Supporting information. Alignier et al. "Configurational crop heterogeneity increases within-field plant diversity"

Appendix S1. Disentangling the role of field border length and semi-natural boundaries

Total border length (*TBL*) and the length of semi-natural boundaries (*SemiNatBound*) were highly correlated (r = 0.70, P < 0.01). As a result, we did not include both *TBL* and *SemiNatBound* in our model and disentangle their respective effects on within-field plant diversity.

To test whether the effect of *TBL* was likely due to correlation with *SemiNatBound*, we selected a subset of landscapes (N = 271) for which *TBL* and *SemiNatBound* were not strongly correlated, i.e. with a Pearson correlation coefficient <0.4 (Table S1).

Table S1.1. Pearson's correlations between landscape variables across all regions. Data are from the 'uncorrelated' subset of 271 1km x 1km landscapes. ns: not significant, *: P < 0.05, **: P < 0.01, ***: P < 0.001. For the code of variables, see Table 1.

	SHDI	TBL	SemiNatCover
SHDI			
TBL	0.04 ^{ns}		
SemiNatCover	-0.30**	-0.16*	
SemiNatBound	-0.39**	0.39***	0.28***

We added SemiNatBound and its interactions as fixed effects to model 1 such as:

Results showed that *SemiNatBound* had no effect on plant diversity except through interaction with within-field position (*POS*) for alpha and gamma plant diversity. Parameter estimates and significance for variables of interest remained quite unchanged. The notable differences between model 1 and model 2 were the appearance of i) the significant and positive effect of *SHDI* on alpha and gamma plant diversity and ii) the significant and negative effect of *TBL* on alpha diversity (Table S1.2).

These results did not confirm that the effect of *TBL* was only due to the effect of *SemiNatBound*.

Table S1.2. Model-averaged standardized estimates and *P* values from LMMs of alpha, beta and gamma within-field plant diversity in relation to compositional and configurational crop heterogeneity, within-field position and the amount of semi-natural cover. Data are from the 'uncorrelated' subset of 1721 transects pertaining to 2711 km x 1 km landscapes in eight agricultural regions. *SHDI* : Shannon crop diversity index, *TBL*: Total length of crop borders, *SemiNatCover*: Proportion of semi-natural cover types in the landscape, *SemiNatBound*: Length of semi-natural boundaries in the landscape, *POS*: within-field position, ns: not significant, *: P < 0.05, **: P < 0.01, ***: P < 0.001.

	Alpha diversity			Beta	a diversit	су.	Gamma diversity		
	Estimate	SE	P value	Estimate	SE	P value	Estimate	SE	P value
Intercept	0.421	0.149	**	-0.191	0.097	*	0.435	0.143	**
SHDI	0.119	0.043	**	0.008	0.034	ns	0.125	0.043	**
TBL	-0.129	0.058	*	0.055	0.057	ns	-0.093	0.055	ns
SemiNatCover	0.249	0.042	***	-0.011	0.036	ns	0.239	0.041	* * *
SemiNatBound	0.049	0.063	ns	-0.040	0.050	ns	0.052	0.060	ns
POS [interior]	-0.722	0.030	***	0.288	0.043	* * *	-0.761	0.030	* * *
SHDI x TBL	0.040	0.032	ns	0.021	0.031	ns	0.054	0.031	ns
SHDI x POS	-0.115	0.035	* * *	0.015	0.044	ns	-0.107	0.034	**
TBL x POS	0.428	0.038	* * *	-0.126	0.043	**	0.396	0.037	* * *
SemiNatCover x SHDI	0.061	0.030	ns	-0.029	0.029	ns	0.052	0.029	ns
SemiNatCover x TBL	-0.032	0.030	ns	-0.025	0.029	ns	0.029	0.029	ns
SemiNatCover x POS	-0.273	0.034	* * *	0.005	0.044	ns	-0.254	0.033	* * *
SemiNatBound x SHDI	-0.008	0.027	ns	0.017	0.023	ns	-0.001	0.027	ns
SemiNatBound x TBL	-0.090	0.054	ns	0.071	0.050	ns	-0.074	0.053	ns
SemiNatBound x POS	-0.335	0.044	***	-0.063	0.044	ns	-0.354	0.043	* * *
Conditional R ²		0.62			0.18			0.62	
Marginal R ²		0.25			0.03			0.26	

Appendix S2. Within-field plant diversity in Ottawa

Contrary to other regions, the field border transects in *Ottawa* encompassed part of the boundary vegetation. This difference in sampling protocol resulted in significant higher alpha and gamma plant diversity in field border transects of *Ottawa* than in other regions (ANOVA tests, p-value < 0.001; Table S2.1).

Table S2.1. Mean and standard error of within-field plant diversity components for field interior transects in each region. *Post-hoc* indicates results of post-hoc tests led after ANOVAs and comparing mean values of alpha, beta and gamma plant diversity between regions. Different letters indicate significant differences between regions at P = 0.05.

	_	Alpha			Beta		Gamma		
	Mean	SE	Post-hoc	Mean	SE	Post-hoc	Mean	SE	Post-hoc
Armorique	9.13	5.98	cd	0.62	0.10	d	17.89	9.80	С
Camargue	12.39	4.63	е	0.55	0.09	ab	22.66	8.46	d
Coteaux	10.83	4.66	de	0.61	0.10	cd	21.92	8.25	d
EastAnglia	5.22	3.26	а	0.57	0.17	bc	10.28	6.57	а
Goettingen	7.79	4.46	bc	0.57	0.11	bc	14.38	7.30	b
Lleida	7.18	5.15	bc	0.61	0.11	cd	14.10	9.49	b
Ottawa	16.89	5.83	f	0.52	0.09	ab	28.51	9.72	е
PVDS	8.29	4.26	bc	0.64	0.13	d	17.65	7.65	с

To test whether our results were dependent of higher plant diversity in *Ottawa*, we excluded *Ottawa* landscapes from our dataset. The subset was made of 339 1km x 1km landscapes in seven regions (Table S2.2).

Table S2.2. Pearson's correlations between landscape variables across all regions. Data are from the subset of 339 1km x 1km landscapes in seven regions (excluding *Ottawa*). ns: not significant, *: P < 0.05, **: P < 0.01, ***: P < 0.001. For the code of variables, see Table 1.

	SHDI	TBL	SemiNatCover
SHDI			
TBL	-0.04ns		
SemiNatCover	-0.29***	-0.06**	
SemiNatBound	-0.35***	0.70***	0.25***

The model used was identical to model 1. Results showed that parameter estimates and significance for variables of interest remained mostly unchanged. The sole exception was the effect of *TBL* on beta plant diversity which became non significant (Table S2.3). These results confirm the slight difference in sampling protocol in *Ottawa* did not influence main results.

Table S2.3. Model-averaged standardized estimates and *P* values from LMMs of alpha, beta and gamma within-field plant diversity in relation to compositional and configurational crop heterogeneity, within-field position and the amount of semi-natural cover. Data are from the subset with 2039 transects pertaining to 339 1 km x 1 km landscapes in seven agricultural regions (excluding *Ottawa*). *SHDI* : Shannon crop diversity index, *TBL*: Total length of crop borders, *SemiNatCover*: Proportion of semi-natural cover types in the landscape, *POS*: within-field position, ns: not significant, *: P < 0.05, **: P < 0.01, ***: P < 0.001.

	Alpha diversity		Bet	a diversi	ty	Gamma diversity			
	Estimate	SE	P value	Estimate	SE	P value	Estimate	SE	P value
Intercept	0.359	0.149	*	-0.139	0.085	ns	0.395	0.159	*
SHDI	-0.009	0.040	ns	0.016	0.032	ns	0.008	0.037	ns
TBL	0.013	0.043	ns	0.017	0.039	ns	0.022	0.041	ns
SemiNatCover	0.149	0.038	* * *	-0.008	0.032	ns	0.137	0.035	* * *
POS [interior]	-0.545	0.031	* * *	0.212	0.041	* * *	-0.619	0.029	* * *
SHDI x TBL	0.014	0.030	ns	0.049	0.028	ns	0.022	0.027	ns
SHDI x POS	0.118	0.032	* * *	0.016	0.040	ns	0.116	0.031	* * *
TBL x POS	-0.045	0.031	ns	-0.068	0.040	ns	-0.054	0.030	ns
SemiNatCover x SHDI	0.038	0.028	ns	-0.045	0.026	ns	0.031	0.026	ns
SemiNatCover x TBL	-0.002	0.024	ns	-0.006	0.022	ns	0.0003	0.022	ns
SemiNatCover x POS	-0.291	0.035	* * *	0.031	0.041	ns	-0.281	0.033	* * *
Conditional R ²		0.54			0.16			0.55	
Marginal R ²		0.10			0.02			0.13	

Appendix S3. Separating field border transects and field interior transects

Owing to significant interactions of landscape variables with the position within-field (*POS*), we repeated the modelling by splitting up the dataset into field border transects in one side (Table S3.1) and field interior transects in another side (Table S3.2). The model formula was:

Model 3 : $y \sim SHDI + TBL + POS + SemiNatCover + SHDI: TBL + SemiNatCover: SHDI + SemiNatCover: TBL + (1|Region/Landscape) + (1|Region/Crop type)$

Table S3.1. Model-averaged standardized estimates and *P* values from LMMs of alpha, beta and gamma within-field plant diversity in relation to compositional and configurational crop heterogeneity, and the amount of semi-natural cover. Data are from the subset with 1416 field border transects pertaining to 432 1 km x 1 km landscapes in eight agricultural regions. *SHDI* : Shannon crop diversity index, *TBL*: Total length of crop borders, *SemiNatCover*: Proportion of semi-natural cover types in the landscape, ns: not significant, *: P < 0.05, **: P < 0.01, ***: P < 0.001.

	Alpha diversity			Bet	Beta diversity			Gamma diversity		
	Estimate	SE	P value	Estimate	SE	P value	Estimate	SE	P value	
Intercept	-0.045	0.169	ns	0.041	0.133	ns	-0.019	0.162	ns	
SHDI	0.049	0.031	ns	0.020	0.032	ns	0.069	0.032	*	
TBL	0.047	0.042	ns	0.036	0.043	ns	0.059	0.044	ns	
SemiNatCover	0.133	0.032	* * *	-0.023	0.034	ns	0.131	0.034	* * *	
SHDI x TBL	-0.002	0.027	ns	0.022	0.029	ns	0.008	0.029	ns	
SemiNatCover x SHDI	0.023	0.026	ns	-0.014	0.028	ns	0.031	0.027	ns	
SemiNatCover x TBL	-0.051	0.027	ns	0.005	0.029	ns	-0.049	0.029	ns	
Conditional R ²		0.61			0.25			0.62		
Marginal R ²		0.03			0.01			0.03		

Table S3.2. Model-averaged standardized estimates and *P* values from LMMs of alpha, beta and gamma within-field plant diversity in relation to compositional and configurational crop heterogeneity, and the amount of semi-natural cover. Data are from the subset with 1372 field interior transects pertaining to 432 1 km x 1 km landscapes in eight agricultural regions. *SHDI* : Shannon crop diversity index, *TBL*: Total length of crop borders, *SemiNatCover*: Proportion of semi-natural cover types in the landscape, ns: not significant, *: P < 0.05, **: P < 0.01, ***: P < 0.001.

	Alpl	Alpha diversity			Beta diversity			Gamma diversity		
	Estimate	SE	P value	Estimate	SE	P value	Estimate	SE	P value	
Intercept	-0.004	0.202	ns	0.020	0.143	ns	-0.003	0.212	ns	
SHDI	0.034	0.035	ns	0.017	0.033	ns	0.042	0.032	ns	
TBL	0.133	0.043	**	-0.046	0.044	ns	0.136	0.040	***	
SemiNatCover	0.165	0.034	***	-0.048	0.035	ns	0.158	0.033	***	
SHDI x TBL	0.003	0.028	ns	0.045	0.029	ns	0.013	0.026	ns	
SemiNatCover x SHDI	0.009	0.027	ns	-0.024	0.028	ns	-0.002	0.026	ns	
SemiNatCover x TBL	-0.007	0.028	ns	0.009	0.030	ns	-0.014	0.027	ns	
Conditional R ²		0.61			0.25			0.62		
Marginal R ²		0.03			0.01			0.03		

Appendix S4. Role of the identity of sampled crop types

To evaluate whether the sample crop type influenced our results, we followed the method of Sirami et al. (2019). Using the whole dataset, i.e. the 2788 transects in 432 landscapes from eight agricultural regions, we compared models with and without adding crop type as a random effect. Crop type was added as a random effect because we were not interested in estimating the specific effect of each particular crop type. We used a restricted likelihood-ratio test based on simulated values from the finite sample distribution available in the function exactRLRT from the "RLRsim" R package (. We compared the estimates and p-values associated with model 1 and 4.

We detected a significant effect of crop type on alpha (RLRT = 154,76, P < 0.001), beta (RLRT = 20.06, P < 0.001) and gamma plant diversity (RLRT = 163.52, P < 0.001). Adding crop type as random effect in the model slightly changed the outcome of model selection: *TBL* in interaction with *POS* had no longer significant effect while we detected a significant and positive effect of *SHDI* with *POS* on alpha and gamma plant diversity (Table S4.1). This result suggests that variation in the identity of crops sampled partly explain the effect of crop heterogeneity, in combination with *POS* and *SemiNatCover*, on within-field plant diversity.

Table S4.1. Model-averaged standardized estimates and *P* values from LMMs (model 4) of alpha, beta and gamma within-field plant diversity in relation to compositional and configurational crop heterogeneity, and the amount of semi-natural cover. Data are from the 2788 transects pertaining to 432 1 km x 1 km landscapes in eight agricultural regions. *SHDI* : Shannon crop diversity index, *TBL*: Total length of crop borders, *SemiNatCover*: Proportion of semi-natural cover types in the landscape, ns: not significant, *: P < 0.05, **: P < 0.01, ***: P < 0.001.

	Alpha diversity			Bet	Beta diversity			Gamma diversity		
	Estimate	SE	P value	Estimate	SE	P value	Estimate	SE	P value	
Intercept	0.266	0.154	ns	-0.109	0.102	ns	0.301	0.165	ns	
SHDI	0.014	0.040	ns	0.027	0.041	ns	0.035	0.039	ns	
TBL	0.017	0.044	ns	0.009	0.039	ns	0.028	0.043	ns	
SemiNatCover	0.145	0.039	* * *	-0.010	0.032	ns	0.134	0.037	* * *	
POS [interior]	-0.539	0.031	* * *	0.205	0.041	* * *	-0.061	0.032	* * *	
SHDI x TBL	0.029	0.031	ns	0.055	0.027	*	0.039	0.029	ns	
SHDI x POS	0.122	0.032	* * *	0.011	0.041	ns	0.119	0.033	* * *	
TBL x POS	-0.046	0.031	ns	-0.067	0.041	ns	-0.059	0.032	ns	
SemiNatCover x SHDI	0.052	0.029	ns	-0.044	0.026	ns	0.045	0.027	ns	
SemiNatCover x TBL	-0.001	0.025	ns	-0.009	0.022	ns	-0.001	0.023	ns	
SemiNatCover x POS	-0.284	0.034	***	0.035	0.041	ns	-0.277	0.035	***	

To complete this analysis, we chose to work on i) cereals, the dominant crop type in the dataset (Table A.2) and ii) grasslands, due to their potential particular vegetation. We repeated the modelling by splitting up the dataset into cereals in one side (Table S4.2) and grasslands in another side (Table S4.3). The model formula was:

Table S4.2. Model-averaged standardized estimates and *P* values from LMMs of alpha, beta and gamma within-field plant diversity in relation to compositional and configurational crop heterogeneity, and the amount of semi-natural cover. Data are from the 'cereals' subset with 1185 transects pertaining to 321 1 km x 1 km landscapes in eight agricultural regions. *SHDI* : Shannon crop diversity index, *TBL*: Total length of crop borders, *SemiNatCover*: Proportion of semi-natural cover types in the landscape, ns: not significant, *: P < 0.05, **: P < 0.01, ***: P < 0.001.

	Alpha diversity			Beta	a divers	ity	Gamr	Gamma diversity		
			Р							
	Estimate	SE	value	Estimate	SE	P value	Estimate	SE	P value	
Intercept	0.448	0.197	*	-0.215	0.118	ns	0.455	0.197	*	
SHDI	0.036	0.047	ns	-0.020	0.042	ns	0.054	0.041	ns	
TBL	0.023	0.055	ns	-0.007	0.051	ns	0.0375	0.049	ns	
SemiNatCover	0.154	0.044	***	-0.003	0.040	ns	0.149	0.040	* * *	
POS [interior]	-0.578	0.039	***	0.292	0.053	* * *	-0.652	0.038	* * *	
SHDI x TBL	-0.007	0.041	ns	0.077	0.036	*	0.012	0.036	ns	
SHDI x POS	0.047	0.039	ns	-0.012	0.053	ns	0.025	0.039	ns	
TBL x POS	-0.017	0.039	ns	-0.068	0.053	ns	-0.021	0.038	ns	
SemiNatCover x SHDI	0.090	0.040	*	-0.069	0.037	ns	0.080	0.035	*	
SemiNatCover x TBL	0.026	0.030	ns	0.001	0.027	ns	0.034	0.027	ns	
SemiNatCover x POS	-0.297	0.039	* * *	0.076	0.053	ns	-0.277	0.038	* * *	
Conditional R ²		0.58			0.20			0.57		
Marginal R ²		0.11			0.03			0.13		

Results for cereals showed that parameter estimates and significance for variables of interest changed a bit (Table S4.2). The main differences between the whole dataset and the 'cereals' dataset were the appearance of i) the positive interaction between *SHDI* and *SemiNatCover* on alpha and gamma plant diversity and, ii) the positive interaction between *SHDI* and *TBL* on beta plant diversity. For all within-field plant diversity components, the interaction between *TBL* and *POS* was no longer significant.

Table S4.3. Model-averaged standardized estimates and *P* values from LMMs of alpha, beta and gamma within-field plant diversity in relation to compositional and configurational crop heterogeneity, and the amount of semi-natural cover. Data are from the 'grasslands' subset with193 transects pertaining to 85 1 km x 1 km landscapes in five agricultural regions (see Table A. 3). *SHDI* : Shannon crop diversity index, *TBL*: Total length of crop borders, *SemiNatCover*: Proportion of semi-natural cover types in the landscape, ns: not significant, *: P < 0.05, **: P < 0.01, ***: P < 0.001.

	Alpha diversity			Bet	Beta diversity			Gamma diversity		
	Estimate	SE	P value	Estimate	SE	P value	Estimate	SE	P value	
Intercept	0.369	0.142	**	0.042	0.123	ns	0.412	0.158	ns	
SHDI	0.169	0.101	ns	0.209	0.094	*	0.180	0.100	ns	
TBL	-0.121	0.149	ns	0.031	0.102	ns	-0.109	0.155	ns	
SemiNatCover	0.449	0.158	**	-0.186	0.099	ns	0.439	0.157	**	
POS [interior]	-0.819	0.102	* * *	0.134	0.133	ns	-0.838	0.113	* * *	
SHDI x TBL	0.062	0.095	ns	0.001	0.099	ns	0.077	0.094	ns	
SHDI x POS	-0.025	0.141	ns	0.121	0.137	ns	-0.019	0.152	ns	
TBL x POS	0.431	0.133	**	-0.192	0.133	ns	0.410	0.130	**	
SemiNatCover x SHDI	-0.090	0.076	ns	-0.033	0.078	ns	-0.112	0.073	ns	
SemiNatCover x TBL	-0.037	0.110	ns	0.216	0.114	ns	0.046	0.109	ns	
SemiNatCover x POS	-0.376	0.153	*	0.094	0.145	ns	-0.390	0.136	**	
Conditional R ²		0.56			0.23			0.46		
Marginal R ²		0.31			0.10			0.28		

Results for grasslands showed that parameter estimates and significance for variables of interest remained unchanged except for beta diversity with a significant and positive effect of *SHDI* (Table S4.3).

References:

Scheipl, F., Greven, S., & Kuechenhoff, H. (2008) Size and power of tests for a zero random effect variance or polynomial regression in additive and linear mixed models. Computational Statistics & Data Analysis, 52(7):3283--3299.

Sirami, C., Gross, N., Baillod, A. B., Bertrand, C., Carrié, R., Hass, A., ... & Fahrig, L. (2019). Increasing crop heterogeneity enhances multitrophic diversity across agricultural regions. *Proceedings of the National Academy of Sciences*, *116*(33), 16442-16447.

1 Supporting information. Alignier et al. "Configurational crop heterogeneity increases within-field

2 plant diversity"



Configurational crop heterogeneity (TBL)

Figure S1. Relationship between compositional (measured as the Shannon crop diversity index, *SHDI*)
and configurational (measured as the total length in km of crop borders, *TBL*) crop heterogeneity for
the 432 agricultural landscapes in eight agricultural regions.

1 Supporting Information. Alignier et al. "Configurational crop heterogeneity increases within-field plant diversity"

2 Table S1. Year and resolution of remote sensing of	data used by each study site to build landcover maps
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Study site	Year	Source (resolution)
Arles	2011	Land use map of the Parc Naturel Regional de Camargue
Ely	2007	Centre for Ecology and Hydrology Land Cover Map
	2011	Landsat images (25 m) - http://glovis.usgs.gov/
Goettingen	2012	Crop map from The Agricultural Ministry of Lower Saxony
Lleida	2010	Orthophotos from ICGC Vissir 3 - http://www.icc.cat/vissir3/index.html?eckR1dTYj
	2009	Regional Geographic Information System of Farming Land (SIGPAC) - http://agricultura.gencat.cat
	2008-2009	Regional database with all crops annually reported by farmers (DUN) - http://agricultura.gencat.cat
Niort	2013-2014	Ground-truthed maps, manually digitized in GIS
Ottawa	2007	SPOT (10m) panchromatic
	2007, 2011, 2012	Landsat TM
	2011-2012	Aerial imagery (visible) custom flown over all sites (5 m)
	2008	Aerial imagery (visible) collected by the Province of Ontario (10 m)
	2011-2012	Worldview2 imagery
	2011	Quickbird imagery
Rennes	2010	Othophotos from IGN - http://www.ign.fr
	2010	Multispectral satellite images from Landsat (30 m) and RapidEye (4 m)
	2010	"Registre Parcellaire Graphique" (RPG)
	2010	Land use map of the Zone Atelier Armorique

Toulouso	2011	Orthophotos "top of atmosphere" SPOT 5 from OSR MiPy Kalideos -
Toulouse	2011	https://osrmipy.kalideos.fr/drupal/fr

3 Table S2. Pearson's correlations between landscape variables across all regions. Data are from 432 1

4 km × 1 km landscapes. ns: not significant, *: P < 0.05, ** P < 0.001. For the code of variables, see

5 Table 1.

	SHDI	TBL	SemiNatCover
SHDI			
TBL	0.01 ^{ns}		
SemiNatCover	-0.28**	-0.21**	
SemiNatBound	-0.29**	0.70**	0.11*

7 Table S3. Number of fields sampled per crop type in each of the eight agricultural regions. In bold,

8 dominant farmland types sampled per region.

Crop type	Arles	Ely	Goettingen	Lleida	Ottaw	a Niort	Rennes	Toulouse
Alfalfa					43	34		
Almond				16				
Bean		9						
Brussel sprou	t	1						
Carrot		1						
Cereal ^a	41	141	103	100	14	102	53	65
Clover						1		
Corn		5			137	14	53	8
Fallow ^b		1			10			
Grassland		3			53	34	14	1
Нау					1			
Linseed		1						
Oilseed rape		20	52			26		
Olive				4				
Onion		4						
Open					1			
Реа		8						
Potato		17						
Rice	79							
Ryegrass						3		
Sorghum								1
Soybean					116			1
Strawberry					1			
Sugar beet		25						
Sunflower						13		19
Vegetable					2			
Total	120	236 1	.55	120	378	227	120	95

9 ^a Mainly winter wheat and winter barley, more rarely oat, rye, spring barley

10 ^b Fields that were ploughed but not actively farmed in the current year

- 11 Table S4. Vegetation survey periods for each agricultural region. '-' indicates that there was no first
- 12 (or second) visit.

	Visit	Survey period	Survey period	
Region	number	(1st year)	(2nd year)	
Arles	1	april - sept. 2013	may - july 2014	
Ely	1	may - august 2012	april - may 2013	
Ely	2	-	june - august 2013	
Goettingen	1	may - june 2013	may - june 2014	
Goettingen	2	july 2013	-	
Lleida	1	april - may 2013	april - may 2014	
Niort	1	april - august 2013	april - july 2014	
Ottawa	1	may - july 2011	may - july 2012	
Ottawa	2	july- august 2011	july - august 2012	
Rennes	1	may - july 2013	may - july 2014	
Toulouse	1	april - july 2013	june 2014	