Towards managing landscapes: how can we interpret and design better environmental monitoring surveys?

Question

How should we interpret extensive environmental monitoring surveys and how can we design them better, especially in the light of different landscape factors, cropping and market share?

Background

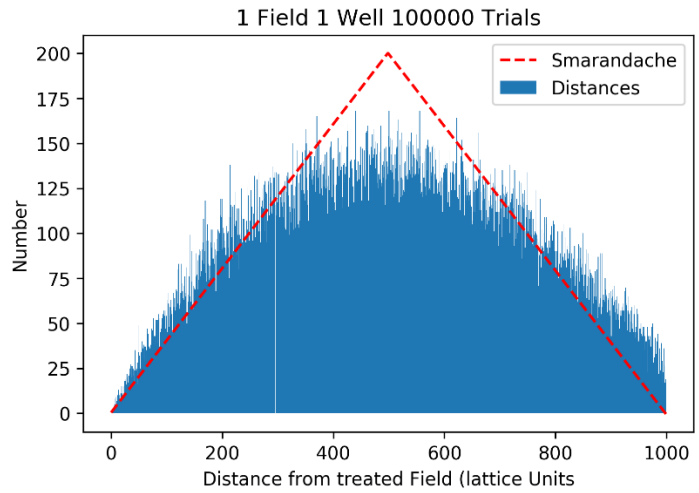
Member states routinely conduct groundwater monitoring surveys to demonstrate compliance of regulatory triggers for groundwater. However the link between the level of detect (concentration) and actual application is often not known, particularly when a large number of wells are monitored across a large landscape (say county level and above). It is therefore difficult to interpret the results of such monitoring exercises in the context of edge-of-field concentrations.

It is well-known that higher concentrations in groundwater are more likely to be found the closer a well is to an agricultural field. We would therefore like to know how varying the number of treated fields (combination of market share and cropping) and number of monitoring wells affects the probability distribution of wells close to treated fields.

An analysis where there are no restrictions on the placement of wells with multiple fields and a single well yields a $\sqrt{d}$ relationship, which would be intuitively expected. However the problem is more complex because wells cannot be placed anywhere: farmers do not like wells placed in fields because of difficulties with operating machinery and landscape factors such as roads and woodlands place restrictions on the placement of wells.

To simplify the problem we considered the random placement of fields on a lattice with the squares representing fields and the nodes possible well locations. Figure 1 shows 100,000 trials where a single well placed randomly in a grid and a centrally placed field yields a simple triangular distribution (Smarandache), however when randomly placed on the grid this relationship no longer holds (see Figure 1), and even with over 100,000 trials the exact form of the distribution is difficult to establish.

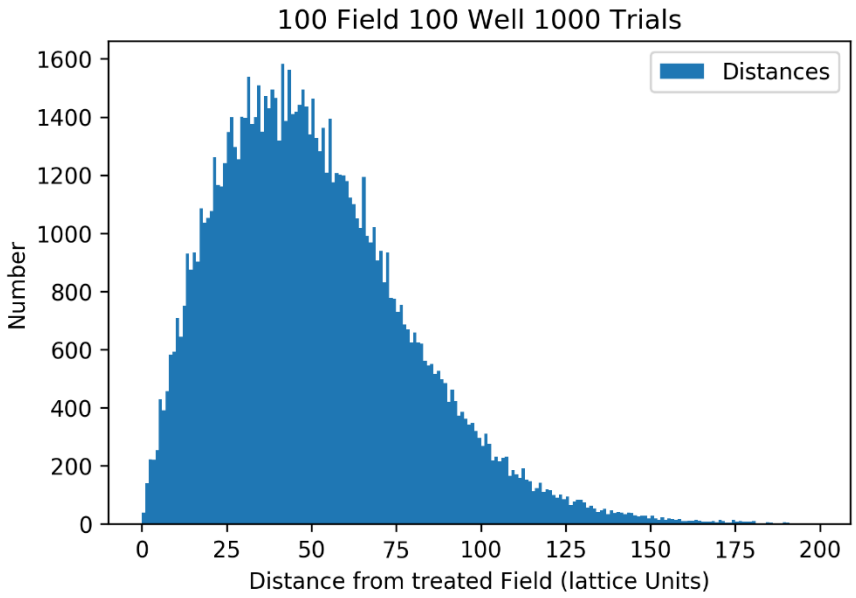
Figure1: relationship between distance to treated field with single well and field placed randomly on 1000x1000 grid



When the number of fields and wells is varied on a grid an approximate log-normal distribution is obtained (see Figure 2), but this relationship is not exact. We would first like to derive an exact relationship between the number of treated fields and proximity of monitoring locations on a lattice as this problem should be solvable and provide valuable insight into the real problem.

Real landscapes may be approximated by grids but are different: fields vary in size and shape, landscapes do not only contain agricultural fields, and groundwater may flow in a direction opposite to the monitoring well even if adjacent. We would like to know how different a real landscape is from the idealised problem and whether the results from the lattice can be bridged to landscapes. Ideally we would like to know how landscape factors affect how we should interpret and design monitoring surveys.

Figure2: Distance to treated field (100 wells and 100 fields on 1000x1000 grid) 1000 trials.



Subsidiary Questions

1. Are there any particular sorts of landscape arrangement that makes finding a well closer to fields more likely? E.g. lots of small fields versus fewer large fields
2. How does the probability change with the presence of non-agricultural areas such as towns, forests etc.?
3. Is it possible to take a general exceedance rate from a number of wells and predict an edge-of-field concentration?
4. Can any landscape be turned into an equivalent grid and analysed that way?