Manuscript nhess-2019-61 "AGRIDE-c, a conceptual model for the estimation of flood damage to crops: development and implementation" – Final response to referee comment 3

We would like to thank the referee for the work he did on our manuscript. We think that several of his comments can contribute to increase the manuscript robustness and, in general, to improve its quality and readability. Conversely, we partly or do not agree on some specific comments. In the following, we supply a point by point reply to referee comments.

RC1: My main concern is on the innovation provided by the article compared to precedent studies. From precedent studies, referred in the state of art section, it can be seen that many bricks presented in the article were already existing. For instance, a "conceptual model" has yet been formalized since the 80's in the USA, combining in a certain way "physical damage" and their "economic implications" in terms of loss of added value. Even if all detail are not given, many specifications are provided (see the user's manual of AGDAM, link provided below). Part of those details may be available from other studies. For instance, in our works (Agenais et al., 2013), we explicit completely how we link "physical damages" with "economic implications". Thus, I recommend that the article should be more specific on what it gets from previous studies, and what it added.

Answer: We agree with the referee when he states that "many bricks presented in the article were already existing". In fact, our effort was to organise "this fragmented knowledge" in a "generic" tool that could potentially improve the reliability and ease the procedure of flood damage assessments to crops in future studies. As stated at pg. 7 line 20-25 "AGRIDE-c has been developed by adopting an expert-based approach, encapsulating and systematising all the available knowledge on damage mechanisms triggered by inundation phenomena, as well as on their consequences in terms of income for the farmers. Information has been derived by a thorough investigation of the literature and by consultation with experts (i.e. agronomists and representatives of the authorities responsible for agricultural damage management and compensation). The result is a general, conceptual model, which identifies the different aspects to be modelled for the assessment of flood damage to crops, their (inter)connections as well as the variables at stake".

We would not define contents included in the AGDAM manual as "a conceptual model". AGDAM is a software and what is included in the manual is a diagram showing software inputs and outputs (pg. 4), and the theoretical background of its calculations. We do also not agree that AGDAM combines physical damage with economic implication. Loss functions in AGDAM are cost-based and assume the total loss of the revenue (pg. 16). The only physical aspect that is considered is the percentage of affected crops according to flood duration, on which base loss functions are weighted, but no reference to the reduction in the yield and/or its quality is made, according to different hazard and vulnerability variables. Given that the translation of physical damage into monetary terms can be challenging and not univocal, we strongly support the implementation of both a physical and an economic model. In fact, the distinction/link between physical and economic damage is present in several past works even if not explicitly (beyond Agenais et al. 2013, in Pivot et al. (2002), Morris and Hess (1988), Morris et al. (2014)); they are all quoted in the paper. We embraced this modelling approach in AGRIDE-c as we did in our previous work on flood damage to residential buildings, following a synthetic approach (Dottori et al., NHESS, 2016).

RC2: in their conclusion (page 20), the authors state that "According to authors' knowledge, AGRIDE-c represents the first attempt to organize all the available knowledge on flood damage to crops in a usable and consistent tool (i.e. the model integrates physical and economic approaches) that can be implemented to guide the flood damage assessment process, in different geographical and economic contexts." I do not master totally the American approach, but it has been developed to be used in different context (USA is a large country...) and has been developed as a tool used by USACE (ADGDAM). Another example is coming from Hess and Morris (1988), that also organized their work on grasslands in a framework comparable to that of AGRIDE-c and included it in a tool (SCADE). Last example, concerning our work, I can specify that in

chapter 3, the presentation of the methodological framework gives a clear explanation that damage are considered as loss of added value and how to link them to physical effects of flood.

Answer: we stress our opinion that AGDAM cannot be considered a conceptual model; moreover, its transferability to other (economic) contexts is limited by the fact that there are not specific guidelines on how to create or adapt loss functions. The work by Hess and Morris (1988) is instead very specific on grassland and is included on a tool for the evaluation of land drainage strategies. We agree that in chapter 3 of Agenais et al., 2013 damage is defined as loss of added value, as other authors did (e.g. Morris and Brewin, 2014; Pivot et al. 2002; Morris and Hess,1988), and that a brief discussion is included on how to link it to physical effects of flood; still, this cannot be considered a conceptual model in our point of view.

RC3 In chapter 4, we give some precision on modelling of damage to sub-component of farms (which include crops, vegetal material, soil, equipment). For crops, we explain how to take into account farmers' strategies (continuation, abandoning, reseeding for instance), depending on when the flood occurs compared to the crop calendar.

Answer: Our model includes knowledge coming from Agenais et al. 2013, as it is stated in the paper. Although, we did not specify in the manuscript which works have been already taken into considerations farmers' strategies (like Agenais et al., 2013 but also Pivot, et. al 2002); we will add these specific references in the paper. Still, we want to stress that alleviation strategies are not explicitly taken into account in existing damage models, neither in the functions reported in chapter 5 of Agenais et al., 2013. In the implementation of AGRIDE-c in the Po Valley, we make explicit the effect of strategies on flood damage as well as when the different strategies can be implemented or not.

RC4 In chapter 5 we explain that all this has been implemented in a tool called floodam (now floodam-agri), which aim is to help to adapt damage modelling to different context, including prices, crops calendars, and even also the question of the typology of culture to best fit with typology of GIS.

Answer: We cannot appreciate the potentialities of floodam as we could not find it online. According to our understating, chapter 5 of Agenais et al., 2013 is about the adaptation of national French functions to local French contexts.

RC5 I want also to point that the authors present results for 4 types of crops, whereas both the American and the French approaches deal with many more types (including permanent crops)

Answer: After reading the referees' comments, we realised that the "scope of use" of our model was not well specified in the original version of the paper, which could lead to incorrect interpretations of our work. In fact, the conceptual model has been designed to supply an estimation of flood damage:

- to annual crops (i.e. not including perennial plants)
- by considering one single culture (i.e. by not considering replacement of one culture with another one)
- by limiting the time frame of the analysis to one "productive year" (i.e. not considering long term damages, e.g. loss of soil productivity in the following years);
- for infrequent flooding (i.e. effect of two, or more, consecutive floods is not considered)

Nonetheless, as specified at page 9 line 11-19, AGRIDE-c do not consider damage to other components/elements of the farm that may induce additional damage to crops, as, for instance, damage to machineries and equipment (e.g. the irrigation plant) that may prevent cultivation for a while. Only damage to soil is considered from the evidence that, during a flood, damage to soil and plants occurs always at the same time, differently from damage to the other components which can occur or not, independently from the damage to plants; as a consequence, damage to soil and plants is modelled together, while damage to the other components could be modelled as separated factors, not included in the conceptual model. We

thank the referees to highlight this limit of the original manuscript that we will address by specifying all these aspects in the new version of the paper.
Regarding the implementation in the Po Valley, its objective was not to create a comprehensive model for the estimation of flood damage to crops in the area, rather it was to exemplify how the conceptual model can be implemented in a specific context.

RC6 I feel uncomfortable with the articulation of the two parts of the article, "conceptual model" and "implementation". From figure 2, it is expected that implementation of AGRIDE-c shall take into account all the phenomena described. But when coming to the implementation, it appears that many of those phenomena are not taken into account (loss of fertility due to sedimentation or loss of quality for instance). This shall be exposed in a clearer way not to induce false expectations on the scope of the study.

Answer: We thank the referee to highlight this lack of clarity in the paper. The idea of dividing the conceptual model from its implementation was also conceived with the objective of highlighting the gap between the available knowledge on damage mechanisms and their drivers/explicative variables, and their present modelling capacities. In fact, in order to be generally valid in any specific context, the conceptual model must include all the phenomena which affect the final loss figure. Then, its implementation must take into account not only the specific features of the investigated context (and then the relevant phenomena) but also modelling and data availability. In the Po Valley, data and models are required to properly take into account damage to soil and loss of quality; in their absence we made simplified assumptions, highlighting also research needs. A comment will be added in the revised version of the manuscript, explaining this point, along with a table summarising the main elements and sources of revenue and cost estimation processes, considered in the application of the model in the Po Valley

RC7 Third, I think that the conceptual model is incomplete, at least for perennial crops (such as vineyard, but also grassland). First, it does not seem clear that the authors get that for some culture it may be useful to separate crops (fruits) and vegetal material (trees). This is not restricted to vineyard and orchards, but may also be important for asparagus, and even certain type of grasslands. If vegetal material is affected by flood, there may be at least two types of effect that last more than one year. For a given plot, if some plants are to be "destroyed" by a flood, it is expected that yield reduction and thus of products, but also variations of charges occur during the following years. This type of effects are for instance implicitly taken into account in Agenais et al.

Answer: see answer to RC5

RC8: Forth, I think there are not sufficient description of the role of the direct consultation of experts for the current work. It is only said (page 7) that some experts were consulted (agronomists and representatives of the authorities responsible for agricultural damage management and compensation), that this expertise were used to produce the production costs for normal activity (page 11, figure 3), the 3 possible strategies after a flood occur (pages 12-13) and an opinion on the suitability of yield reduction model coming from our works for maize grain (page 12). As many of the implementation seem to rely on the consultation of experts, I think a much more detailed description of this consultation shall be provided: how many experts has been consulted? What were their precise expertise, especially concerning flood impacts? What were their opinions on the data they provided? Have they been consulted on the results? What were their opinion on those results? What were their opinion on the transferability of those results on other context? This would strengthen this part of the work, that is almost invisible at the moment

Answer: We really thank the referee to highlight this lack in the original version of the manuscript. A new sub-section will be added to the revised version of the paper explaining the whole process of experts' involvement.

Experts were involved with two main objectives. The first one is to support the definition, and validate the quality, of the conceptual model. The second one is to give suggestions/information on the implementation of the model in the Po Valley, above all regarding expected physical damage and costs.
With respect to the first objective, an iterative process was followed. First, a semi-structured interview was conducted, by asking experts about the main damage mechanisms/phenomena in case of flood, possible interconnections among them, important explicative variables. In this phase, results from the literature review were proposed to experts for their judgment. In the following step, experts were asked to evaluate a draft version of the conceptual model we draw according to the literature review and results from interviews. Then, there was an iterative revision process of improved versions of the model until an agreement on its final structure was reached.
With respect to the second objective, several individual meetings were organised with the aim of asking experts about context-specific information on: crops calendars, yields and prices, type, timing and costs of cultivation practices. In this phase, the transferability of the model by Agenais et al. 2013 was also discussed. Three kinds of experts were involved. One representative of the Regional Authority responsible for agricultural damage management and compensation, with more than 20 years of expertise in the management and compensation of flood damage to farms in the Lombardy Region. Two agronomists of the local association of farmers (Coldiretti Lodi), with specific knowledge on the investigated context and with direct experience in managing floods in the last 20 years. During the work, the two agronomists asked for data/information also to individual local farmers that were flooded in the past years, including also their viewpoint in the process. Finally, an academic economist, with specific expertise in agriculture, has been involved in validating the final model.

RC9: I would therefore recommend to be less ambitious in terms of interest of the article and to reorient it on the question of what has been necessary to adapt from previous works to a specific context. I invite the authors to be more precise on what they really include in their model, not on what they would have liked to include, because this makes things unclear for the reader. Another perspective would be to make a clear list of what that have not included. I also invite the authors to be more specific on how they have really implement their "local" model, by precising all the steps about consultations of experts. This seems important, especially for a expert-based approach. For those reasons I recommend a major revision.

Answer: we thank the referee for the comment as we think that, by addressing it, we could better specify (in the new version of the paper) which is the added value of the work (i.e. the conceptual model of available knowledge), which are its limits (i.e. the focus on the only crops component, the time frame of the analysis to one “productive year”, the existing gaps between knowledge and modelling) and the implemented methodologies, above all with respect to expert ‘s consultation (see also answer to RC5, RC6 and RC7)

RC10 Given the scope of the article, I am not totally convinced that the state of the art analysis should be done in such a detailed way. This is more convenient for a kind of review articles. If this section should stay in such a detail version, some imprecision needs to be corrected. For instance: - P3-L16. "No model in Table 2 considers instead the behavior of farmers after the occurrence of the flood (e.g. the decision of abandoning the production or to continue with increasing production costs)..." Agenais et al. does (see chapter 4) - P3-L22. The distinction between "physically based" and "cost based". is not clear. As formulated "cost based" models appears as simpler models where yield reduction is always total, which is not the case for "physical based" models. But for "physical based" models consequences in terms of production costs are considered. - Table 2. I am not convinced by the way some works are classified. For instance AGDAM cannot be said as "cost based", as it also consider some physical aspects on flood for yield reduction. I have not the time to check for all the works. Thus, I am not confident by what is presented in table 2. - P5-Table2 Agenais et al. present damage functions for 14 crops type, based on a detailed model of 50 crops types.

Answer: We think that the detail of the state of art is required in order to highlight research needs and then the objective of our work. We verified imprecisions suggested by the referee, individual comments are supplied:

- The model by Agenais et al. (i.e. functions in chapter 5) does not explicitly take into account alleviation strategies in damage estimation.
- According to us the distinction between physically-based and cost-based model is clear, laying in considering or not the estimation of physical damage. Accordingly, the AGDAM model must be correctly classified as “cost-based”
- Table 2 refer only to (annual crops); this will be specified in the new version of the paper

RC11 I haven’t seen the demonstration of what is promised in the abstract about "comprehensive cost-benefit analyses of risk mitigation actions". What is said in the discussion (page 17) is just that AGRIDE-c provide a way to estimate direct damage to crops, but in fact, it is only one contributions among others. I also feel that the authors did not get that for CBA purpose, it should be considered a "collective perspective", without considering possible transfers. This is not clear (see remarks on the "spreadsheet" tools). I think that should be reformulated.

Answer: The objective of the paper is to present a model and to discuss its potentialities, not demonstrating its usability**.** In fact, another manuscript is under preparation on the use of AGRIDE-c for the CBA of flood risk mitigation strategies in Lodi. We agree with the referee that including the potentialities of the work for CBA in the abstract can lead to misunderstanding of papers’ results and findings. In the new version of the paper, we’ll remove reference to CBA in the abstract, limiting its discussion in the introduction/discussion sections. The CBA of flood risk mitigation strategies would require a comprehensive estimation of benefits linked to the different strategies, i.e. of the avoided loss to all exposed sectors and at different temporal scales (i.e. direct and indirect/long term damages). Present damage modelling capacity prevents comprehensive flood damage assessments, which usually include only direct damage to people and some of the exposed assets (typically residential buildings). In such a context, by allowing the estimation of the expected loss to crops in a specific flood scenario, AGRIDE-c may support more comprehensive CBAs of public risk mitigation strategies. Of course, to meet such an objective, the tool must be critically used, e.g. by considering possible transfers of losses/gains between farmers in an economic perspective, according to the temporal and spatial scales of the analysis. With respect to other available tools, we think that AGRIDE-c, by conceptualising the whole damage estimation process, may lead to more reliable and transparent estimations. More comments will be added on this point in the new version of the paper.

RC12 I haven’t seen neither the demonstration that AGRIDE-c is a "a powerful tool to orient farmers’ behaviour towards more resilient damage alleviation practices". I do not know in detail what is the context of management of flood and agriculture in Italy. It is not presented in the article. But, this context may have some implications on what strategy would be follow by farmers, independently of what AGRIDE-c shall demonstrate. For instance, in France, if a farmer expect to receive some compensations from "Calamités Agricoles" (a State compensation scheme) or from "Assurances Récoltes" (Private insurance), he shall have to follow some recommendations concerning what he can follow as a strategy. If he does not, he may not receive any compensation. Also, it is not clear that the consequences presented are really those supported by the farmers. If there exists some compensations in Italia, this shall be included to provide a true "financial perspective" (point of view of the farmers).

Answer: We stress that the objective of the paper is to present a model and to discuss its potentialities, not demonstrating its usability. By supplying the expected damage for different types of crops and alleviation strategies (according to the expected yield reduction for different flood intensities and period of occurrence), AGRIDE-c may help individual farmers exposed to flood risk in preventing losses by supporting: the choice of the most appropriate crops to be cultivated, the choice of the best alleviation strategy to be followed once flooded, the evaluation of the opportunity to ask for a flood insurance scheme and the definition of the premium. This is a specific finding of the paper that will be better specified/commented in the new version of the manuscript.
Insurance in Italy is not compulsory and is not linked to specific recommendations/strategies to be followed in case of flood.

RC13 I am not convinced by the starting line 19 on page 19, concerning the necessity of "sediment and contaminant transport models" as the authors said before that they did not find available models to estimate the effects of sediment and contamination. This appears not coherent.

Answer: The effect of sediments and contaminants transported by flooding water on the yield is well documented in the literature (see Agenais et al., 2013; AGDAM, 1985, The Multi Coloured Manual, 2013, Hussain, 1996), as stressed in the paper. Accordingly, we included this effect in our conceptual model, although (of course) the importance of the phenomenon varies from place to place, being negligible in some areas like the one investigated in the manuscript. However, hazard assessments (i.e. flood hazard maps) usually do not supply estimates of sediments and contaminants load, even in such contexts when the phenomenon plays a crucial role, avoiding the estimation of its effect on flood damage to crops. This is a limit of present tools that we want to highlight in the paper.

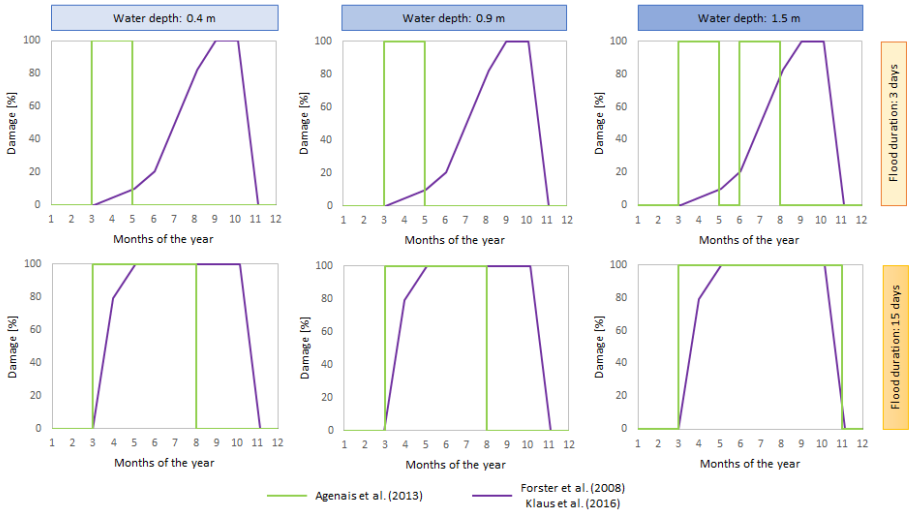
RC14 I think that some of the figures presenting the results shall be changed. In fact, in the title, the authors say that they analyze "damage to crops" but none of the figures clearly present a "net" damage. The reader has to make a mental effort to understand what are the damage from those figures (5 and 7): - make a difference between last point of the curve of scenario 0 and last points of three other curves for the production costs part - make a difference between a value given by a bar for scenario 0 and 3 other values for the "turnover" part - and then make a difference between the difference of turnover and the difference of production costs... Well, this should be done for the reader! This could allow to have a representation of the flood damage depending on the season of occurrence (as a function).

Answer: We thank the referee for the comment. We will improve Figures 5 and 7, explicating the value of the absolute damage. However, we want to stress that Figures 5 and 7 do not represent the damage model but they are only functional to the description of the process leading to it. The final output of the damage model is displayed in Figure 6. From this, the calculation of the damage is immediate, by multiplying the relative damage by the GP of the specific farm.

RC15 Concerning figure 1, the authors announce that relative damage is supplied by our works (Agenais et al. 2013), but this is not the case. Our results are expressed in absolute damage (see page 51 of our report). Thus, the figure 1 is an interpretation of what we have done, but this interpretation is not explained. Moreover, this interpretation is necessary incorrect, as our results are presented on a seasonal time step (3 months) whereas the time scale in the figure 1 is one month. Moreover, as seen in our reports, relative damage are maximum only in summer, for long duration, and height over 130 cm, thus it is impossible to have relative damage of 100 % for any other case. I have not verified what is announced about the presentation of the results of Forster et al., but it shall be verified.

Answer: The referee is right as we did not use absolute damage functions at pg. 51 of Agenais et al., 2013 but relative “physical damage functions” supplied in the annex (pg. 200-202), and reported in Figure 4 of the paper. In fact, the objective was to highlight differences between physically-based and cost-based approaches. On the other hand, we choose the two models to allow a direct comparison in terms of relative damage, avoiding possible errors in transferring relative damage to absolute damage and vice versa. The physical damage functions in Agenais et al., 2013 are expressed for vegetative stages of the plant (not for three months) that we have linked to the months of the year, according to the Italian climate and cultural calendars (Initial phase: April-May, Growing phase: June, Flowering phase: July-August, Maturation phase: September-October, see Table 3). According to the functions, for a 3 days flood, a 100% physical damage occurs in the Initial phase (for any water depth value) and in the flowering phase for water depth greater than 130 cm. This is reflected in the first row of Figure 1 with a 100% peak of damage in April and July, which are representative, respectively, of the initial and flowering phases. For a 15 days flood, a 100% physical damage occur in the Initial, growing and flowering phase (for any water depth value) and also in the maturation phase, for water depth greater than 130 cm. This is reflected in the second row of Figure 1 with a 100% damage from April to July (for water depth equal to 0.4 e 0.9 m) and from April to October (for water

depth equal to 1.5 m), which are representative, respectively, of the initial, growing and flowering phases, and of the whole cultural cycle. To be more clear, we'll replace Figure 1 with the following where 100% damage is reported for the whole duration of the different vegetative stages.



Although an explanation was required to clear referee doubts, we do not think that the detailed explanation of how we implemented the model must be included in the paper, as it is out of the scope of the meaning of Figure 1. Foster et al. was implemented at the best of our understanding.

RC16 I had a look at the "spreadsheet" tool, and I share some comments on it, as I understood that all the application where made thanks to it: - There is not a manual to help people use the tool, it would be nice (necessary?). - Technically this tool is not designed to produce damage function but to estimate damage for specific value of hazard. This is not very practical for a user interested in a "damage function".

Answer: The tool was designed to support analysts in the calculation of damage for a specific hazard and vulnerability context, by implementing the damage functions we derived for the Po Valley, and which are reported in Figure 6 and in the Appendix. Such functions are included in the spreadsheet but can be also partly modified (by changing revenue and costs parameters). A user-manual will be added in the new-version of the paper to increase its usability.

RC17 I have some questions on how the value coming from "Agenais" were filled, as I cannot remember that the authors asked for those values, which are not detailed in our report. - For instance, in some cases (maize, germination) yield reduction may occur for flood with a duration of 0 day, and in other cases (maize, flowering) there is no yield reduction for such flood with duration of 0 day. This may be a misunderstanding of what we developed. This leads to possible damage for a flood of 0 day and 0 cm for maize, which has no sense in our works. Such a flood is typically a flood with no consequences.

Answer: The referee is right when he says that the report by Agenais et al. does not detail model's values, which is a limit for its transferability. He is also right in saying that we did not ask for such values. In fact, given the simplicity of the functions, we made some assumptions that were supported by local experts' opinions. In particular, we used the relative physical damage functions reported in the Agenais report at pg. 200-202 (and also reported in our Figure 4) by assuming a linear increase of damage from 0 to 100% when required (see pg. 12 line 15)
According to such functions, in the initial phase, any flood will lead to a 100% damage (see pg. 200 of the Agenais et al. report), and it is in this sense that figure 4 must be read, with respect to the red square related to the initial phase. On the contrary, in the flowering phase, a flood with a duration of 0 days will not lead to damage, and this is correctly reported in Figure 4 as in pg. 201 of the Agenais et al. report.

While tuning the model for the Po valley we started from the model of Agenais et al., 2013 we kept the same structure, we approximated trends with very simple functions (straight lines) while defining limits of such lines by a comparison of the original model and opinions of local experts. Due to the strong imprinting of Agenais et al. 2013 on our model, we considered as honest to declare the latter as an adaptation of the former. However, if the reviewer (and the editor) consider our model to be too loosely connected with the original one, we have no problem to indicate our model as freely inspired to that of Agenais et al., 2013 thus avoiding claiming any responsibility of the original one on our results.

RC18 Another thing is that it is not specified that all data used from Agenais et al. are only specified for negligible flow velocity. This is particularly important for maize, wheat, and barley, that are very sensitive to this parameter. This may induce a bad use of the tool.

Answer: The referee is right. In fact, this is one of the reason for which we chose the model by Agenais et al., 2013, for the Po Valley, where riverine long-lasting floods are the typical flooding events. We will better specify this in the new version of the manuscript.

RC19 One of the aspects that may change from site to site is the list of actions inside the crop management sequences. There are many reasons for which those actions may differ, not only in value but also in nature. This aspect is not taken into account, and doesn't seem to be easily taken into account with the provided tool.

Answer: The referee is right. By referring to the model we implemented for the Po Valley, the spreadsheet allows changing revenue and costs parameters, but not the type of cultivation practices. Still, as an open tool it can be easily modified to take into consideration of other context-specific cultivation practices.

RC20 In the tool, "EU contributions for agriculture" are included. This is more oriented for a financial analysis (point of view of a specific farmer, including transfers) than for a Cost-Benefit Analysis (collective point of view, excluding transfers). I think a clear precision on the usage of damage produced should be added. If a financial perspective is to be promoted, all insurance or compensations mechanisms should be also included to give a better view of net consequences for the farmer.

Answer: The tool refers to the model implemented for the Po Valley where insurance is not compulsory. However, in order to use the tool in a financial perspective for a specific farm with an insurance, the tool can be easily adapted to include also this form of revenue/cost. Otherwise, if required, the tool can also be used for CBA of public mitigation strategies, by resetting cost parameters that may be included in transfers.