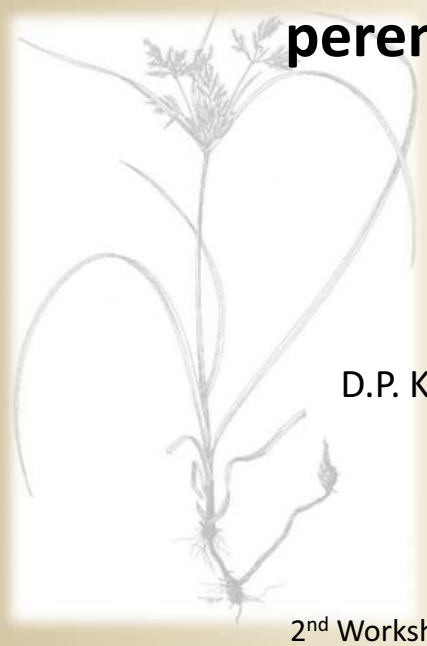
GIS analysis of spatial structure in annual and perennial weed populations*



*funded by EWRS

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Aims

- ✓ Identify the most important cotton weeds
- ✓ Correlate weed appearance with abiotic factors (soil properties)
- ✓ Study the spatial weed distribution and spatial outliers
- ✓ Check the spatio-temporal weed stability

Questions

- Is there a spatial dependence (spatial autocorrelation) based on weed appearance location and weed density/ uniformity?
- How concentrated (clustered) are high or low values of weed density/ uniformity for the whole study area?
- Is there a spatial dependence between weed appearance and soil properties?
- If there is any density spatial outliers or if there is any sampling site clusters with similar values?

Introduction

- Cotton is one of the most important crops in Greece and farmers enjoy high yields and profits
- Weeds constitute a major problem in Greek cotton fields
- Both mechanical and chemical means are used to control weed populations
- Pre- emergence weed control manages to control annual species
- On the other hand some perennial species thrive

Materials and Methods -1

- Crop area: 40,000 ha
- The survey area is situated in one of the most important cotton areas in Greece
- Monoculture is a fact due to high profit

Materials and Methods -2

- Study area: Karditsa's prefecture (Central Greece)

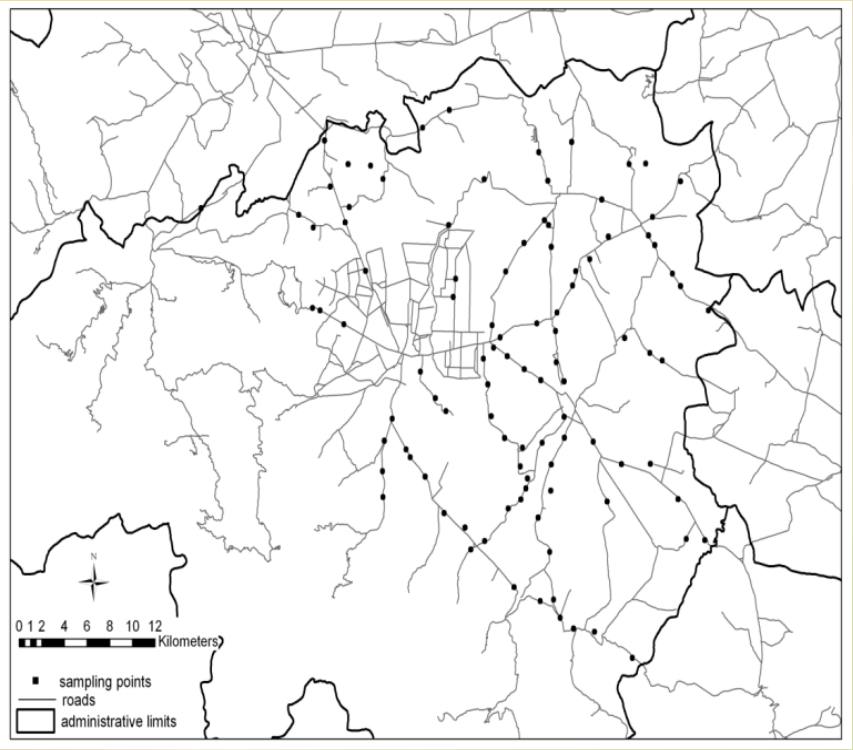


Figure 1: Study area

Materials and Methods -3

- Survey was conducted for 4 consecutive years (2007-2010)
- Crop stage: pre- anthesis stage, when the crop- weed competition is characterized as critical
- Grid sampling scheme (cell size was 2,6 km^2)

- Number of sampling sites:

  101 in 2007

  80 in 2008

  85 in 2009

  40 in 2010*

*The sampling was conducted to validate spatial interpolation estimations

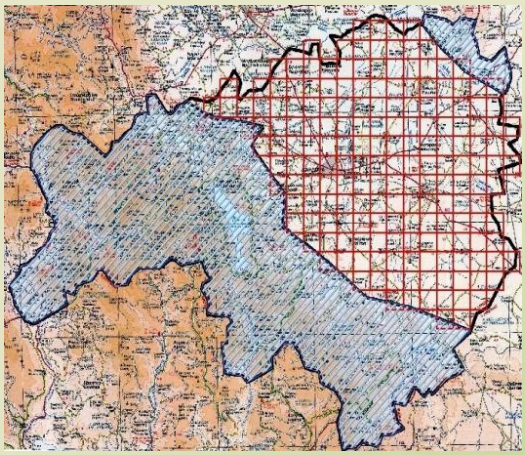


Figure 2: Applied grid

Materials and Methods -4

- 5 quadrats (each one was 5 m^2) were sampled per sampling site
- Samplings took place between rows
- The quadrats were 3 meters apart from each other
- In each quadrat weed density and uniformity were recorded and estimated respectively
- 5 surface soil samples (one of each quadrat) were mixed
- Coordinates were recorded from the central quadrat of each sampling point

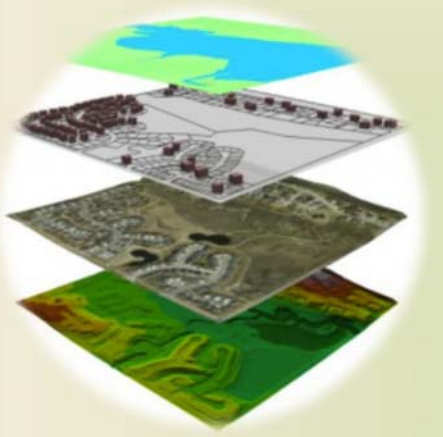
Materials and Methods -5

Soil sample analysis

- $CaCO_3$
- Organic matter
- Soil texture (silt, sand, clay)
- Cation Exchange Capacity
- pH
- Content of elements (Na, K, Ca, Mg)

Materials and Methods -6

Introduction of all the recorded information in a GIS database for further analysis (ArcGis 9.3 software)



Materials and Methods -7

Methods of analysis

Non spatial

- Descriptive statistics
- Correlation coefficient (Spearman c.c.)
- Wilcoxon test for paired samples. It is the non-parametric equivalent of the paired samples t-test.

Spatial

- Autocorrelation analysis (Moran's I)
- Clustering of low or high values (Getis-Ord General G)
- Spatial outliers (Anselin's Local Moran's I)

Results -1

	Density 2007			Density 2008			Density 2009		
	Mean	Std	CV%	Mean	Std	CV%	Mean	Std	CV%
Cypro	**3,0360**	3,05241	100,5	**3,0160**	4,52061	149,9	**3,4706**	5,00724	144,3
Conar	**,3487**	,72585	208,1	**,2035**	,43181	212,2	**,2339**	,66740	285,4
Cynda	**,1810**	,39580	218,7	**,1830**	,41431	226,4	**,2358**	,79347	336,6
Sorha	**,1034**	,36090	349,1	,0375	,12048	321,3	,0456	,11164	244,6
Porol	**,190**	,5489	288,7	**,2570**	1,02176	397,6	**,1064**	,37885	356,2
Xanst	,0859	,25938	301,8	,0160	,05643	352,7	,0282	,14939	529,1
Solni	,0760	,17776	233,8	**,0680**	,19161	281,8	**,0904**	,30055	332,6
Amare	,0420	,24386	580,9	,0245	,20131	821,7	,0254	,18942	745,4
Chrtin	,0364	,15790	433,4	,0300	,19949	665,0	,0094	,04260	452,7
Dats	,0321	,14389	448,5	,0080	,03892	486,5	,0066	,03993	606,0
Hibr	,0198	,10577	534,2	,0175	,10685	610,6	,0588	,43816	744,9
Echcg	,0218	,12047	553,1	,0665	,51343	772,1	,0080	,05266	658,3
Amabl	,0198	,10683	539,5	,0240	,11035	459,8	,0056	,03216	569,5
Abuth	,0099	,03640	367,6	,0210	,11804	562,1	,0113	,04303	381,0

- The perennial weeds were the most abundant followed by the annuals
- The annuals' CV were 2-5 times bigger than the perennials

Results -2

	Density - Spearman Correlation coefficients		
	2007 - 2008	2007-2009	2008-2009
Cypro	0,682**	0,230*	-
Conar	0,485**	0,405**	0,456**
Cynda	0,377**	0,321**	-
Sorha	-	-	-
Porol	0,471**	-	-
Xanst	0,250*	0,317**	
Solni	-	0,256*	-
Amare	0,222*	-	-
Chrtin	0,493**	0,580**	0,404**
Datst	0,239*	-	-
Hibrtr	0,474**	0,356**	0,384**
Echcg	0,241*	-	-
Amabl	0,654**	0,332**	0,347**
Abuth	0,384**	-	-

C. rotundus, *C. arvensis* and *C. dactylon* had a stable occurrence since their densities were highly positively correlated

Results -3

	Uniformity- Spearman Correlation coefficients		
	2007 - 2008	2007-2009	2008-2009
Cypro	0,673**	0,254*	0,275*
Conar	0,558**	0,462**	0,508**
Cynda	0,391**	0,310**	-
Sorha	-	-	0,307*
Porol	0,340**	-	-
Xanst	0,243*	0,375**	-
Solni	-	0,227*	-
Amare	-	-	-
Chrtin	0,519**	0,575**	0,404**
Datst	0,234*	-	-
Hibrtr	0,465**	0,349**	0,391**
Echcg	0,241*	-	-
Amabl	0,642**	0,329**	0,347**
Abuth	0,380**	-	-

C. rotundus, *C. arvensis* and *C. dactylon* had a stable occurrence since their uniformities were highly positively correlated

Results -4

	2007-2008		2007-2009		2008-2009	
	Wilcoxon	Cases with same values (%)	Wilcoxon	Cases with same values (%)	Wilcoxon	Cases with same values (%)
Cypro		48,8		32,5		31,7
Conar		50,0		42,9		46,0
Cynda		58,8		53,2		57,1
Sorha		75,0		64,9		71,4
Porol		68,8		64,9		66,7
Xanst		72,5		72,7		87,3
Solni		56,3		58,4		58,7
Amare		83,8		77,9		88,9
Chrtin		85,0		88,3		87,3
Dats		83,8		83,1		87,3
Hibr		92,5		89,6		93,7
Echcg		92,5		89,6		93,7
Amabl		88,8		89,6		87,3
Abuth		87,5		81,8		82,5

*Grey color stands for no statistical significance

The results indicated non significant differences for the majority of the uniformity comparisons (p values > 0.05)

Results

perennial-soil properties correlations

Weeds	Year		Soil attributes											
			pH	CaCO3	C	O.M.	Sand	Clay	Silt	CEC	Na	K	Ca	Mg
			%							meq/100gr		ppm		
C. rotundus	'07	D	-0.20*	-0.20*								-0.26**		
		U	-0.24*	-0.24*				-0.23*	0.27**			-0.22*		-0.27**
	'08	D			-0.33**	-0.32**	0.27*	-0.31**				-0.33**		
		U										-0.25*		
	'09	D				-0.22*	0.28*							
		U				-0.23*	0.27*	-0.26*		-0.24*			-0.23*	
C. arvensis	'07	D	0.26**	0.23*	0.24*	0.23*	-0.38**	0.43**		0.28**		0.32**		0.20*
		U	0.28**	0.24*	0.25*	0.24*	-0.37**	0.43**		0.25*		0.34**		0.22*
	'08	D					-0.27*	0.29**				0.42**	0.28**	
		U					-0.30**	0.33**				0,42**	0.28*	
	'09	D	0.24*	0.23*	0.23*	0.25*		0.27*		0.30**		0.36**	0.31**	
		U	0.26*	0.25*	0.26*	0.29**	-0.25*	0.28*		0.32**		0.32**	0.29**	
C. dactylon	'07	D												
		U												
	'08	D												
		U												
	'09	D												
		U												
S. halepense	'07	D							0.25*					
		U							0.24*					
	'08	D												
		U												
	'09	D	-0.27*	-0.29**										
		U	-0.28**	-0.30**										

C. arvensis was the only weed that was steadily affected by the soil properties and more specifically by the soil clay content

Results

Moran's I & Getis-Ord General G for Perennial Weeds 2007

	Moran's I spatial autocorrelation			Getis-Ord General G high/low clustering
	Maximum Moran's I	Distance (m)	Range (m)	Distance for maximum value of z-score (maximum intense of clustering)
Cypro density	0,067401	3500		9500
Cypro uniformity	**0,35563**	3500	6500	**9500**
Conar density	**0,585187**	2500	7500	**2500**
Conar uniformity	**0,486618**	2500	7500	**6500**
Cynda density	**0,342291**	2500	7500	**2500**
Cynda uniformity	**0,361309**	2500	5500	**3500**
Sorha density	**0,550908**	2500	8500	**2500**
Sorha uniformity	0,045412	3500		2500

Moran's I values in bold and Distance for Getis-Ord General G values in bold indicate that the corresponding z score values are significant at P <= 0.05

All z score values for Getis-Ord General G are positives

Results

Moran's I & Getis-Ord General G for Perennial Weeds 2008

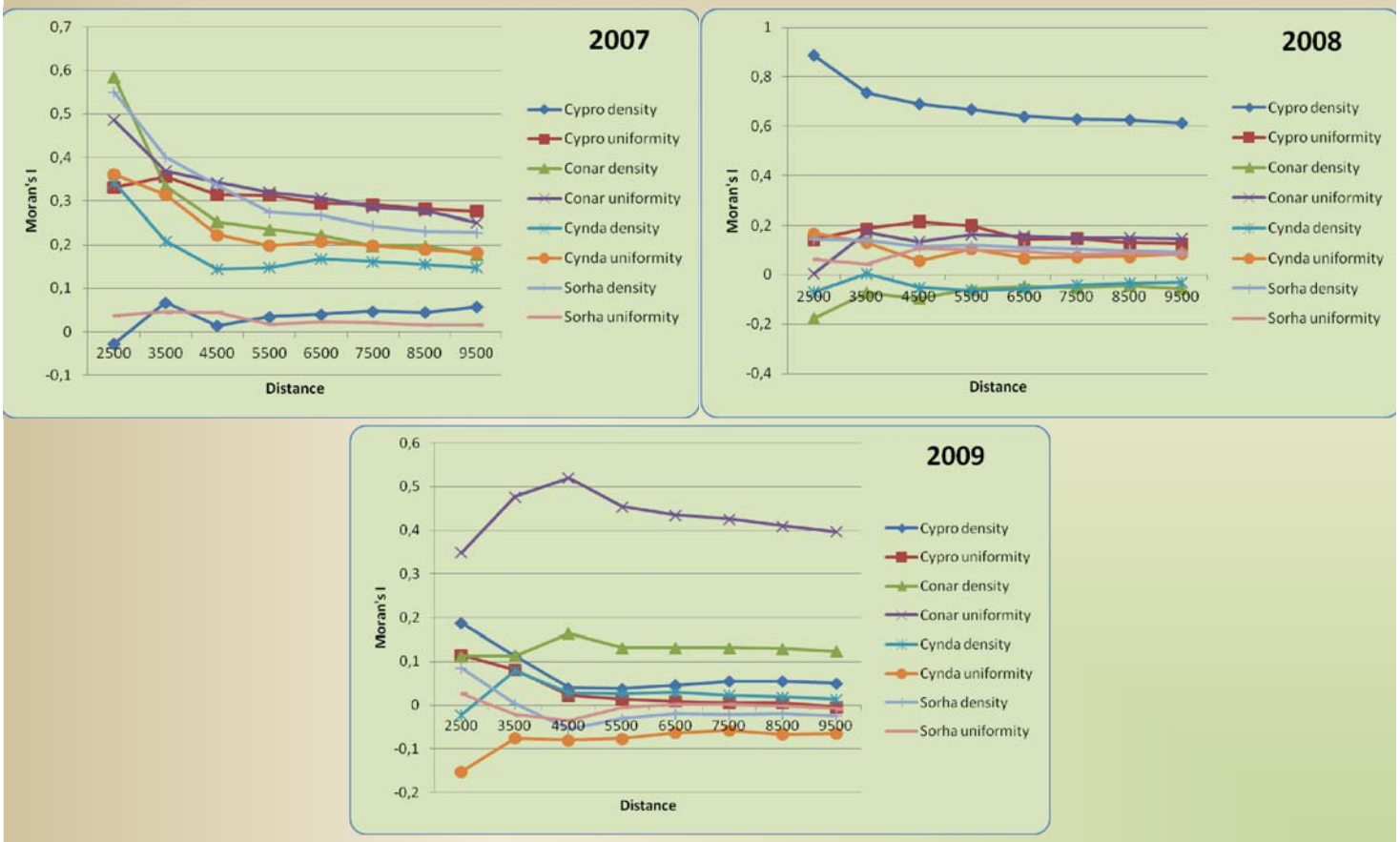
	Moran's I spatial autocorrelation			Getis-Ord General G high/low clustering
	Maximum Moran's I	Distance (m)	Range (m)	Distance for maximum value of z-score (maximum intense of clustering)
Cypro density	**0,887809**	2500	6500	**5500**
Cypro uniformity	**0,213225**	5500	8000	**5500**
Conar density	-0,177019	2500		
Conar uniformity	**0,163464**	3500	5500	**8500**
Cynda density	-0,031171	9500		
Cynda uniformity	0,167557	2500	6500	5500
Sorha density	0,144452	2500	6500	
Sorha uniformity	0,107015	4500	5500	

Results

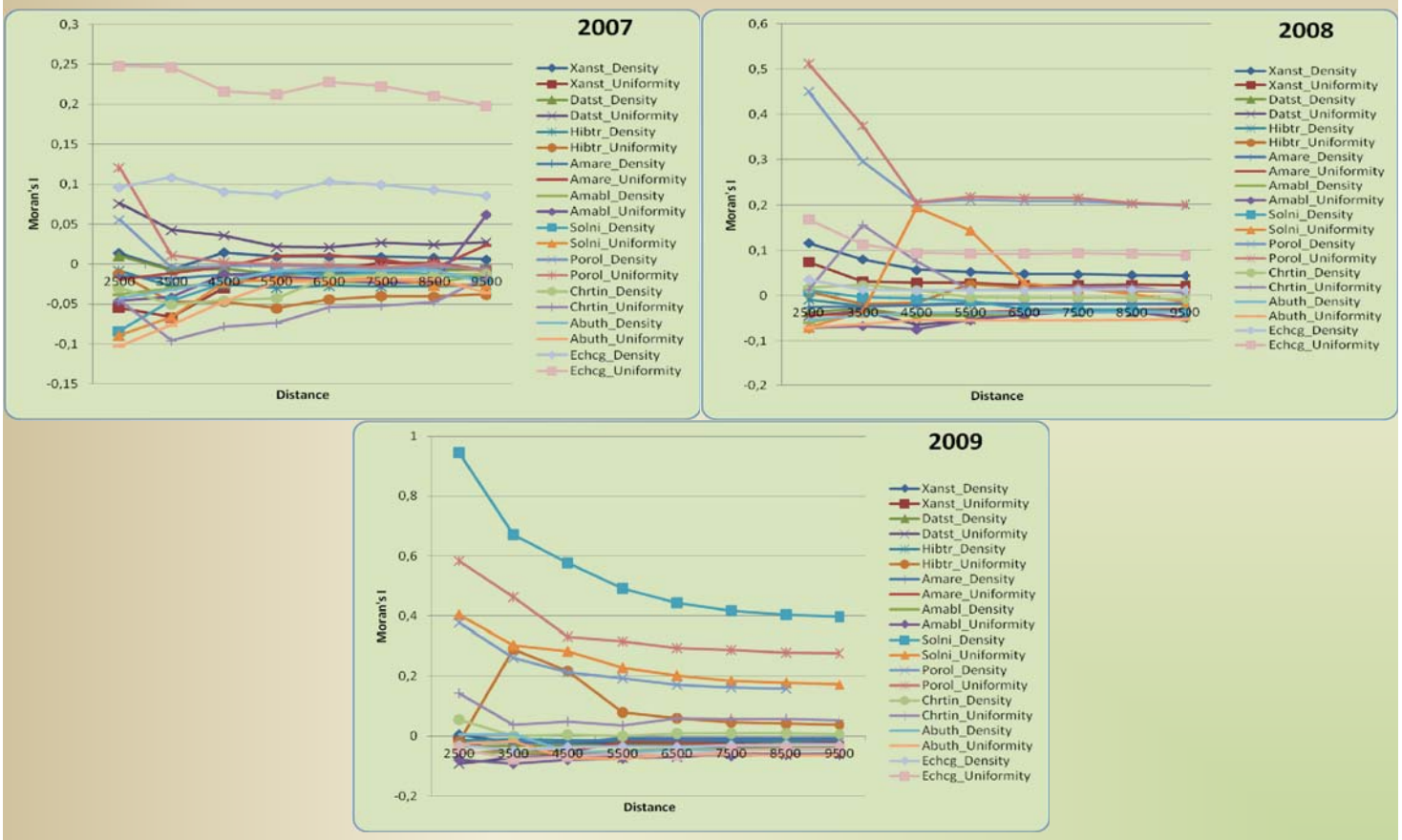
Moran's I & Getis-Ord General G for Perennial Weeds 2009

	Moran's I spatial autocorrelation			Getis-Ord General G high/low clustering
	Maximum Moran's I	Distance (m)	Range (m)	Distance for maximum value of z-score (maximum intense of clustering)
Cypro density	0,187587	2500	7500	
Cypro uniformity	0,114905	2500	7500	
Conar density	**0,164291**	4500	5500	**4500**
Conar uniformity	**0,520494**	4500	8500	**4500**
Cynda density	0,079578	3500	6500	
Cynda uniformity	-0,06277	6500		
Sorha density	0,085497	2500	5500	
Sorha uniformity	0,027313	2500		

Results- Morans' I correlogram of perennial weeds



Results- Morans' I correlogram of annuals weeds



Results -Spatial autocorrelation (Morans I)

Is there a Spatial autocorrelation?

- Based on Morans' I values, the associated z score and p-values, 5 out of the 12 perennial weed densities showed spatial dependence (statistically significant). The respective proportion regarding uniformities was 7 out of 12
- The Moran's I values were pretty low (close to zero) while the z score was not statistically significant for the majority of the annual weeds. Only 4 out of the 30 annual weed densities (10 weeds * 3 years) showed spatial dependence. The respective proportions regarding uniformities was 5 out of 30. Most of them refer to *S. nigrum* and *P. oleracea* which demonstrated significant appearance (based on densities and uniformities)

Are there any similarities of Spatial autocorrelation?

- According to the shape of the correlograms and to the values of Moran's I there is not a clear tendency that the annual weeds spatial distribution shows the same pattern between the studied years

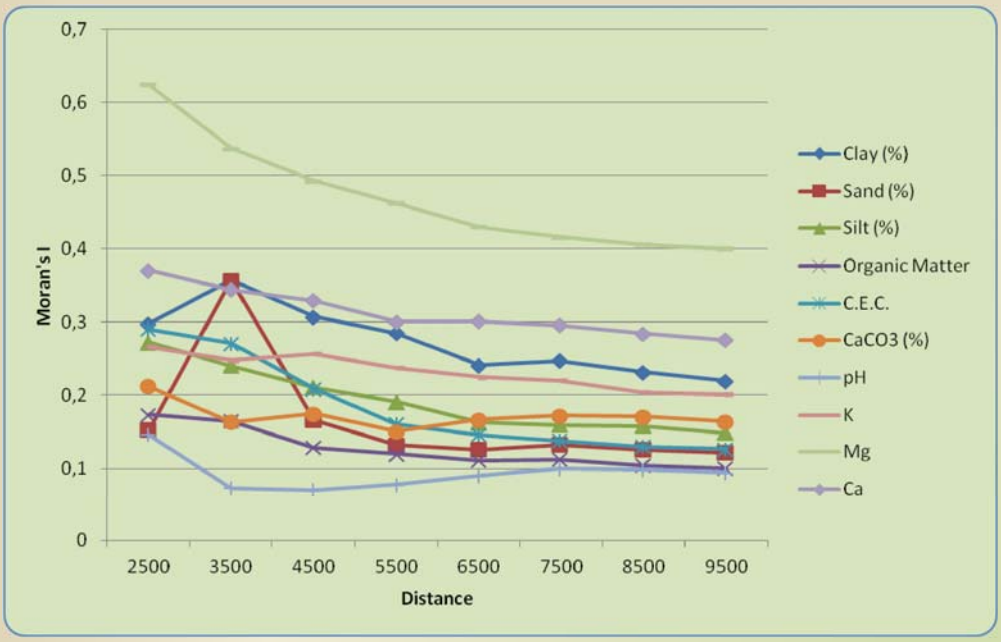
Results

Moran's I & Getis-Ord General G for *soil properties*

	Moran's I spatial autocorrelation			Getis-Ord General G high/low clustering
	Maximum Moran's I	Distance (m)	Range (m)	Distance for maximum value of z-score (maximum intense of clustering)
Clay	**0,357771**	3500	8500	**4500**
Sand	**0,176888**	3500	7500	5500
Silt	**0,272489**	3500	7000	**8500**
Organic Matter	**0,165484**	3500	8000	7500
C.E.C.	**0,290479**	2500	7500	**3500**
CaCO3	**0,212078**	2500	6000	**8500**
pH	0,188661	2370	6000	**9500**
K	**0,266211**	2500	8500	**4500**
Mg	**0,624035**	2500	9500	**5500**
Ca	**0,370817**	2500	8500	**7500**
Na	-0,029061	2500		3500

Moran's I values in bold and Distance for Getis-Ord General G values in bold indicates that the corresponding z score values are significant at P <= 0.05

Results- Morans' I correlogram for soil properties



Results – High/Low clustering (Getis-Ord General G)

Is there a concentration of high or low values?

- Almost all perennial weeds (densities and uniformities) and soil properties presented statistically significant clustering of high values, in distances less than a range of the corresponding correlograms

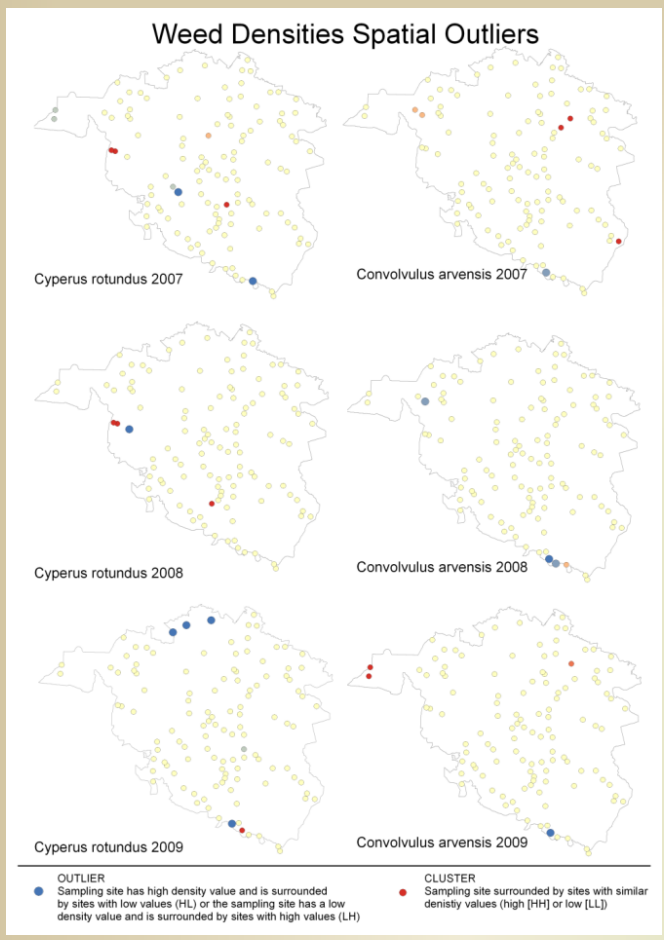
Results -Spatial autocorrelation (Moran's I)

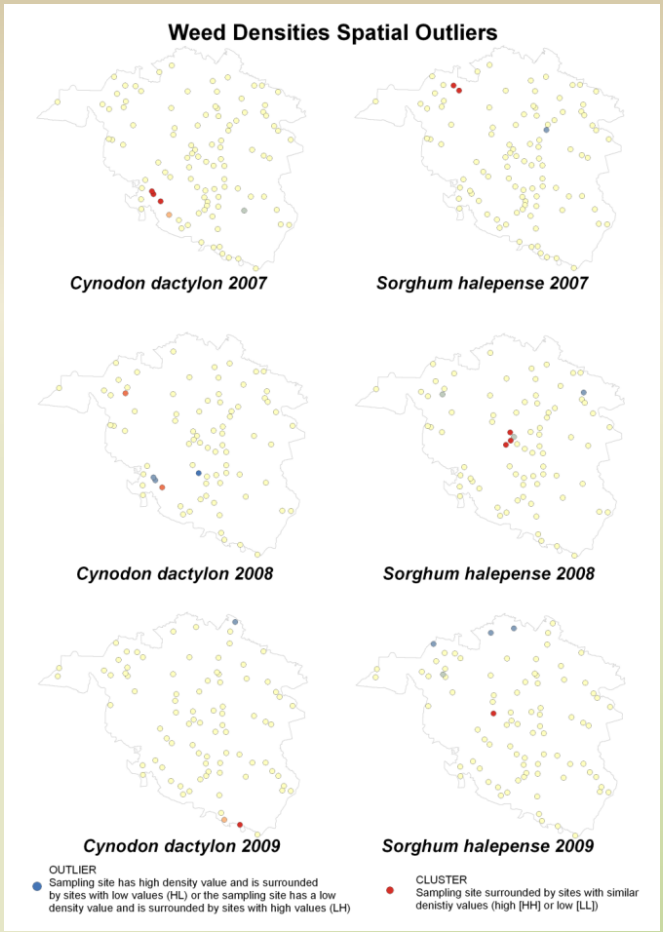
Is there a spatial dependence between weed appearance and soil properties?

- The soil variables and the perennial weeds showed a statistically significant spatial correlation (z-score>1.96) at almost the same distance (~8500 m), which indicates the same spatial dependence. Taking into consideration that perennial weeds are not sufficiently suppressed by the employed weed control methods, spatial distribution of weed densities could be assigned to soil properties variation

- No spatial correlation was found for the annual weeds. Chemical control overshadows possible differences in annual weed appearance caused by abiotic factors

Results -4





Only few are identified and situated on the borders of the study area

Conclusions

- Overall, densities play a key role in identifying spatial autocorrelation
- Uniformities can be used to better estimate spatio temporal stability (fixed values)
- Spatial autocorrelation analysis constitutes a prerequisite in weed mapping since it identifies the spatial dependence and spatial outliers
- Soil properties consist a close related co-factor in weed appearance and therefore important in weed mapping

Thank you!