

## ***Interactive comment on “Societal breakdown as an emergent property of large-scale behavioural models of land use change” by Calum Brown et al.***

**Gunnar Dressler (Referee)**

gunnar.dressler@ufz.de

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In this manuscript, the authors present an intriguing example of an agent-based model applied at the European scale that is able to produce realistic long-term projections of land-use change. The model – CRAFTY-EU – is an extension of the CRAFTY model that has been developed by the same author group. The main aim of the paper is therefore not to comprehensively present the model itself, but to rather to deliver a “proof-of-concept” that such an agent-based model a) can be applied at a large spatial scale and b) although it surely simplifies several relationships, e.g. regarding the representation of land-users, is well suited to explore long-term land-use change dynamics. It actually allows more flexibility in this regard, as it does not impose any constraints regarding optimality of the emerging land-use patterns and is therefore also able to simulate a –

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although undesirable – breakdown of the land system.

Overall, the manuscript is well-written with regards to wording and grammar, and as such is pleasant to read. Especially the Introduction and Discussion Sections are clearly structured and the argumentation, backed by a range of references, is sound. However, the description of the model itself, and parts of the results, require some improvement, as they are not always fully and clearly described - which is also my main critique of the manuscript.

Parts of the manuscript – especially in the Methods & Results Sections – are a bit hard to follow, as the manuscript makes ample references to the Appendix here (11 references to the Appendix in Section 2, 6 references to the Appendix, respectively results in the Appendix in Section 3). At some points, it is therefore hard to follow the manuscript without jumping back and forth, respectively without fully reading the Appendix, in addition to the main text.

Examples in the **Methods** section are:

- p. 4, l. 24-26: “Behavioural differences between AFTs (in terms of willingness to change land use or abandon land, and range of variations in capital sensitivities and ecosystem service production levels) were also introduced to assess the robustness of model outcomes to behavioural variations (see below and Appendix A)” how these behavioural variations between AFTs is implemented is not clearly evident from the manuscript, there’s only a very brief explanation on how behavioral parameters are varied at the end of Section 2.6 (p. 7, l. 11-14). As the authors stress that the representation of behavioral differences between AFTs is a crucial aspect of the model, some more information on this should be added to the main text.
- p. 5, l. 23-24: “with the agents producing the most (or the most highly valued) services gaining the highest benefit values and therefore best-placed to win the

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competition for cells (Appendix A)” from this, it is not clear how agents compete for cells – in the appendix

In the **Results** Sections, this applies particularly to the model evaluation in Section 3.1, where the simulations starting with no initial land use map and with the baseline map are described. If these results are considered important, then the corresponding figures should also be included in the main text – otherwise, they should only be addressed in the Appendix.

#### **Questions regarding the Results:**

- Is there any explanation for the fact that “the model spontaneously produced realistic land use configurations on the basis of land productivities, AFT parameterisations and demand levels” (p. 8, l. 8-10) – i.e. the strength of external forcings?
- What are the main reasons for the “widespread extensification and abandonment of land occurred and large shortfalls in service levels” (p. 8, l. 24) – is it because agents only decide about profit?
- I did not fully understand the “peak effect” (p. 10, l. 1) with regard to individual behavioral variations and how irrational agents are selected out – can you explain this effect in more detail?
- Figure 1: Where do the sharp transitions in the mean capital value plots at specific points in time come from?

In the **Discussion** Section, the authors address both aspects regarding the model design (and its limitations), as well as regarding the model results. Although the authors clearly state that the current model represents a “a first-step towards improved understanding of behavioural processes within large-scale land systems.” (p. 10, l. 30),

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some of the simplifications that the model assumes could be addressed in more detail. One of the main limitations of the model is its relatively coarse resolution of only 10 arcminutes, and with that the limitation to only being able to represent generic agent functional types, rather than individual land managers. As such, the model is not able to represent individual land user’s decisions or interactions. This does not diminish the results of the current study, but I would expect some statements here on a) how the focus on generic AFTs only vs. individual land managers may influence results and b) how a more detailed representation of individual land users may be achieved in future versions of the model.

#### **Questions regarding the Conclusions:**

- You state that “behavioural effects may be partially ‘self-correcting’, with more extreme behaviours being selected out by a competitive process.” (p. 13, l. 28-29) – could show this, e.g. by plotting the distribution of behavioral parameters at the beginning and end of the simulation?

#### **Technical corrections:**

- p. 2, l. 30: “If a new generation of behavioural models are to make. . . ” : are is
- p. 13, l. 18: “CRAFTY-EU”
- Figure 1: please label the subfigures, e.g. a, b, c, d
- Figure 2: I found it very unintuitive to read the plot with negative values indicating a surplus, and positive values indicating a shortfall – could you show supply / demand instead, which would make it much easier to read over-/undersupply? Also, this would align better with Figure B2 in the appendix.

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- Overall: in places, where references are cited with “e.g.” , these references are enclosed in double brackets, e.g. p. 2, l. 23-35

### **Appendix A & B:**

As the appendix includes a number of information that are quite essential to understand the manuscript, I would also suggest a number of minor corrections here:

1. Ordering of tables: You refer to Table A2 in the text only after referring to Tables A3 & A4 (p. 30, l. 19) – please correct the numbering.
2. Table A3: You refer to standard deviation values formatted in red, but table values are only black, this should be corrected. Also, the maximum service production levels are quite different from each other – what’s the unit/scale of each service?
3. Table A4 that contains all the details on the variation of the behavioral parameters is only explained in the table caption – there’s no explanation of the parameter variations in the text at all. This should definitely be added. Also, the Name column shows only abbreviations of the AFT names, which aren’t used anywhere else – please use the full names here, as it the table is otherwise difficult to read and the column width is not limiting factor.
4. p. 31, l. 5-6: use subscript or \_ for better readability for ms, us, rs, i.e. m\_s, u\_s, r\_s
5. Figure B2 a) + b): readability of the figure would be improved if you add a grid to the figure, so that numbers of agents could be more easily compared, b) add a 1.0 line to make it easier to see whether an over-/undersupply occurs.
6. Figure B4: at first, I was wondering whether this figure made sense here, as numbers of agents per AFT did stay constant over the whole simulation run (as

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per definition of the behavioral parameters in Table A4, where giving up / giving in thresholds are 0 in the baseline run) - only after careful examination I noticed some tiny changes towards the end of the simulation, e.g. for the Intensive Pastoral AFT - could you highlight these changes in the graph? Otherwise, I would omit this figure from the manuscript, as it does not provide a substantial benefit.

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