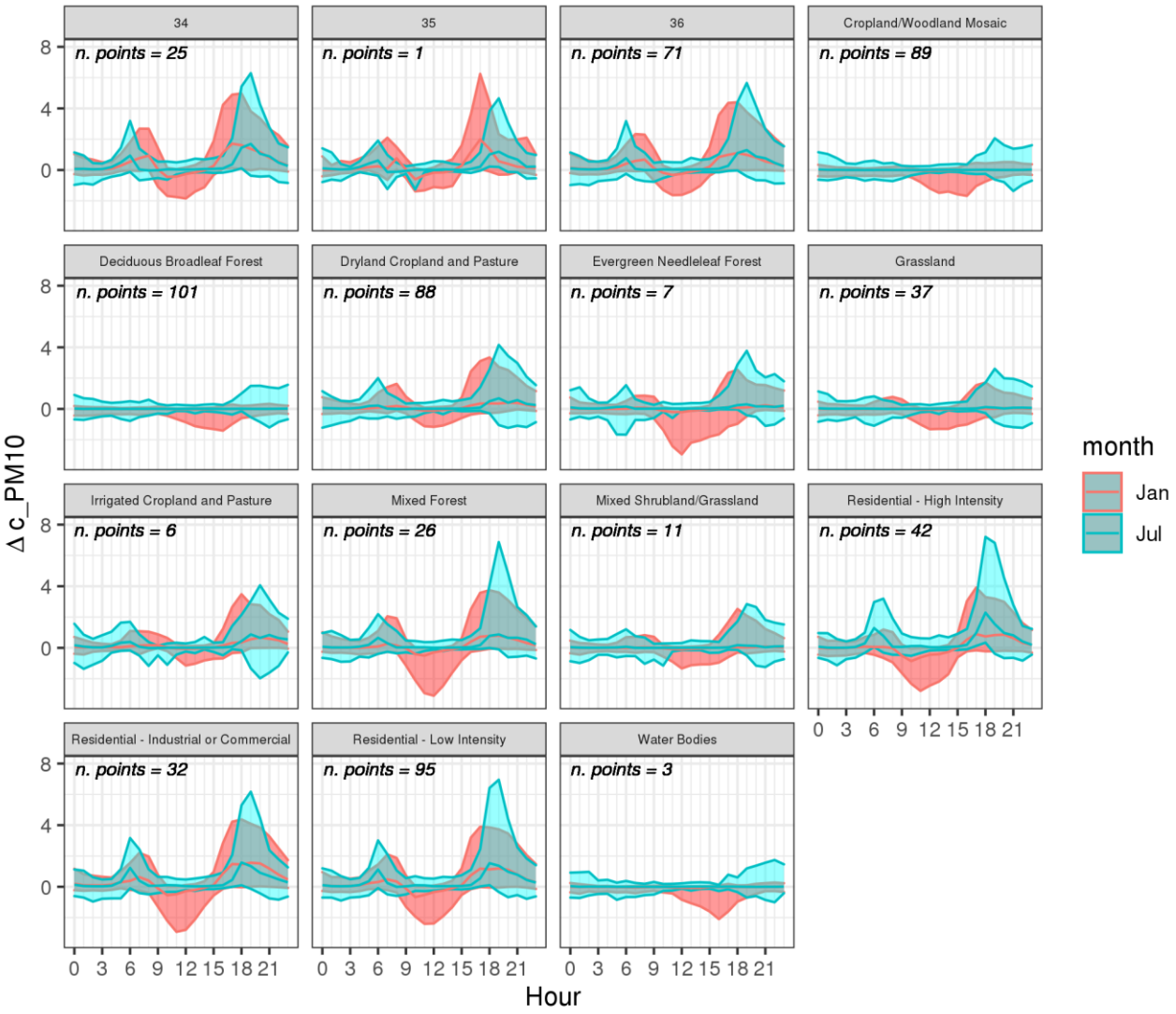


Figure S4cc3. Daily cycle of PM10 concentrations differences (VEG-NOVEG) (mg/m^3) as a function of land-use, considering only grid points inside the Madrid municipality. Medians are shown as lines and shaded area covers the interval 10th to 90th percentiles. Cyan and red colours refer to July and January, respectively.

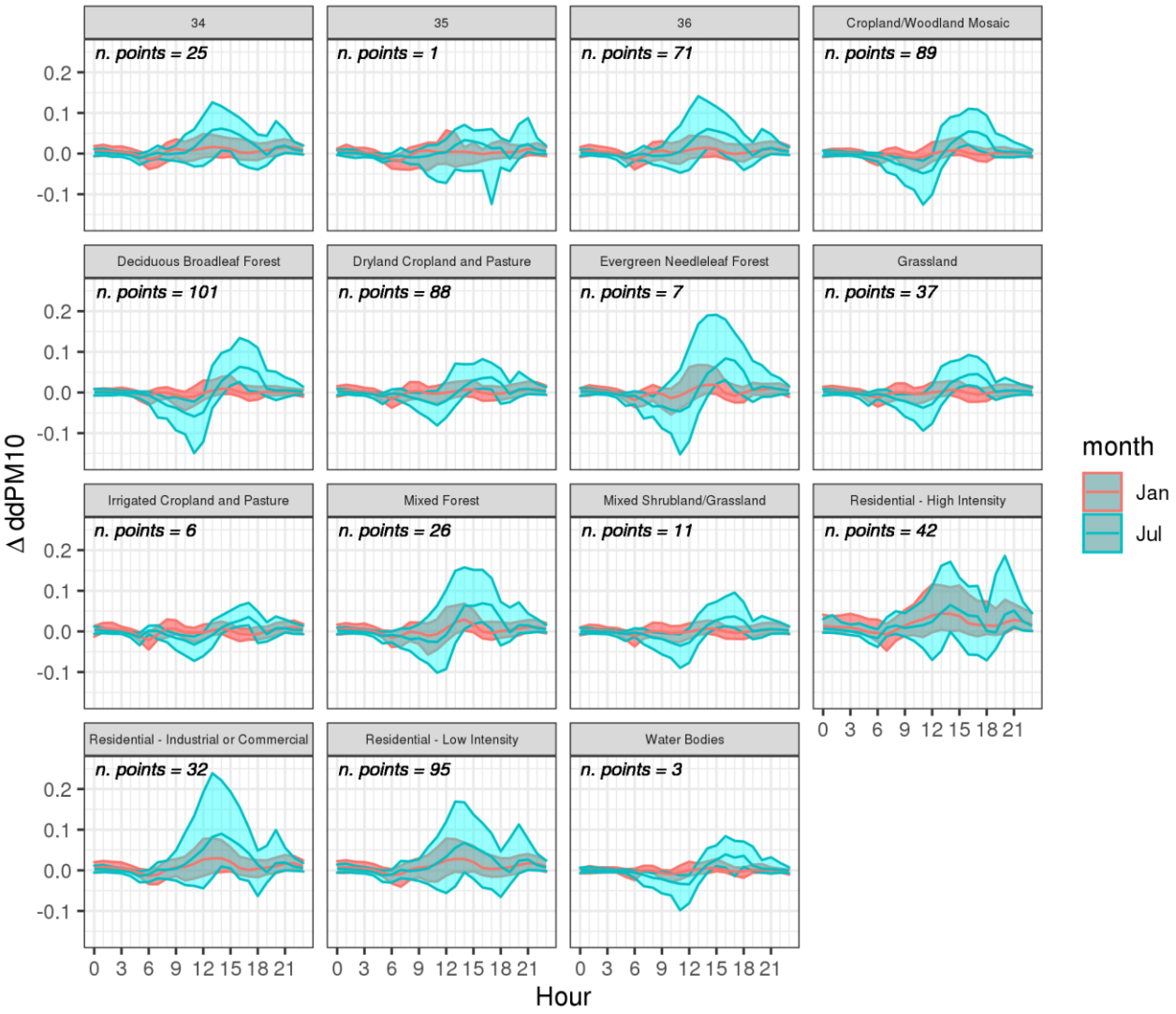


Figure S4cd2. Daily cycle of PM10 deposition differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the Madrid municipality. Medians are shown as lines and shaded area covers the interval 10th to 90th percentiles. Cyan and red colours refer to July and January, respectively.

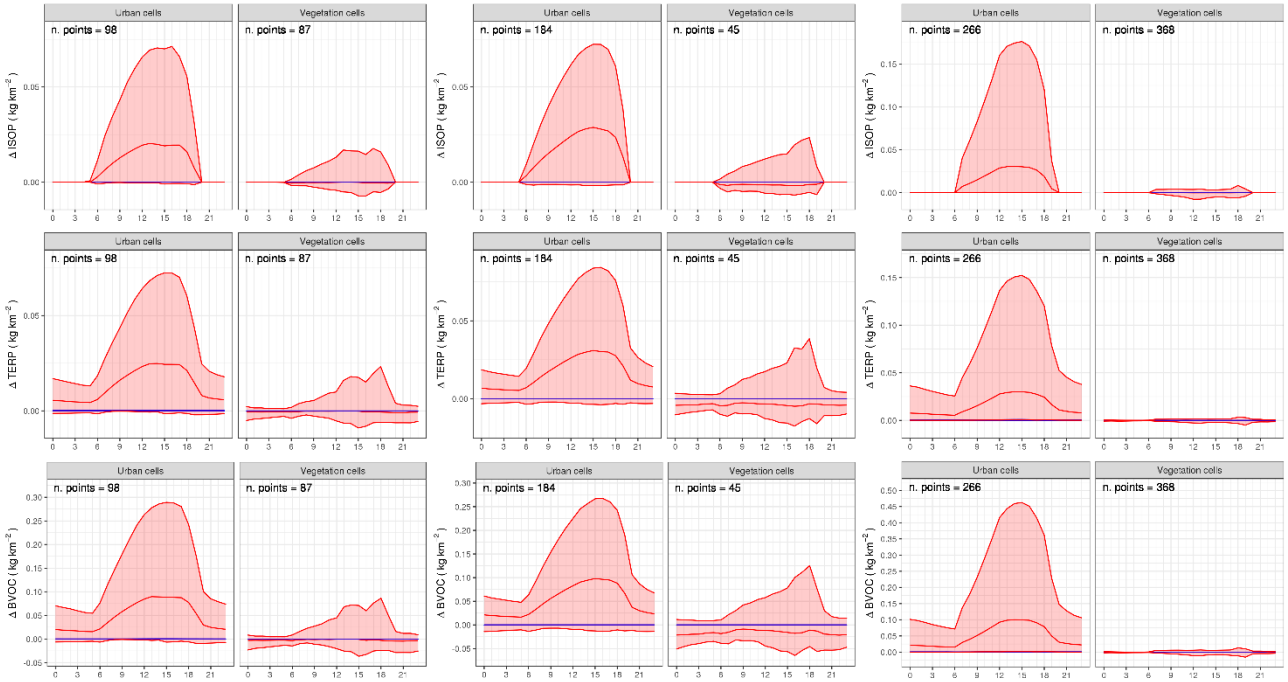


Figure S5. Daily cycle of BVOC emissions differences (VEG-NOVEG) (kg/km^2) as a function of land-use, considering only grid points inside the municipality for Bologna, Milan and Madrid from left to right. Medians are shown as lines and shaded area covers the interval 10th to 90th percentiles. Cyan and red colours refer to July and January, respectively.

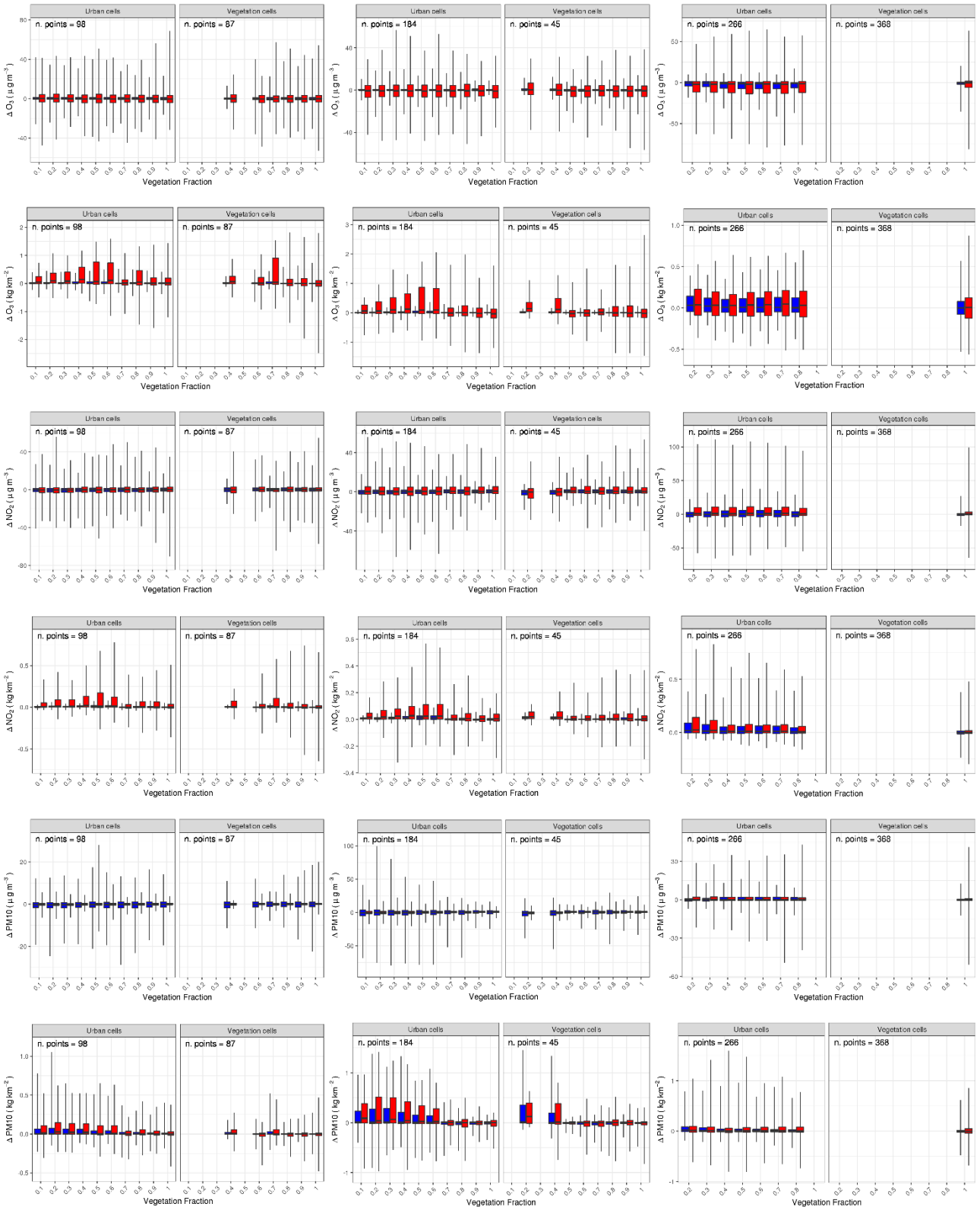


Figure S6. Boxplots of concentration (mg/m^3) and deposition (kg/km^2) differences (VEG-NOVEG) for O_3 (upper panels), NO_2 (middle panel) and PM10 (bottom panels) as a function of vegetation fraction for different land-use classes, considering only grid points inside the Bologna (left column), Milan (middle column) and Madrid (left column) municipalities. Whiskers span the interval 10th to 90th percentile. Red (blue) colour refers to July (January).