Response to Referee #2

The referee comments are given in quotation marks. As a preamble, we emphasize that most of the answers to the referee's questions can be found in the original manuscript.

Response to the general comments

"This study used the measurements of carbon stock and 14C of soil carbon at different soil layers to constrain the carbon fluxes into and out of the Bh layer and its carbon turnover rate. Even for a single –pool model of soil carbon in Bh layer at non-steady state, there are three unknowns: influx, efflux and turnover rate, with only two observations for each site (total amount of carbon and carbon age). Theoretically, the optimization problem is under-determined, there will be infinite number of solutions. However only a unique solution was found in this study. Therefore I must have missed additional data constraint used in the optimization by the authors."

Response: In a first step (§ 3.1.2) we used the single-pool model to determine two particular solutions for which there are only two unknowns, the conditions for obtaining the stationary state (input = output) and the minimum formation time (output = 0). This first step showed that the output fluxes from older Bhs were too low compared to the measures reported by previous studies and that it is therefore necessary to consider two Bh pools. In the second step (§ 3.2.2) we clearly stated that " there is an infinity of solutions for modelling the Bh formation" (line 225) and that "We therefore carried out a sensitivity analysis to determine how the main parameters (size of the fast pool of the Bh, C flux input and output C rates for the Bh pools) affected the profile genesis time and to understand the relationships between these parameters" (lines 226-228). This analysis and data from literature allowed to exclude unrealistic values and to constrain C fluxes and mineralization rates, as explained on lines 245 to 251.

"In general I found that the manuscript provides quite a lot of details and reasoning for the approach taken in this study. However the key message was somehow buried by detail as presented. Significant modifications should be made to distil wealth of information to highlight the key message. That is what are the magnitudes of carbon influx and efflux from the Bh soil layer and its turnover rate."

Response: The magnitude of carbon influx and efflux to the Bh pools are given on Fig. 12. We did not specify the turn-over rates because the slow pool of the Bh is not in a steady state. However, we agree with the referee that it would be informative to give instantaneous turnover times.

"Estimates of carbon influxes by previous studies varied by one order of magnitude, and result from this study suggests that a lower estimate of the carbon influx is more likely."

Response: It is indeed our conclusion, which is even more important for us that several authors of the present study were also authors of the previous study which gave a higher estimate.

"After presenting the modelling results of the one-pool model for the Bh layer, the section was unfortunately ended with one sentence "These observations are not consistent with very low A to Bh rates, suggesting that a single Bh C pool is incorrect and that two pools of Bh C are required to adequately represent Bh C dynamics". I find that quite disappointing."

Response: The ending sentence cited by the referee was preceded by another sentence (lines 201-203), which, based on data from the literature, explained that the Bh output flow should be at least 2 mgC L-1, which is not consistent with the 1-pool model. We think we need to demonstrate to the reader that the one pool model was not suitable.

"The authors went on to model the formation of the whole profiles with soil carbon Bh being represented using a two-pool model. My question is then how the results in Section 3.1 were used in Section 3.2, ie how the fluxes and turnover rates of the two-pool model for the Bh soil layers are es-

timated? This is quite unclear to me. In presenting optimization problem, you need to state clearly: observations, optimizing model parameters, the model and optimization method including cost function. This has not been done adequately in this manuscript. Therefore I recommend major revisions."

Response: Section 3.1 was necessary to show, from a simplified system, the conditions for obtaining the stationary state and the minimum formation time. These notions seem indispensable to us to understand the sensitivity study given in § 3.2.2. As replied above, the choice of values for a certain number of rates and flows to constrain the model is explained on lines 245 to 251.

"Some additional comments.

The results are quite specific to the sites you studied. What are more broad implications? L56 and L58. In L56, you stated that data from 11 test areas were used to constrain a model of C fluxes, but you actually only presented results of four profiles (see L58). Inconsistent!""

Response: We agree with the referee (as well with referee #1) that this is unclear. As explained on lines 63-64, four podzol profiles were selected as representative both from the point of view of the profile characteristics and the 14C apparent age of the Bh organic matter stock. These profiles were selected from a database of 80 podzol profiles (from 11 test areas) which have been studied in detail and of which 11 have been dated. This database will be the subject of a further publication dedicated to the podzolic system genesis.

"Section 2.3 Would it be simpler to assume that soil carbon pools at different layers were at steady state before 1950 and solve the model analytically at 1950, then integrate the model forward after 1950 to match both the observed carbon pool and age using optimization?"

Response: As stated in section 3.1.2, there is no evidence that a steady state has been reached, especially in the case of the two youngest profiles. Considering the possible C influx values in the Bh, which are very small with regard to the C stock, no correction for the bomb carbon was needed. This is not true for the topsoil horizons, which show Fa values greater than 1: a correction for bomb carbon was therefore necessary to calculate the steady state conditions and the Fa values to be used for the carbon transferred for topsoil to the Bh pools.