

### 3.c. Uncertainty Analysis of a Soil Carbon Model

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**The Problem:** Climate change is one of the biggest environmental problems of the 21<sup>st</sup> century. Key to the process of climate change is the anthropogenic release of CO<sub>2</sub> from the burning of fossil fuels. To predict the future development of the Earth's climate system, estimation of the global carbon budget is essential as it determines the CO<sub>2</sub> concentration in the atmosphere. A major pool of carbon is the soil, which stores up to  $1400 \times 10^{15}$  g carbon, twice the amount of carbon in the atmosphere. As temperature changes, soil organic carbon stocks (SOC) change because the processes that decompose carbon are temperature and moisture dependent. Computer models are valuable tools for investigating these complex systems. Estimates of changes in temperature and precipitation are uncertain, and this uncertainty propagates through the model and influences the estimates of future SOC. To analyse the propagation of uncertainty through the system and to estimate the range of uncertainty for the estimated SOC, we need to perform an uncertainty analysis.

**The Method:** A number of different methods could be used to analyse the response of the model to uncertainty. Here, we need to understand the effect of different combinations of input variables, their interactions, and their response to changes in individual parameters. The Monte Carlo sampling method is the most appropriate approach. Monte Carlo sampling requires the definition of the range of uncertainty in input variables and the distribution of inputs within the range. To do this, we define Probability Density Functions or PDFs, (Fig. 1 & 2). We have assumed a uniform distribution, because we have limited information about future variation in the inputs. The model is run by selecting a random value from each PDF, which produces an estimate of SOC. The process is repeated many times to produce a PDF for the estimated SOC. This represents the uncertainty of the model prediction (Fig. 3). A Monte Carlo sample size of 1000 was used, the range in temperature was assumed to be 0-5.8°C, and the range in precipitation of 800mm per year  $\pm$  20%.

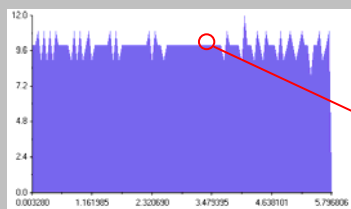


Fig. 1: Uniform distribution of temperature values, 1000 Monte Carlo samples

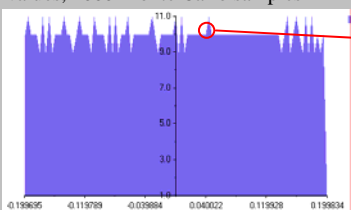


Fig. 2: Uniform distribution of precipitation values, 1000 Monte Carlo samples

Model

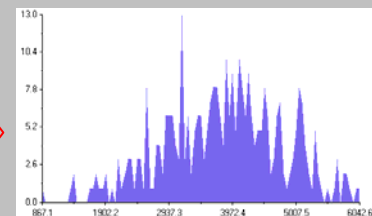


Fig. 3: Output distribution shows the whole range of uncertainty in carbon storage values derive from the two input pdfs

**The Result:** By entering all values sampled by the Monte Carlo process, the range and distribution of potential model outputs can be determined. This gives the margin of error on the estimate of soil carbon stocks, accounting for all possible variation in the models inputs. This provides an indication of how likely it is that the the model predictions are to wrong, and suggests the range of values that the model might produce. In the above Fig. 3, there is a range of possible values for the output, but because the output is not uniformly distributed it also tells us that values at the extreme ends of the range are less likely than those in the middle.

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Morgan, M.G. & Henrion, M. (1990). Uncertainty: A guide to dealing with Uncertainty in Quantitative Risk and Policy Analysis. Cambridge University Press