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Establisment of a long term experiment into tillage and traffic management. Part two:

Evaluation of spatial heterogeneity for the design and layout of experimental sites

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Aim of the project:

To develop practical recommendations for determining the spatial variability of potential experimental agronomic sites.

Objectives:

- To monitor and evaluate the field to identify the spatial variability in soil properties for the selected field,
- To develop a methodology for good practise on doing field experiments,
- To make recommendations for potential layout and establishment of experiments on the selected field.

Hypothesis:

Field monitoring used in the Precision Farming (PF) to define the site-specific management zones could be used to identify uniform areas within the field for layout and design of potential experimental agronomic sites.

Background:

Accurate treatment comparisons over a range of conditions are the primary objectives of most agricultural experiments.

The natural spatial variability of soil properties adversely affects the accuracy and efficiency of agricultural experiments because error estimates based on observations from replicates of the same treatment are often inflated due to soil heterogeneity (Banton *et al.*, 1997; Auerswald *et al.*, 2001; Clay *et al.*, 2001; Sudduth *et al.*, 2001; Sudduth *et al.*, 2003; Mueller *et al.*, 2003; Heiniger *et al.*, 2003).

As discussed the conventional soil sampling is costly and labour-intensive, but dense measurements of soil conductivity (ECa) are relatively rapid and inexpensive (Kitchen *et al.*, 1999; Smith *et al.*, 2001).

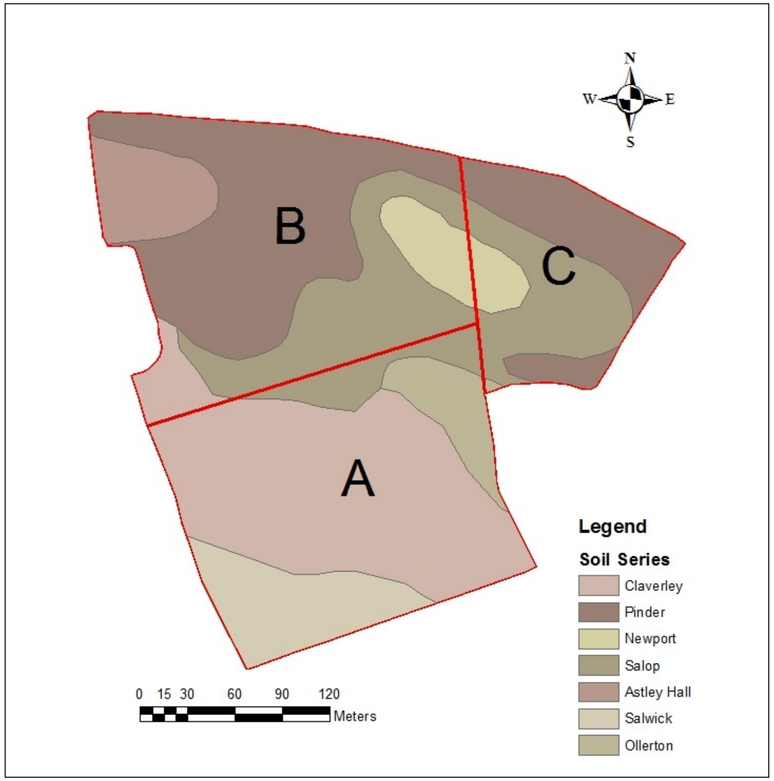
Experimental Site:

- Large Marsh field: 8.51 ha, Harper Adams University College, Shropshire, UK,
- evaluation of the uniformity of the selected field,
- field divided into 3 areas (A,B,C) – based on the historical field boundaries,
- parameters considered:
  - plot trial requirements
  - topographic data
  - soil and water related data
  - crop performance and yield

Distribution of soil series in field

BLOCK NAME	AREA [ha]	SOIL SERIES	AREA [ha]	% of AREA
B	3.45	Newport	0.24	6.88
		Claverley	0.18	5.33
		Pinder	1.73	50.04
		Astley Hall	0.41	11.73
		Salop	0.90	26.02
C	1.42	Newport	0.13	8.85
		Pinder	0.68	47.75
		Ollerton	0.01	0.53
		Salop	0.61	42.87
A	**3.32**	Claverley	**2.14**	**64.40**
		Salwick	0.62	18.72
		Ollerton	0.30	9.15
		Salop	0.26	7.73

Spatial distribution of soil series in field



(Beard, Soil Survey and Land Research Centre)

Methodology:

- <u>Topographic data:</u>
  - Elevation by *RTK GPS*
- <u>Soil and water data:</u>
  - Electromagnetic conductivity using *DUALEM-2S* (DUALEM Inc., CANADA): SHALLOW (0-0.5 m) and DEEP (0-1.2 m) - *September 2011*
  - Electromagnetic conductivity using Geonics EM-38, Geonics Ltd., Canada): SHALLOW (0-0.75m) and DEEP (0-1.5 m) - *April 2012*
  - <u>Crop performance and yield:</u>
  - NDVI data from Crop Circle ACS-210 (Holand Scientific Inc., USA) – *May 2012*
  - Remote sensing of crop canopy (satellite images; SOYL Precision Farming, UK) – *May 2012*
  - Yield map using Ceres 8000i (RDS Technology Ltd., UK)

Data analysed using the classical statistics in *GenStat* (VSN International Ltd., UK) and geostatistics in in *ArcGIS* (ESRI Inc., USA).

Classical statistical evaluation:

Performed:

- by comparing Variance and Coefficient of variation [c.v.(%)]
- graphically expressed by Box-plot charts (see below)

Variance:

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2$$

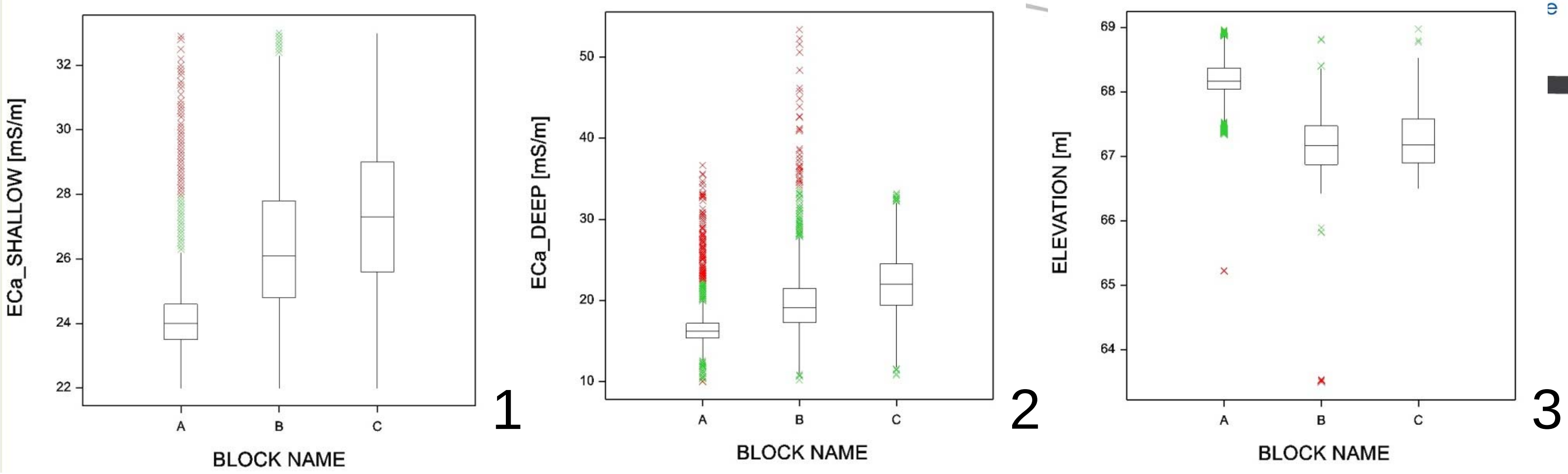
where population mean is:

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i$$

Coefficient of variation:

$$c.v.(\%) = \frac{\sigma}{\mu} \times 100$$

Results: classical statistics



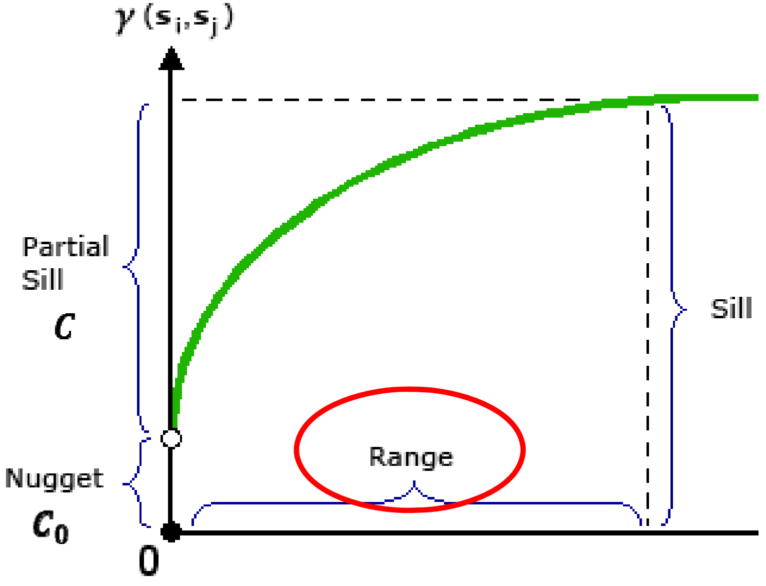
Boxplot variables charts with single grouping factor (A,B,C); **1** – ECa 0-0.5 m, **2** – ECa 0-1.2 m, **3** – elevation

Statistical parameter	ECa – SHALLOW (mS/m)			ECa – DEEP (mS/m)			ELEVATION (m)		
	A	B	C	A	B	C	A	B	C
Mean	24.190	26.38	27.26	16.67	19.53	21.73	68.19	67.20	67.25
Minimum	22	22	22	10	10.2	10.8	65.22	63.50	66.50
Maximum	23.9	33	33	36.7	53.4	33.2	68.97	68.82	68.98
s.d.	1.216	2.209	2.469	2.325	3.464	4.090	0.297	0.403	0.407
s.e.m.	0.0147	0.0264	0.0448	0.0282	0.0414	0.0742	0.0036	0.0048	0.0074
Variance	**1.479**	4.880	6.095	**5.406**	12.00	16.73	**0.0884**	0.163	0.165
c.v. (%)	**5.027**	8.373	9.056	**13.95**	17.74	18.83	**0.436**	0.600	0.605

Geostatistical evaluation: ordinary kriging interpolation

The distance where the model first flattens is known as the range. Sample locations separated by distances closer than the range are spatially autocorrelated, whereas locations farther apart than the range are not.

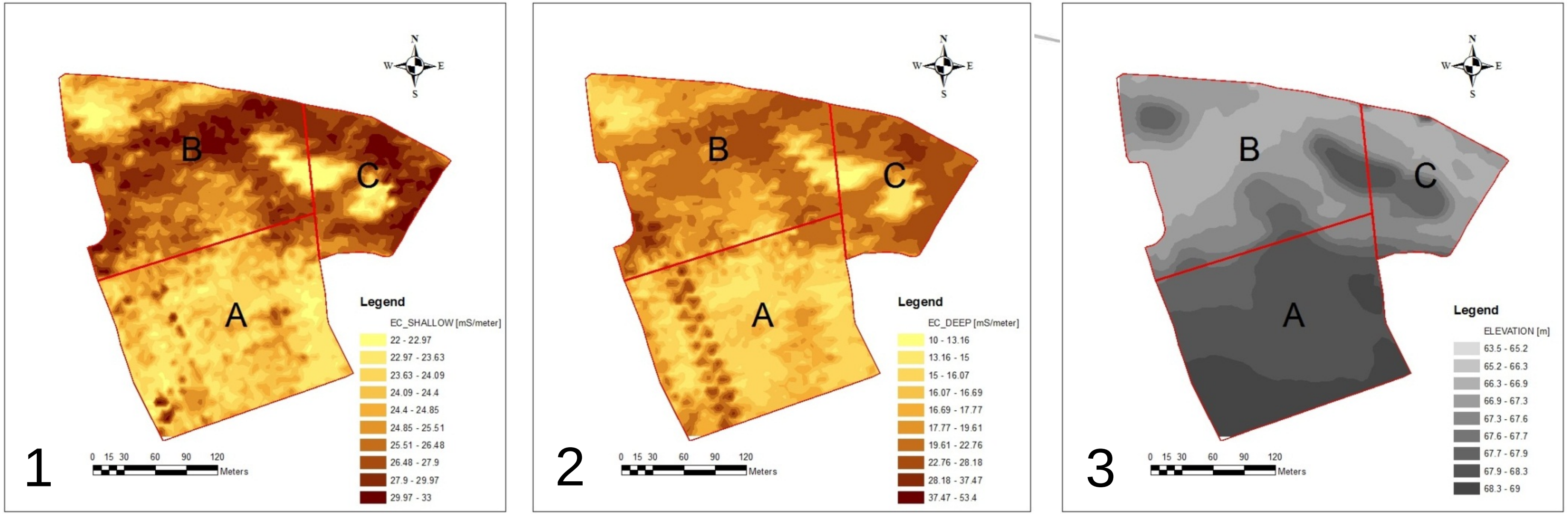
Model of spherical semivariogram:



Expression of semivariance:

$$\gamma^*(h) = \frac{1}{2N(h)} \sum_{i=1}^{N} (z_i - z_{i+h})^2$$

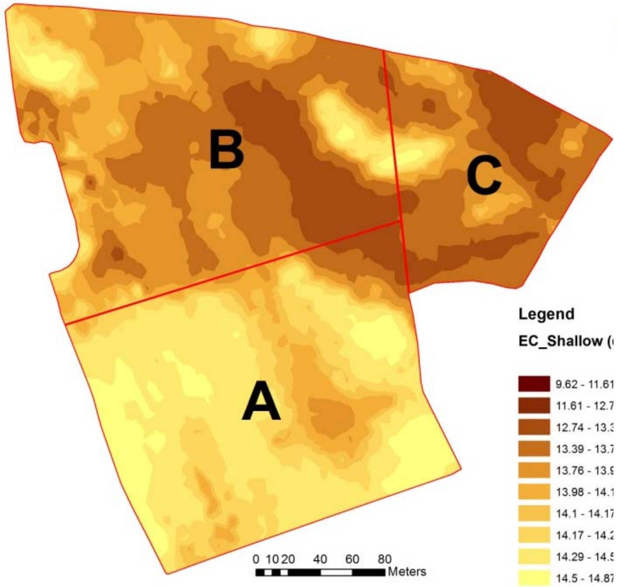
Results: geostatistics

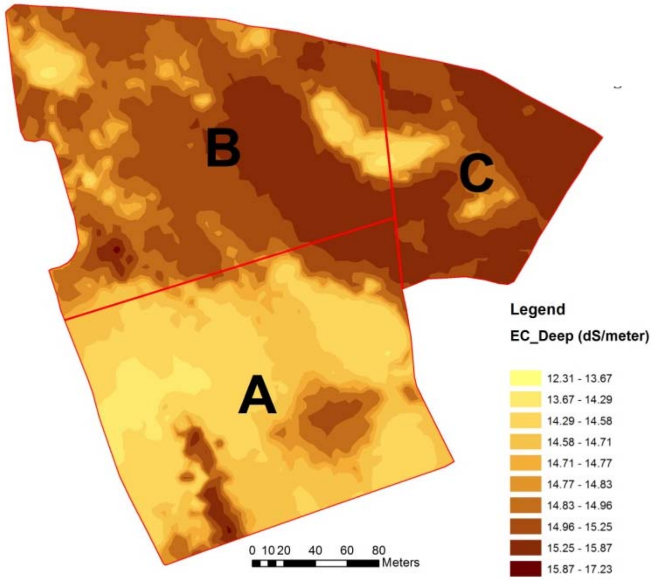


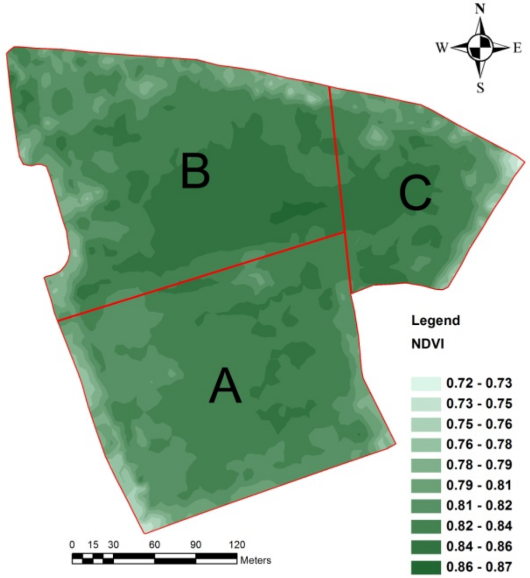
Spatial distribution of measured parameter divided into evaluated areas (1 – ECa 0-0.5 m; 2 – ECa 0-1.2 m; 3 – Elevation)

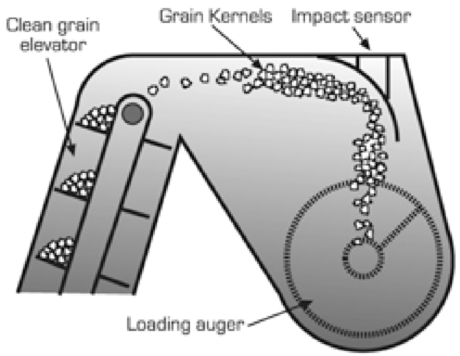
Parameter	ECa – SHALLOW (0-0.5 m)			ECa – DEEP (0-1.2 m)			ELEVATION (m above sea level)		
	A	B	C	A	B	C	A	B	C
Nugget C_0	0.09	1.81	0.90	1.55	6.78	0.92	6.36	0	0
Sill C_0+C	0.63	6.22	8.21	5.17	14.87	22.38	6.49	0.19	0.23
Range A_0(m)	**107.74**	69.18	51.22	**265.62**	147.40	53.59	**265.63**	111.58	93.14
$C_0/(C_0+C)$	0.14	0.29	0.11	0.30	0.46	0.04	0.98	0	0
Model	Spherical			Spherical			Spherical		

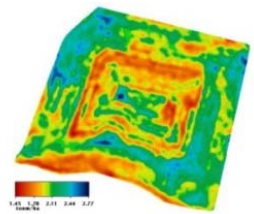
Results: soil, crop performance and yields



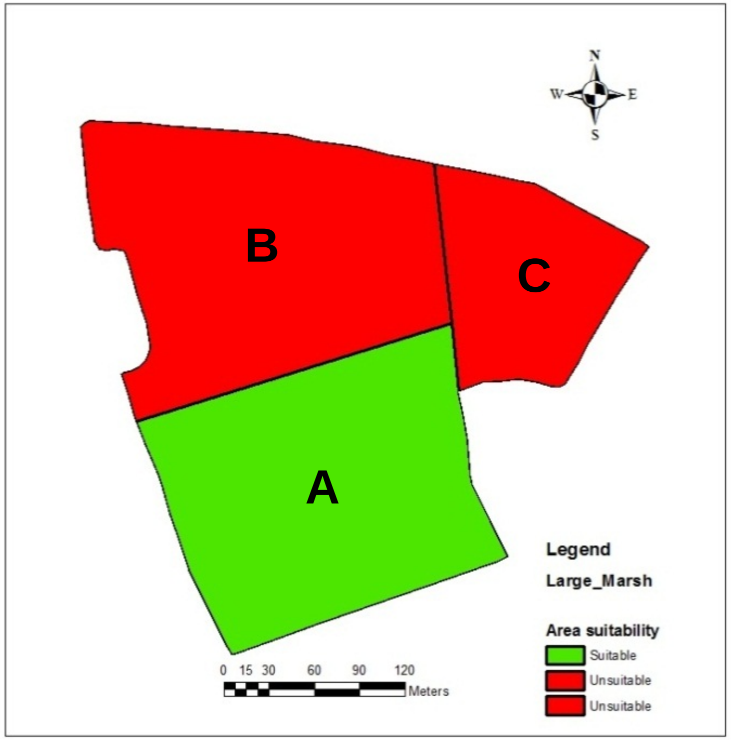


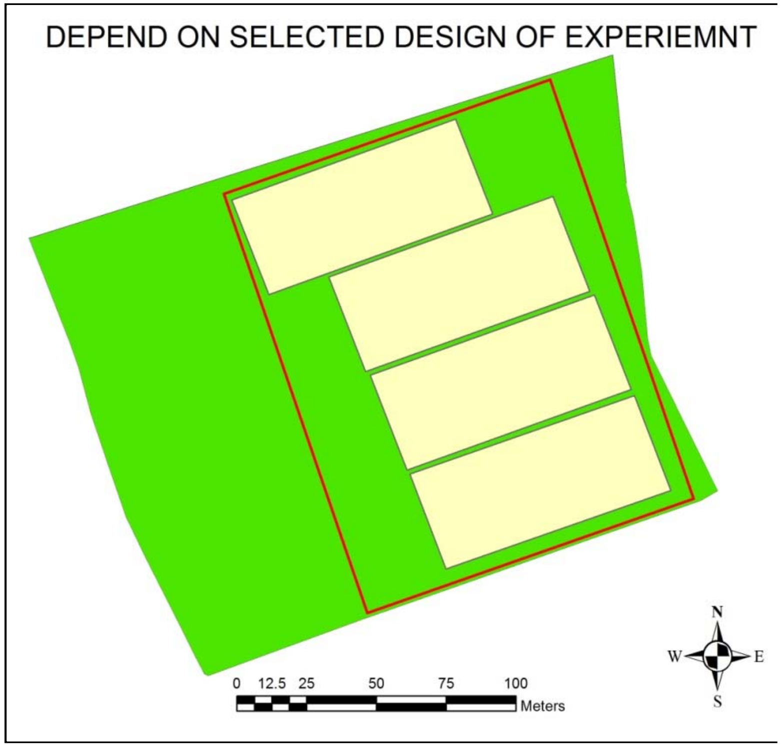






Recommendations: plot layout and design





Conclusions:

- This study evaluated a selection of commercially available rapid methods used to assess the within-field variability.
- The area A was found to have the lowest variability and, therefore, the establishment of an experimental study in this section is recommend.
- Further data analysis will provide recommended field survey protocols and methods to assess spatial heterogeneity for a design and layout of experimental sites.
- Employment of the recommended approach will ensure an estimation of significant differences between treatments (not influenced by heterogeneity of the field).
- It may also result in a reduction in required number of replications and experimental blocks.

Acknowledgement:

Harper Adams University College

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SOYL Precision Farming

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Thank you for your attention

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