Field-scale spatial isotope ($\delta^{13}C$ and $\delta^{15}N$) variability in the surface of an intensively managed grassland

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Introduction

Studying variations in stable isotope natural abundance ($\delta^{13}C$ and $\delta^{15}N$) give insight into ecosystem processes[1]. Disregarding spatial variability in isotope studies may have confounding effect and negatively affect the reliability of results [2].
Even fields which have been presumably homogenized by cultivation can show substantial spatial variability [3].

Field-scale isotopic spatial variability, in combination with several other soil chemical and physical properties, was quantified in preparation for a "farm-scale ecosystem services" project in an intensively managed grassland area in south-west England to:

1.) create soil surface prediction maps
2.) understand the causes of stable isotope spatial variability

Study Site and Methodology

Sampling was conducted in Great Field, one field of the experimental farm at North Wyke, Rothamsted Research (Figure 1a). Great Field is located on a slope (Figure 1, left) and had been managed as two separate fields before 2010, old boundary shown in Figure 1, middle). The northern part of the field has been permanent grassland for 25 years, whereas the southern part was re-seeded in 2007 after it was in a grass- barley rotation.

84 samples were taken in a nested geostatistical sampling pattern (Figure 1, right). Ordinary kriging was conducted to create surface prediction maps (ArcGIS).

Soil surface (0-7.5cm depth) properties quantified: $\delta^{13}C$, $\delta^{15}N$, total nitrogen (TN), total carbon (TC), soil organic matter (SOM), bulk density (BD), particle size distribution (PSD).

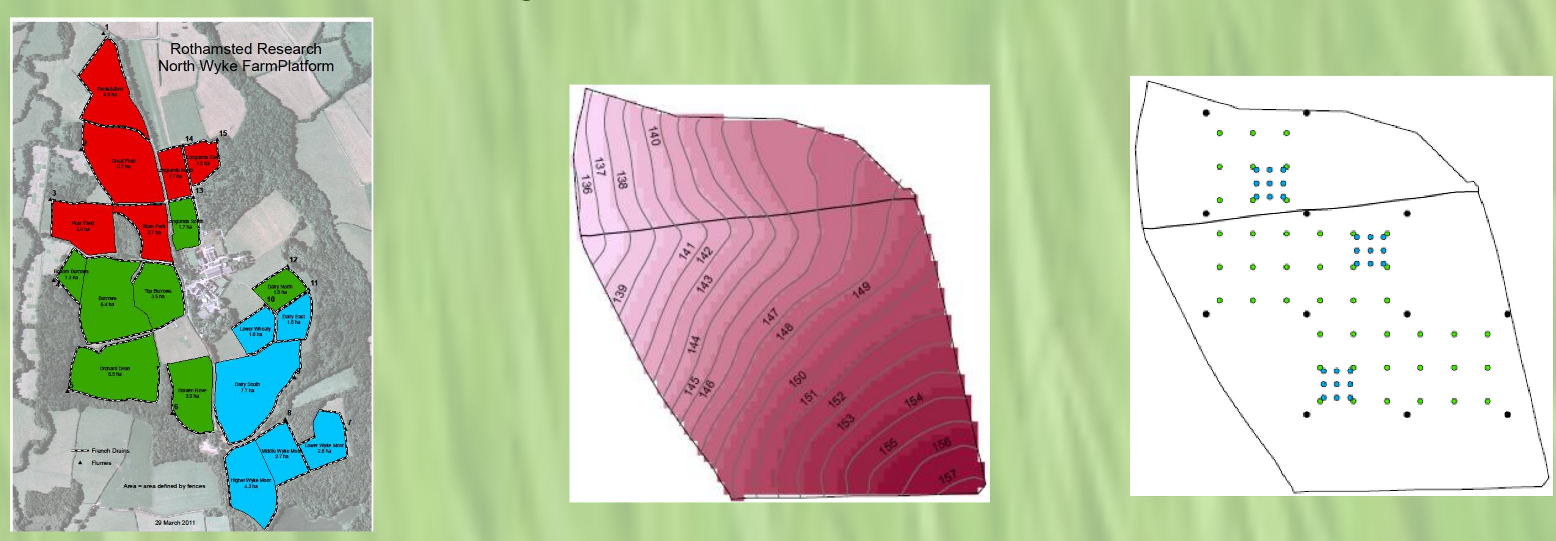

Figure 1. Sampling location. Left: Location of Great Field within the Farm Platform. Middle: Great Field topography. Right: Geostatistical sampling pattern: Black dots illustrate a 75x75m grid, green dots the 25x25m grid, blue dots the 10x10m grid. The line shows the old dividing field boundary.

Preliminary Results and Discussion

1.) Isotope Surface Prediction Maps

There is clear spatial variability in stable isotopes and total C and N. $\delta^{13}C$ is negatively correlated to TC and $\delta^{15}N$ is positively correlated to TN (Table 1). $\delta^{15}N$, TN and TC all show distinct spikes in the north of the field and mostly areas of lower values in the south. $\delta^{13}C$ shows the opposite patterns.

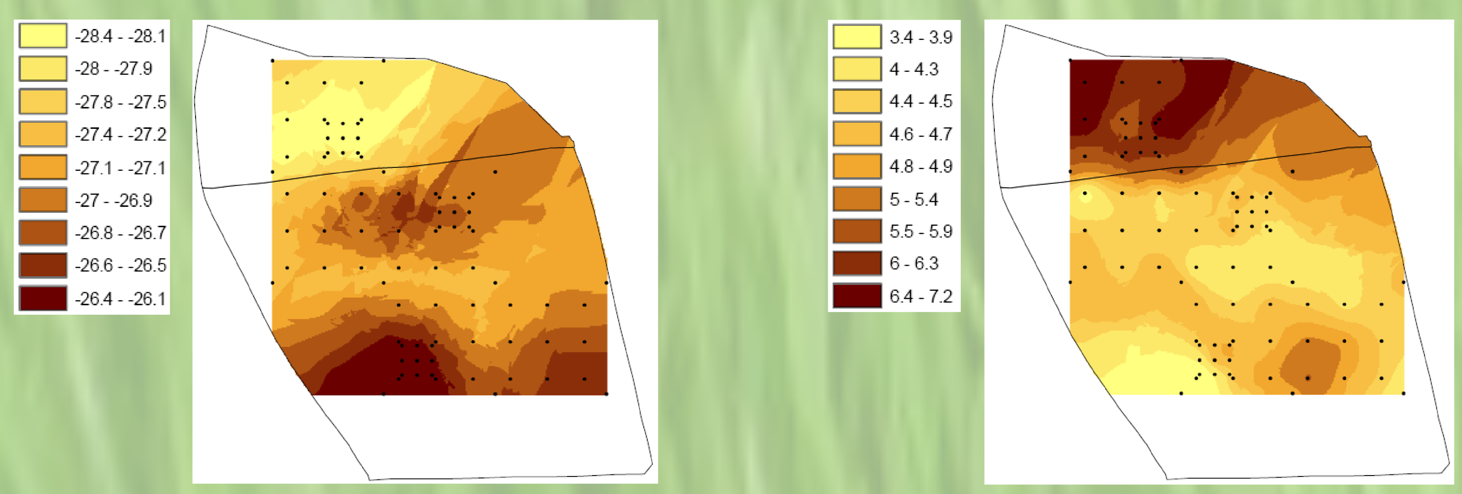

Figure 2. Surface prediction maps. Left : $\delta^{13}C$), Right: TC.

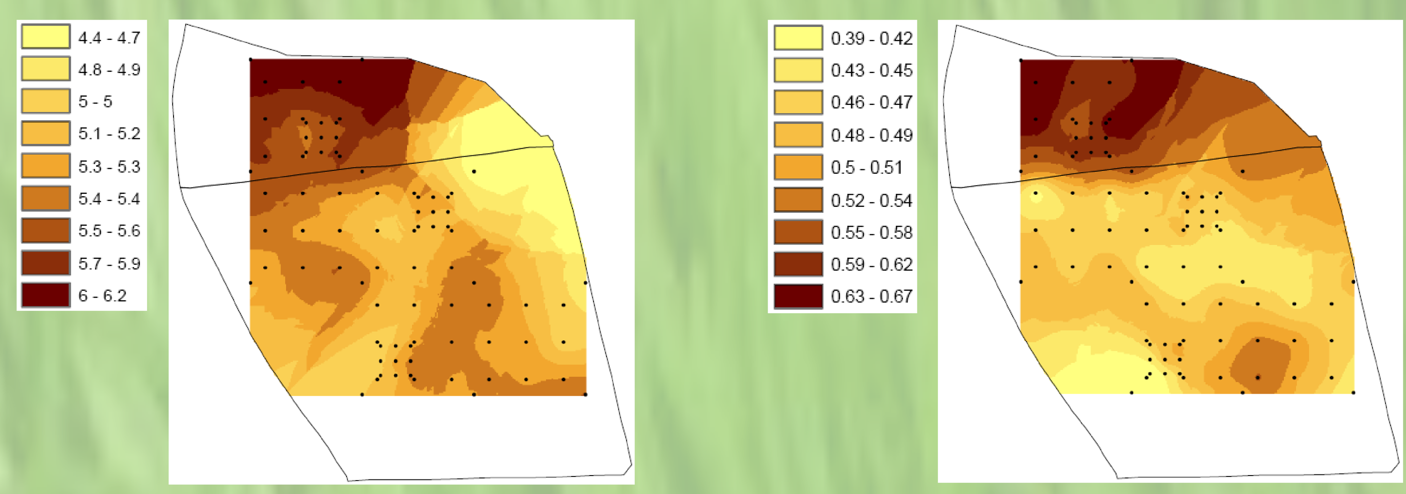

Figure 3. Surface prediction maps. Left : $\delta^{15}N$, Right: TN.

2.) Potential Causes of Isotope Spatial Variability

Preliminary simple regressions showed $\delta^{13}C$ and $\delta^{15}N$ to be significantly correlated to their corresponding total nutrients, OM content, bulk density and elevation (as a surrogate for hydrology). Here, low density soils generally contained the highest $\delta^{15}N$ and the lowest $\delta^{13}C$ values , even though dense soils have been previously found to conserve organic matter and stable isotopes [4]. Clay content was not correlated to isotope values, in contrast to previous findings [5]. Figure 4.

Table 1.
Linear regression between several soil properties. Significant correlations are underlined.

	C	N	OM	Sand	Silt	Clay	BD	Elevation
$\delta^{13}C$	P<0.0001 R=0.6095		P<0.0001 R=0.6227	P=0.0965 R=0.1825	P=0.2309 R=0.1321	P=0.3478 R=0.1037	P=0.0072 R=0.2910	P=0.0002 R=0.3977
$\delta^{15}N$		P<0.0001 R=0.5541	P<0.0001 R=0.5	P=0.4030 R=0.0924	P=0.7304 R=0.0382	P=0.0774 R=0.1937	P=0.0049 R=0.3044	P=0.0072 R=0.2910

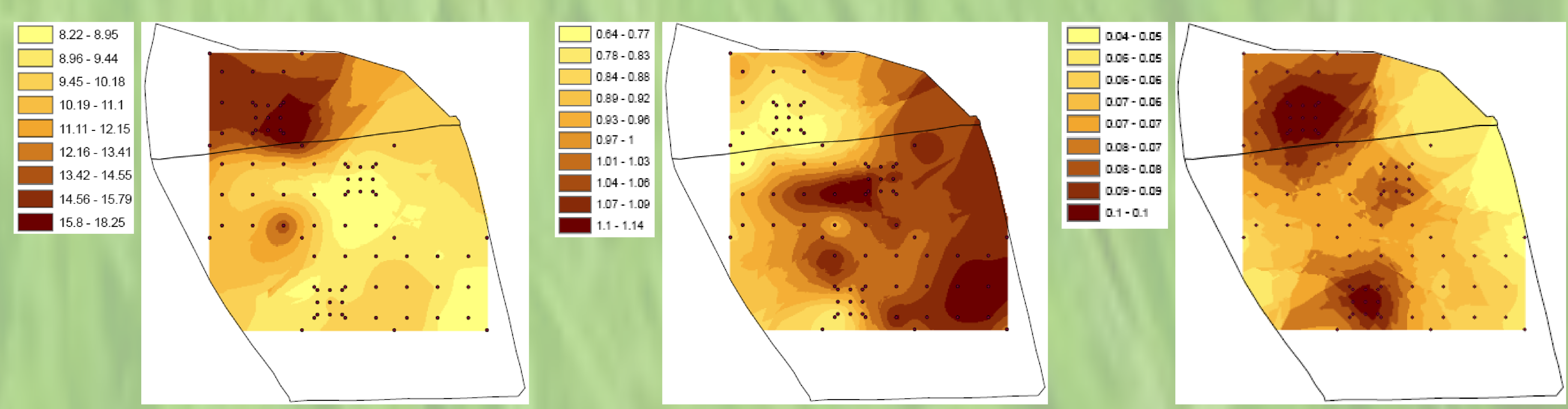

Figure 4. Surface prediction maps. Left: OM, Middle: BD, Right: Clay.

However, surface maps of all correlated soil properties exhibit clear differences between the northern and southern part of the field, which was confirmed by t-tests (Table 2). There are two distinct isotope populations for the two previously distinct fields (Figure 5). Differential past field management may have had a distinct influence on current isotope values by affecting the above identified soil properties, which influence stable isotope values.

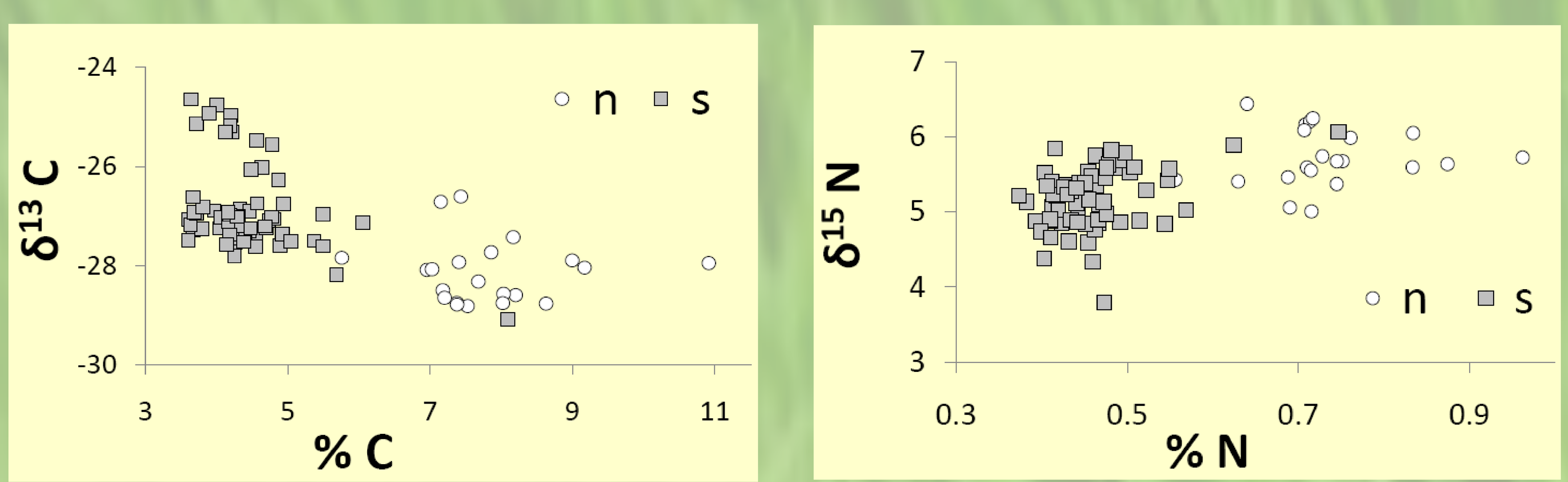

Figure 5. Total C and N and their respective stable isotope correlation divided into measurements taken in the two parts of Great Field. Left: TC, Right: TN.

Table 2.
Results of paired t-test. 20 DF.

$\delta^{13}C$	$\delta^{15}N$	%C	%N	OM	BD
P< 0.0001	P< 0.0005	P< 0.0001	P< 0.0001	P< 0.0001	P= 0.0001
T= -6.061	T= 4.154	T= 8.3148	T= 11.4296	T= 0.6227	T= -4.797

Conclusion

Spatial analysis is useful in identifying the general processes which control $\delta^{13}C$ and $\delta^{15}N$. The measured soil variables all showed spatial variability. Here, management history may have had an influence on current soil chemical and physical properties, which in return affected $\delta^{13}C$ and $\delta^{15}N$ distribution at the field scale. Management history therefore must be taken into consideration when designing sampling strategies to investigate ecological processes in these ecosystems.

References

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