



Supplement of

Process-based flood damage modelling relying on expert knowledge: a methodological contribution applied to the agricultural sector

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Process-based flood damage modelling relying on expert knowledge: a methodological contribution applied to agricultural sector. Supplement material

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1 Supplement 1 – Interview guides

Content of the supplement

This supplement contains the interview guides that were used with the experts consulted for the arboriculture. It consists of two parts:

- 5 – a first part on the impacts on crops and plant material,
- a second part on the recovery, replanting and variation in production costs.

These interview guides were developed for the five crop families treated in the development of the national damage functions, namely grasslands, cereals, grapevines, arboriculture and vegetable crops.

Arboriculture expert

To be prepared in advance:

- Crop production cycles (and alignment with the locally established calendar).
- Existing damage curves for these crops.

Introduction

Under the impetus of the Ministry in charge of sustainable development (MEDDTL), a reflection is being conducted on the development of a methodology for the monetary evaluation of flood-related damages in order to assess the profitability of flood management measures. INRAE is in charge of the agricultural issues.

For the assessment of damage to agricultural activities, we distinguished between damage to farm buildings and damage to plots. Within the damage to plots, we distinguished between damage to crops, damage to plant material, damage to soil and damage to equipment. This interview focuses on crop and plant material damage.

Crop damage corresponds to the loss of income for the farmer, mainly due to variations in yield and costs. Damage to plant material corresponds to the loss of income and expenses incurred by the farmer following the destruction of perennial plant material. The objectives of this interview are to :

- Formalise your knowledge of the impacts of flooding on crops,
- Estimate, quantitatively as much as possible, the variations in yield and the losses of plant material according to the characteristics of the hazard.

1 Flooding experiences

- Have you experienced any flooding events since you started working on arboriculture? Are you aware of any experiments whose results can be applied to flooding or related phenomena (e.g. drainage)?
- Have you been involved in managing the consequences of these floods (advice, damage assessment) / experiments?
- What type of flooding was involved (excess rainfall, rising groundwater, overflow, runoff) ?
- Can you describe the course of the floods and their overall consequences?
 - In which period(s) did they take place?
 - What were their characteristics (current speed, duration of submersion, etc.)?
 - What crops were affected? What was the nature and extent of the consequences (no. of ha, yield losses, uprooting of trees, total damage, etc.)?
- Do you have any contacts of people who followed the event, specialists in other cultures?

2 Physiological cycles

According to the work on flood damage to crops, losses of plant material depend on whether the flood occurs during the growing season or not, and the yield losses to be expected depend strongly on the phase of the production cycle when the flood occurs.

Here is the detailed production cycle for apples (or pome fruits in general).

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
dormancy												
flowering												
flower induction												
fruit growth												
maturity												

- Do you have any comments on the timing of this cycle in relation to possible local specificities?
- From what you have told me, have you been able to observe the effects of a flood for such and such a phase(s) of the cycle?
- Can you provide me with information on the impact of flooding on the yield for other phases of the cycle?
- Is it possible to simplify this cycle by distinguishing the main phases during which, in your opinion, the sensitivity of the crop to flooding is relatively homogeneous (presence of the crop, sensitivity of the roots, etc.)?

3 Loss of plant material and hazard characteristics

Damage to plant material is initially understood as the loss of trees as a result of a flood, the characteristics of which are given. Damage is understood as the monetary translation of these losses. Trees can be lost through uprooting or death (root asphyxia, disease).

3.1 Fruit type Apple

3.1.1 Vegetation

According to the literature, the loss of plant material depends mainly on the current speed and the duration of the flooding. [Excluding marine flooding].

- Does this correspond to what you have observed? Are there any other parameters to consider (height, material load)?

[In the following address the speed/time parameters, or those mentioned here].

- For each parameter :
 - Is there a value below which no tree is lost?
 - Is there a value beyond which all trees are almost certainly lost?
 - Are there other intermediate values for which you can provide the associated plant material losses, especially in relation to the events you have monitored? Is this a point damage value or a range of values?

- With regard to the uprooted trees, is it possible to put them back in the ground as soon as the flood waters subside? If so, will there be any consequences?
- Can the losses of plant material envisaged here be predicted from the time of flooding? If not, when can the final losses be predicted relatively reliably (from what stage or how long after the flood)?

3.1.2 Dormancy

- Are the thresholds identified for the vegetation stage different during the dormancy stage? Is the vulnerability of trees in the dormant period lower (longer sustained flooding)?

If yes, repeat the questions as for the vegetative period.

3.1.3 Renewal strategy for plant material

- What are the replanting strategies of a farmer who has lost part of his orchard? Replanting of uprooted trees / Ripping out and replanting the whole orchard / Nothing
 - Does the strategy adopted depend on the percentage of trees lost? What are the thresholds?
 - Does it depend on the age of the orchard?
- How is the renewal of an orchard usually managed? Progressively on the farm and over time / the whole orchard at once after X years?

4 Yield losses and hazard characteristics

Damage to crops is understood in the first instance as the reduction in yield following a flood, the characteristics of which are given, on living trees (or those not uprooted). Damage is understood as the monetary translation of these losses. In order to estimate the yield losses, it is assumed that the usual technical itinerary is continued after the flood and that the necessary restoration actions are carried out.

4.1 Fruit type Apple

[Stages to be considered if no grouping proposed: flowering, floral induction, fruit growth, maturity, vegetative rest].

4.1.1 Stage 1

According to the literature, losses at this stage depend mainly on the water level and the duration of the flooding.

- Does this correspond to what you have observed? Are there other parameters to take into account (speed, material load)?

[In the following, address the parameters height/duration or those mentioned here].

- For each parameter :
 - Is there a value below which losses are negligible ("normal harvest")?
 - Is there a value beyond which losses are almost certainly 100% ("all loss crop")?
 - Are there other intermediate values for which you can provide the associated loss of performance, especially in relation to the events you have monitored? Is this a one-off damage value or a range of values?
- How do these parameters combine in terms of their impact on yield losses?

- Are the thresholds provided for the duration of flooding valid for low, medium or high water?
- *Confirm that low/medium/high height correspond to the thresholds defined above.*
- For heights not addressed, what are the corresponding duration thresholds?
- In general, can the yield losses formulated here be predicted from the time of flooding? If not, when can the yield losses that will be suffered be predicted with relative reliability (from what stage or how long after the flood)?
- If it is not possible to identify high and low threshold values for each of the parameters: What have you observed during the floods you have monitored?

4.1.2 Stage 2, etc.

For this stage, according to the literature, the damage also depends on the height of the water and the duration of the flooding mainly.

- Are the thresholds identified for each of the parameters at the previous stage different at this stage?

If yes, repeat the questions as in stage 1.

5 Other consequences

- *Following a flood, can there be consequences on the quality of the production that affect the expected selling price? (For production that can be sold and that is not lost).*
 - *If so, at what stage of the crop? According to which hazard parameters?*
- Following a flood, do you have any idea of the consequences it may have on the farmer's operating expenses?
 - *If yes, questionnaire Production costs.*

Expert Arboriculture

To be prepared in advance:

- Crop production cycles (and alignment with the locally established calendar).
- Main operating expense items and their distribution over time.

Introduction

Under the impetus of the Ministry in charge of sustainable development (MEDDTL), a reflection is being conducted on the development of a methodology for the monetary evaluation of flood-related damages in order to assess the profitability of flood management measures. INRAE is in charge of the agricultural issues.

For the assessment of damage to agricultural activities, we distinguished between damage to farm buildings and damage to plots. Within the damage to plots, we distinguished between damage to crops, damage to plant material, damage to soil and damage to equipment. This interview focuses on crop damage specifically.

Crop damage is the loss of income for the farmer, mainly related to variations in yield and expenses. The objective of this interview is to formalize your knowledge about the impacts of flooding on crops. To do this, the interview will follow the questions raised after a flood:

- what are the necessary restoration operations following a flood, according to its characteristics;
- how do operating expenses vary with yield and plant material losses caused by a flood ;
- what are the possible replanting strategies.

1 Flooding experiences

- Have you experienced any flooding events since you started working on field crops? Are you aware of any experiments whose results can be applied to flooding?
- Did you participate in the management of the consequences of these floods (advice, damage assessment)?
- What type of flooding was involved (excess rainfall, rising water table, overflow, runoff)
- Can you describe the course of the floods and their overall consequences?
 - In which period(s) did they take place?
 - What were their characteristics (current speed, duration of submersion, etc.)?
 - What crops were affected? What was the nature and extent of the consequences (no. of ha, yield losses, uprooting of trees, total damage, etc.)?
- Do you have any contacts of people who followed the event, specialists in other cultures?

Following a flood, farmers' behavior can vary enormously depending on many parameters such as the cash flow of the farm, the equipment available to the farmer, etc. In the rest of the questionnaire, we will reason as much as possible by considering an average behavior which can correspond to the recommendations formulated after the event by the Chambers of Agriculture and the Technical Institutes.

2 Soil restoration

Following a flood, the soil of the plots may suffer structural damage (deposition of debris, compaction, destructuring, erosion) or in its composition (loss of organic matter, salinization). Carrying out restoration operations entails additional expenses that may include: labor, fuel, rental of appropriate equipment, purchase of soil improvers, sowing of a "useful" crop.

The damage caused to the soil by a flood depends on the characteristics of the hazard.

The main types of damage considered are: deposition of debris, soil compaction, soil overturning, erosion, degradation of organic matter, salinization and sodicity.

- Does this list seem complete to you?

2.1 Type 1 damage

2.1.1 Damage and hazard characteristics

- Does the damage depend on:
 - the height of the flood water? At what threshold does it appear?
 - the speed of the current? At what threshold does it appear?
 - the duration of the flooding? At what threshold does it appear?
- Can we define several levels of damage (low / medium / high for example)?
 - What height thresholds do they correspond to?
 - What speed thresholds do they correspond to?
 - What duration thresholds do they correspond to?

2.1.2 Rehabilitation operations

- Level 1/2/3/etc. of damage:
 - What are the operations to be implemented to repair?
 - What do they require in terms of :
 - Equipment? Is it available on the farm in general?
 - Manpower?
 - Quantity of amendment?
 - Seeds?
 - Other?
 - Which of these operations are absolutely necessary for the continuation of the technical route?
 - When should they be done (at a given time, after complete drying, etc.)?
 - What is the compatibility of this damage with the crop:
 - Is the occurrence of this damage necessarily associated with the loss of plant material (e.g., if there was erosion the trees were washed away with the soil)?

- Can the restoration related to this damage be carried out without intervening on the plant material?
- Can this level of damage or the complexity of related operations cause the orchard to be abandoned?

3 Variations of Intermediate Consumptions

The variations in expenses considered here do not include the work of restoring the soil and/or equipment following the damage caused by the flood or the investment in replanting trees.

It is assumed that for a homogeneously damaged area (scattered losses of plant material), the load variations depend on the yield loss due to flooding, as follows:

- for treatments, tillage, irrigation, pruning: the surface to be exploited remains the same and the farmer therefore incurs the same operational expenses as usual until the following season;
- for harvesting: the costs incurred will depend on the yield obtained, although even in the event of a loss of the entire production, the fruit must be harvested.

3.1 Fruit type 1

3.1.1 Expenses for item 1 (tillage, pruning, treatments, irrigation, harvesting)

- Following a flood, can interventions related to this item be modified if yield decreases are expected or are they continued as normal in all situations (zero yield for the season)?
- If they can be modified, how can the technical itinerary vary:
 - unchanged;
 - stopped;
 - modified downward based on damage ;
 - modified by increasing the number of interventions?
- For each possible change, for what range of performance losses can this occur?
- For lost trees:
 - if the loss is certain (uprooting), how can the savings in operational expenses generated (especially for pruning and harvesting) be evaluated?
 - if there is uncertainty about the death of some trees, are these interventions continued or are additional interventions performed to save it?

4 Replanting strategy for plant material

4.1 Fruit type 1

- What are the replanting strategies of a farmer who has lost part of his orchard? Replanting of uprooted trees / Ripping out and replanting of the whole orchard / Nothing?

- o Does the strategy adopted depend on the percentage of trees lost? What are the thresholds?
- o Does it depend on the age of the orchard?
- If replanting, does it have to be done at a specific date or is it done as soon as possible?
- Over how many years is there a loss of yield due to the delay in entry into production? Does the yield increase gradually?
- How is the renewal of an orchard usually managed? Progressively on the farm and in time / the whole orchard at once after X years?

2 Supplement 2 – French national flood damage functions for agriculture developed using **floodam.agri**

Content of the supplement

20 This supplement presents in graphical form the national damage functions produced using **floodam.agri** for use at the national level in Cost-Benefit Analyses carried out for the evaluation of flood management projects.

It contains the damage functions for 14 categories corresponding to the Graphical Plot Register (GPR) which is the national database allowing the location of agricultural surfaces in France. How the hazard parameters were aggregated to produce these graphical outputs is specified in Appendix B.

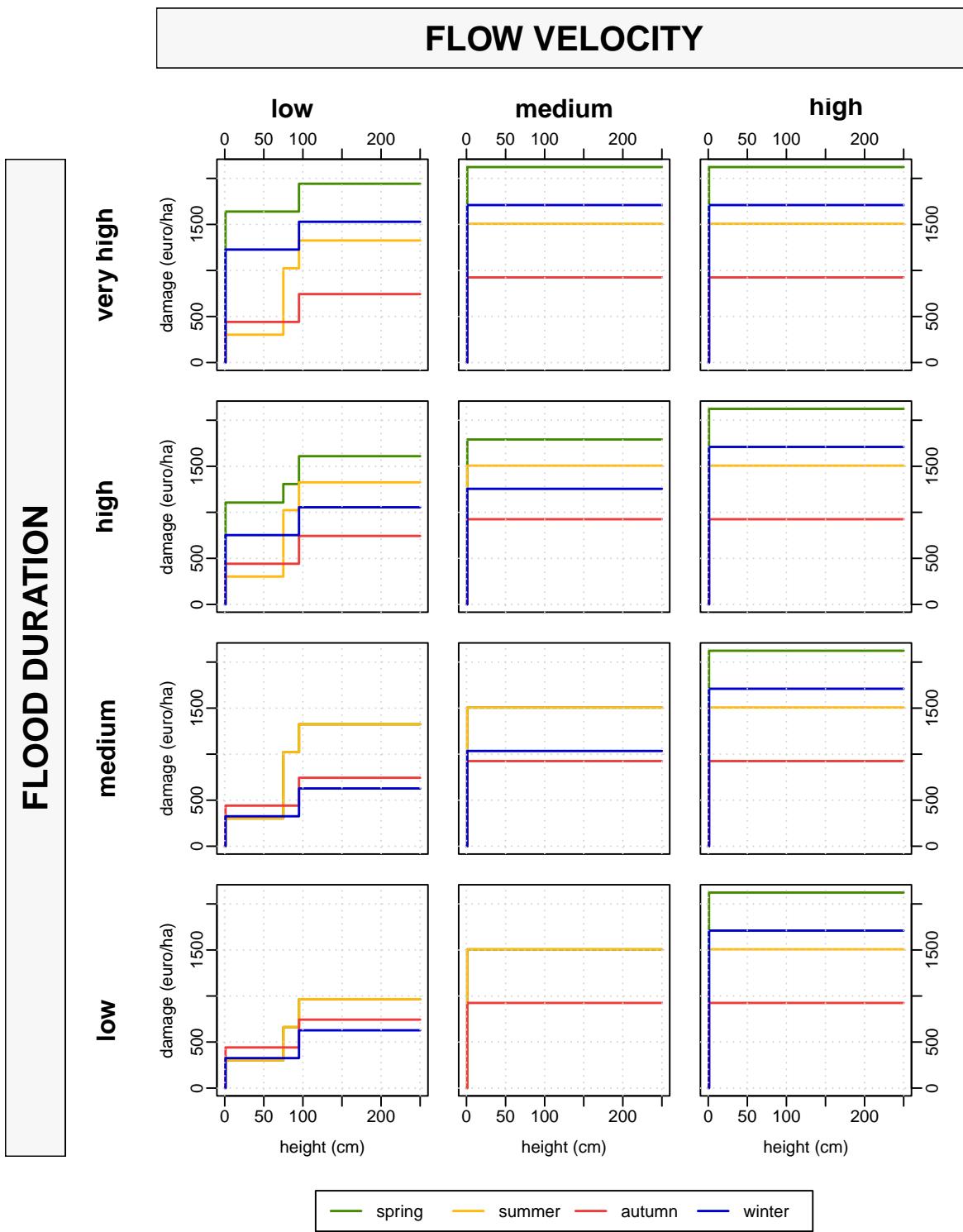


Figure 1. National flood damage function developed using for the category "soft wheat"

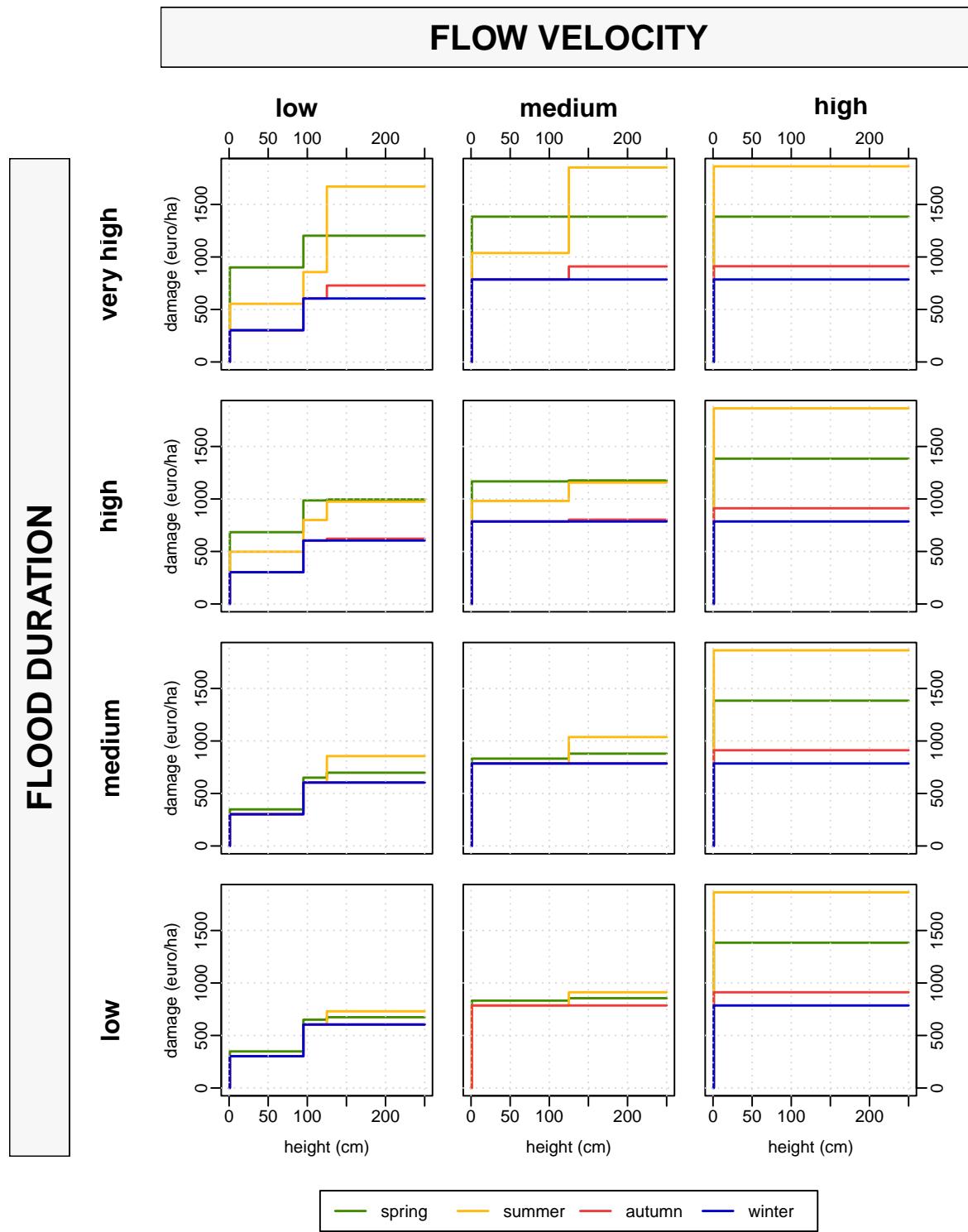


Figure 2. National flood damage function developed using for the category "Grain and silage corn"

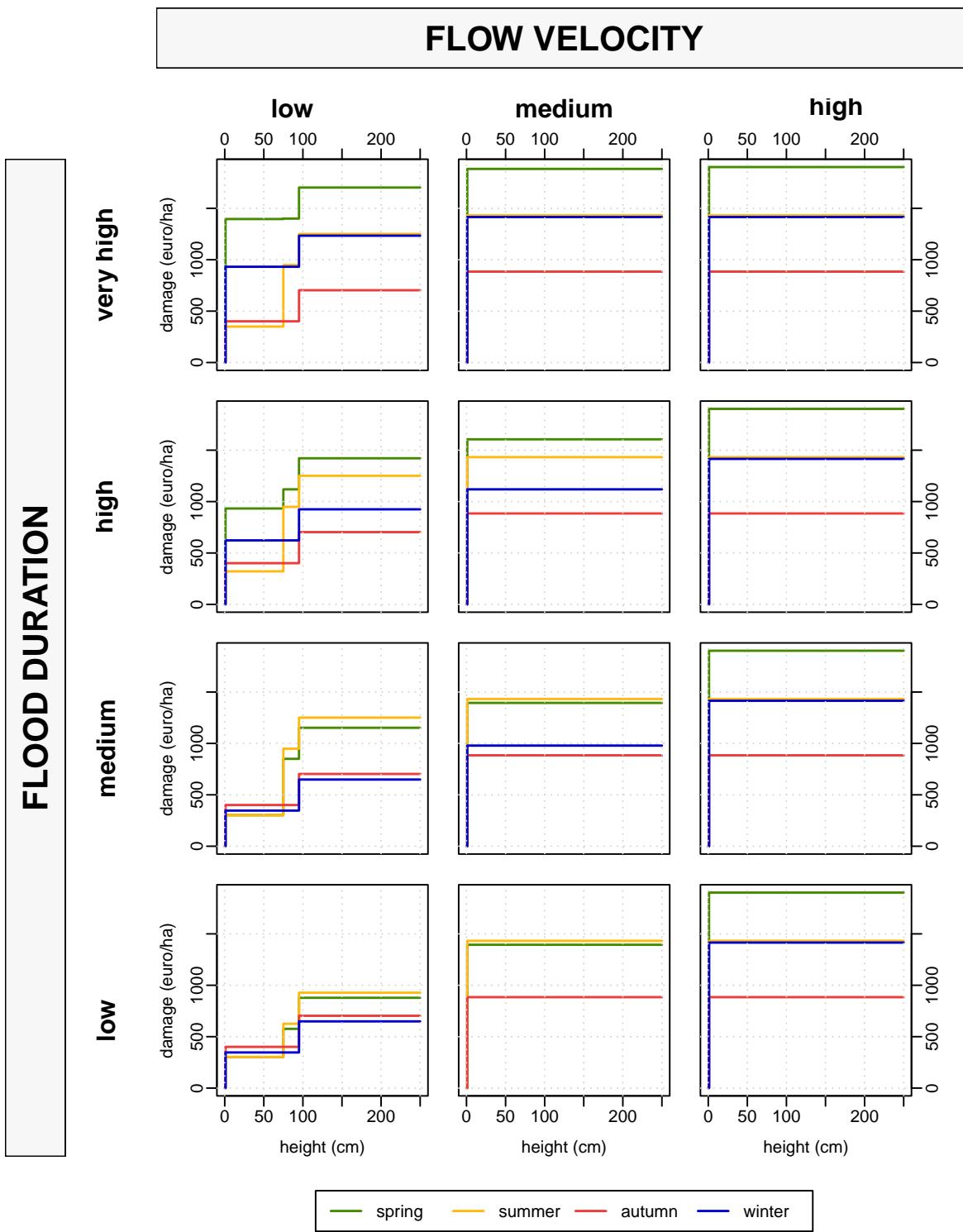


Figure 3. National flood damage function developed using for the category "Barley"

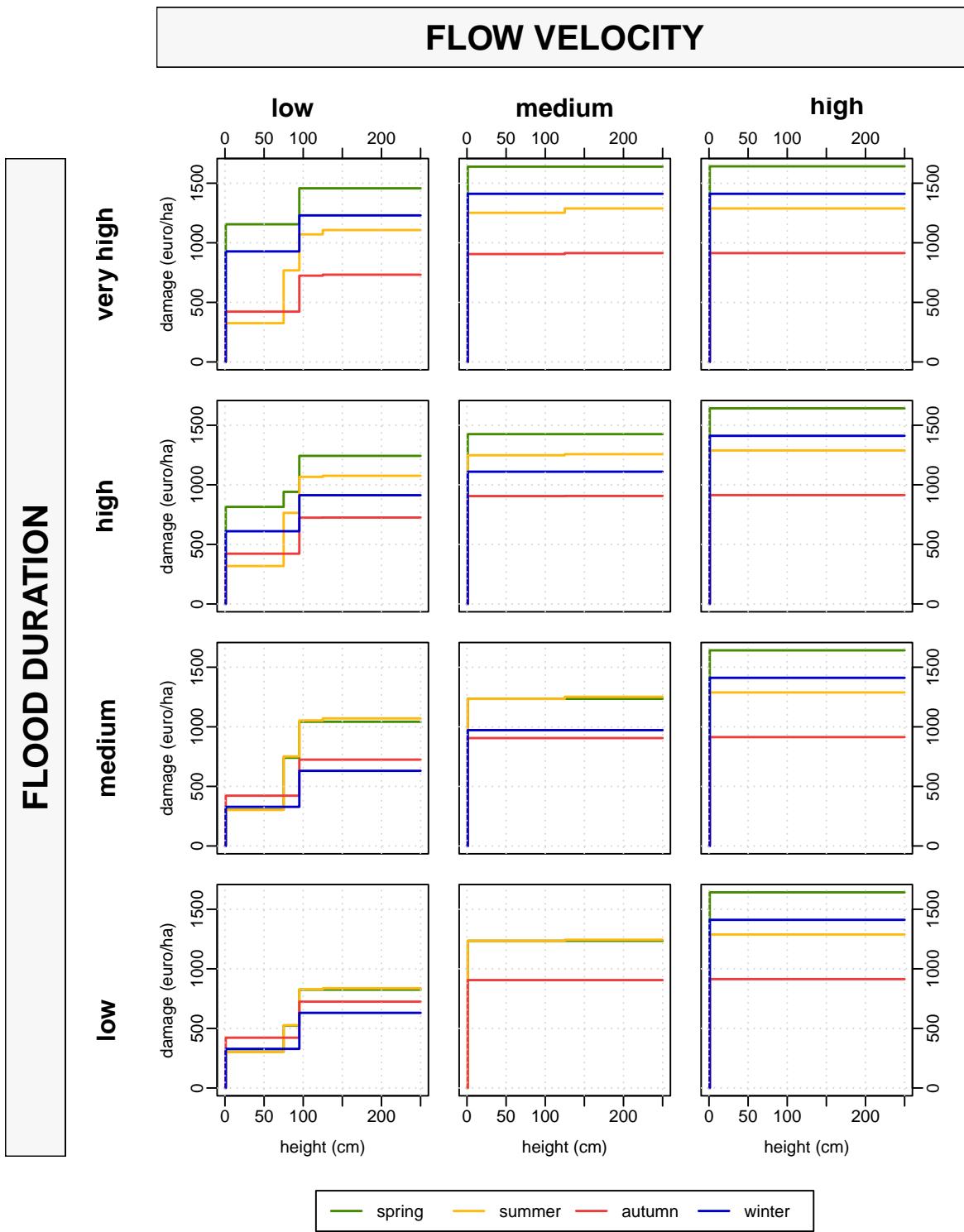


Figure 4. National flood damage function developed using for the category "Other cereals"

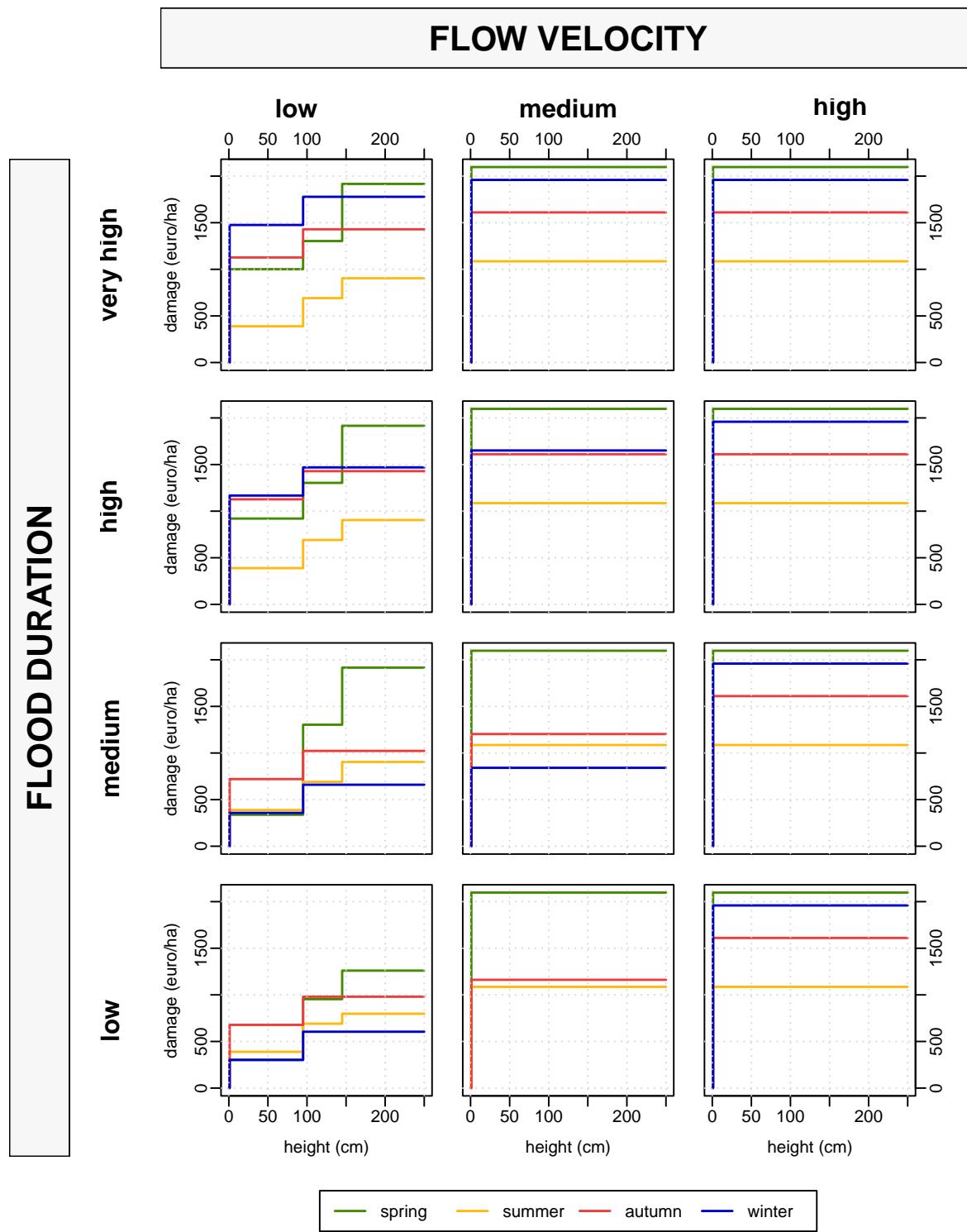


Figure 5. National flood damage function developed using for the category "Rapeseed"

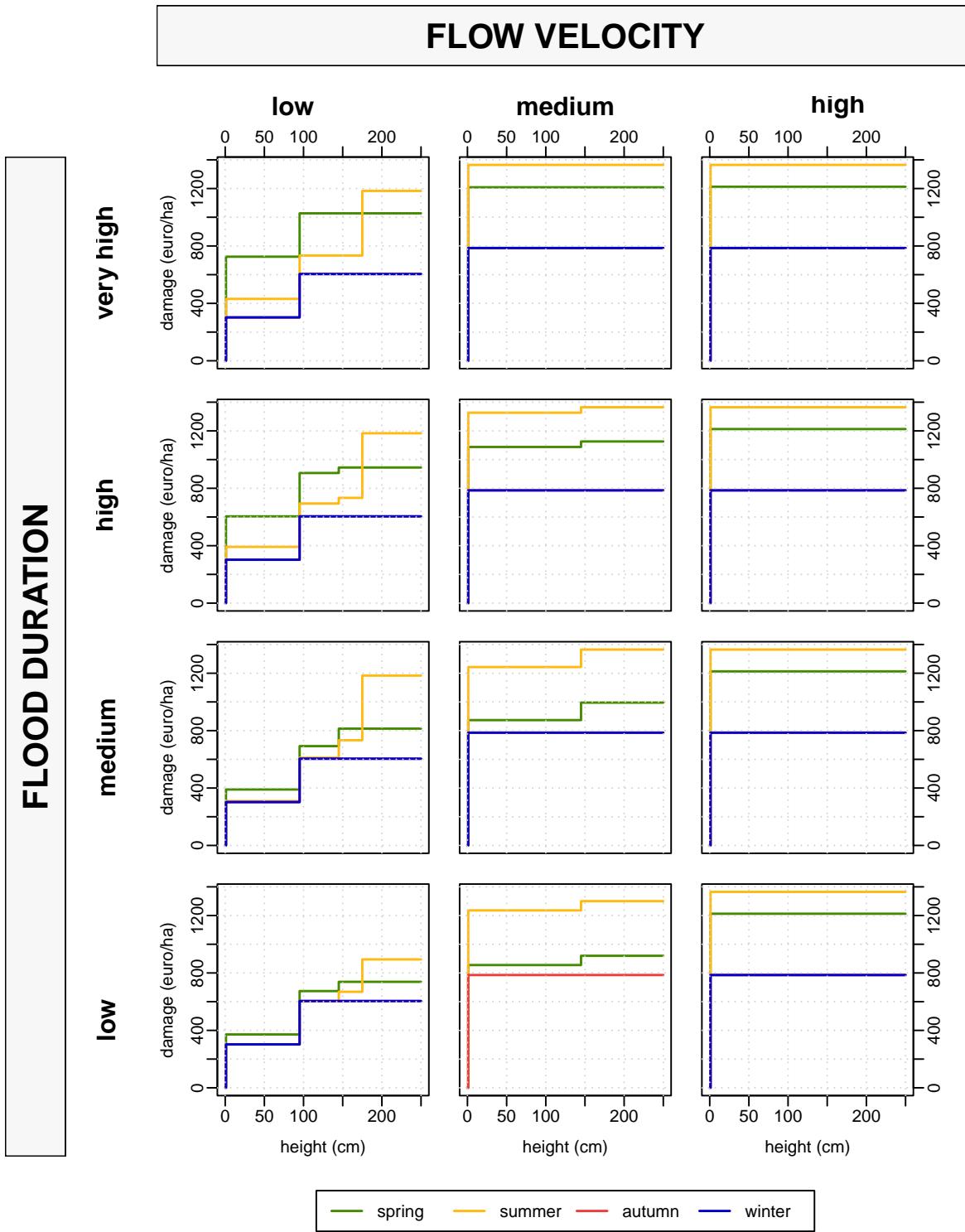


Figure 6. National flood damage function developed using for the category "Sunflower"

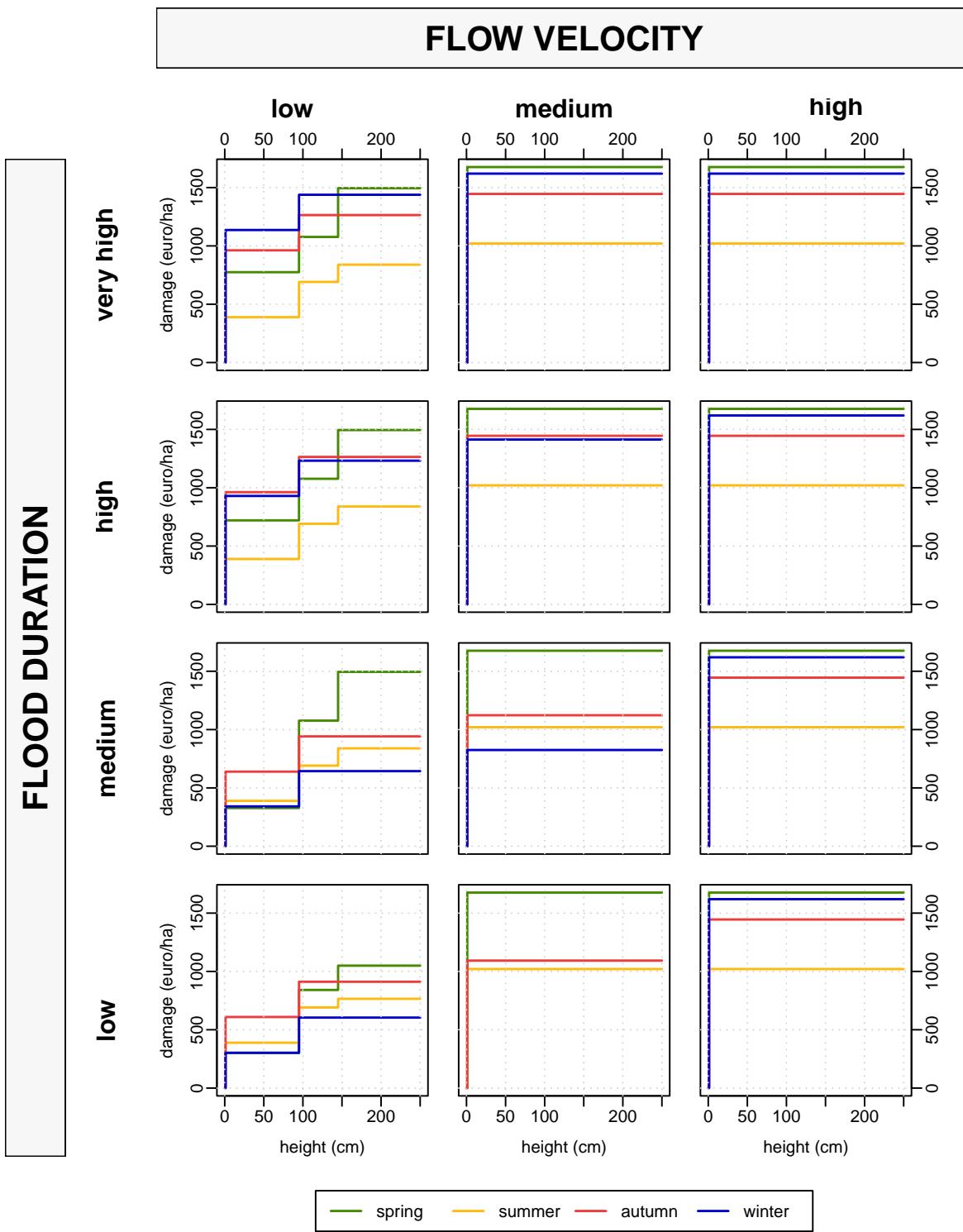


Figure 7. National flood damage function developed using for the category "Other oleaginous"

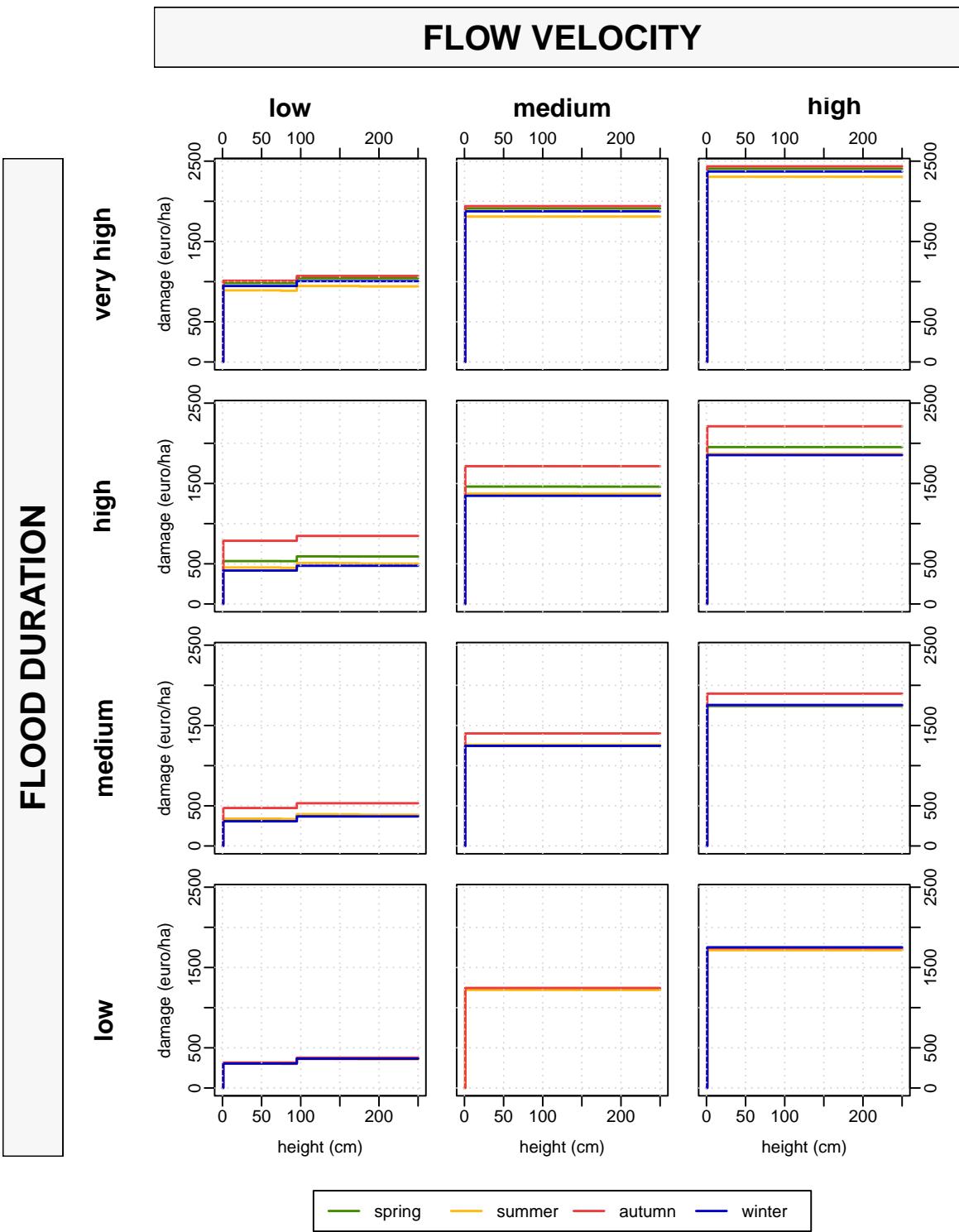


Figure 8. National flood damage function developed using for the category "Fodder"

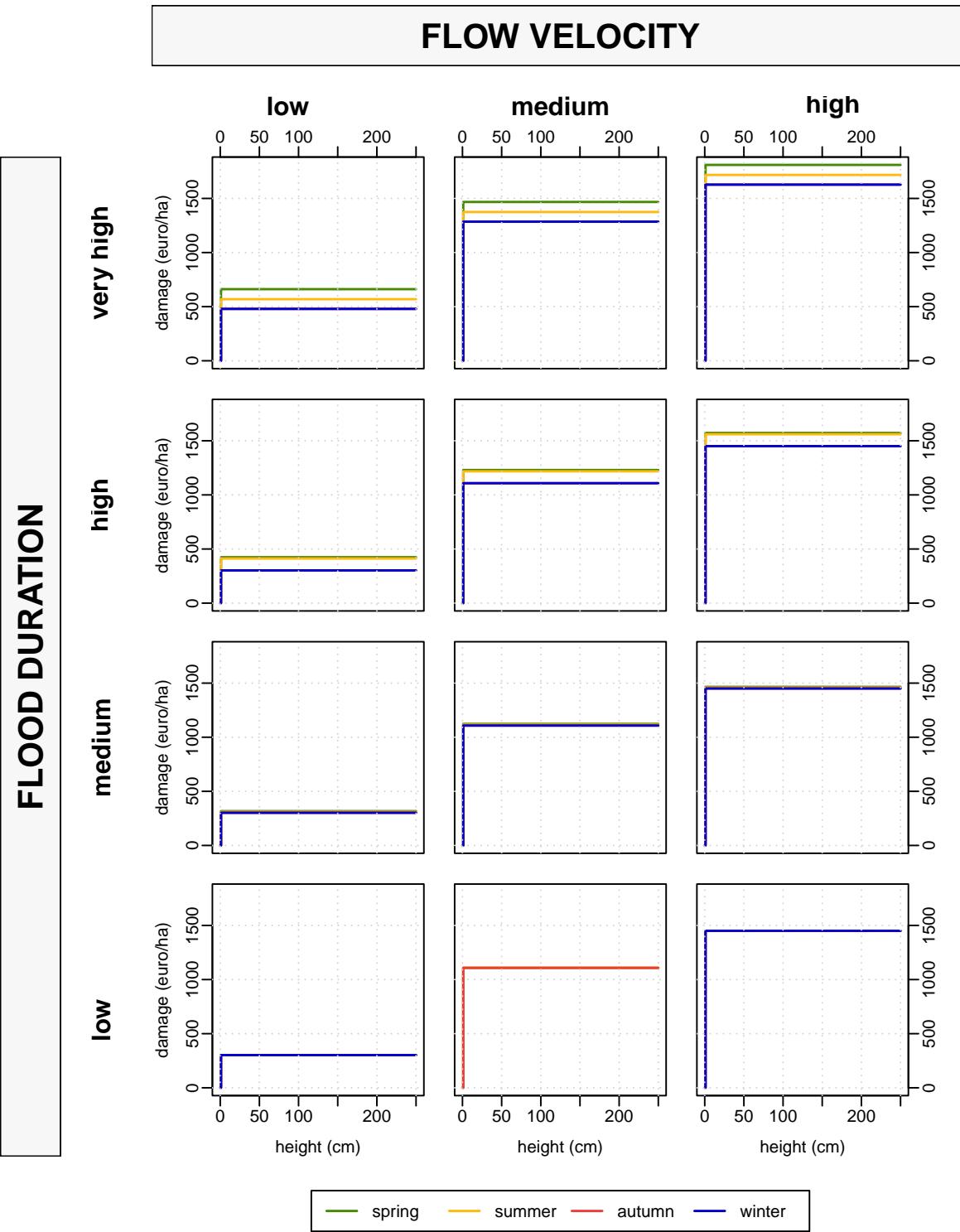


Figure 9. National flood damage function developped using for the category "Permanent grassland"

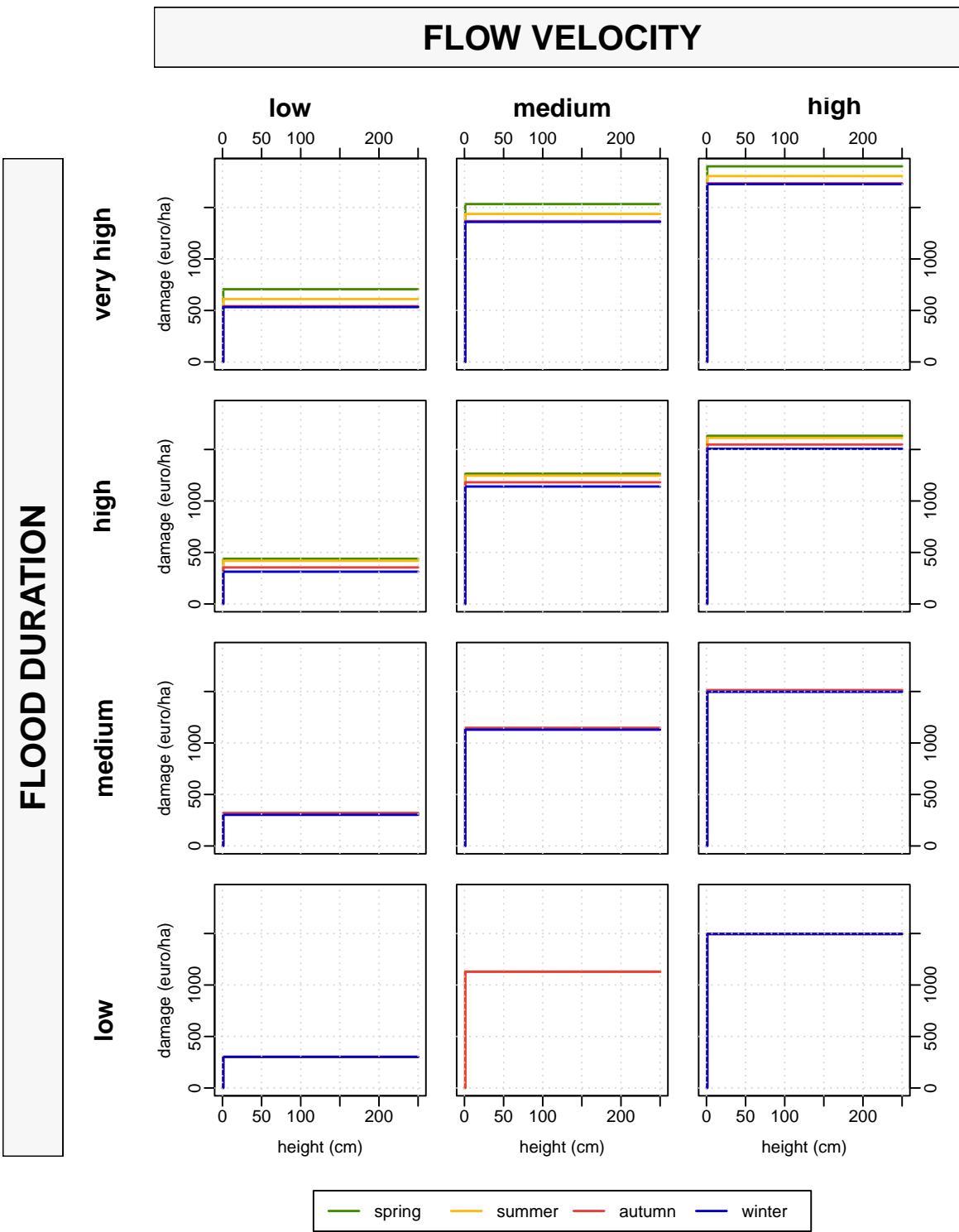


Figure 10. National flood damage function developed using for the category "Temporary grassland"

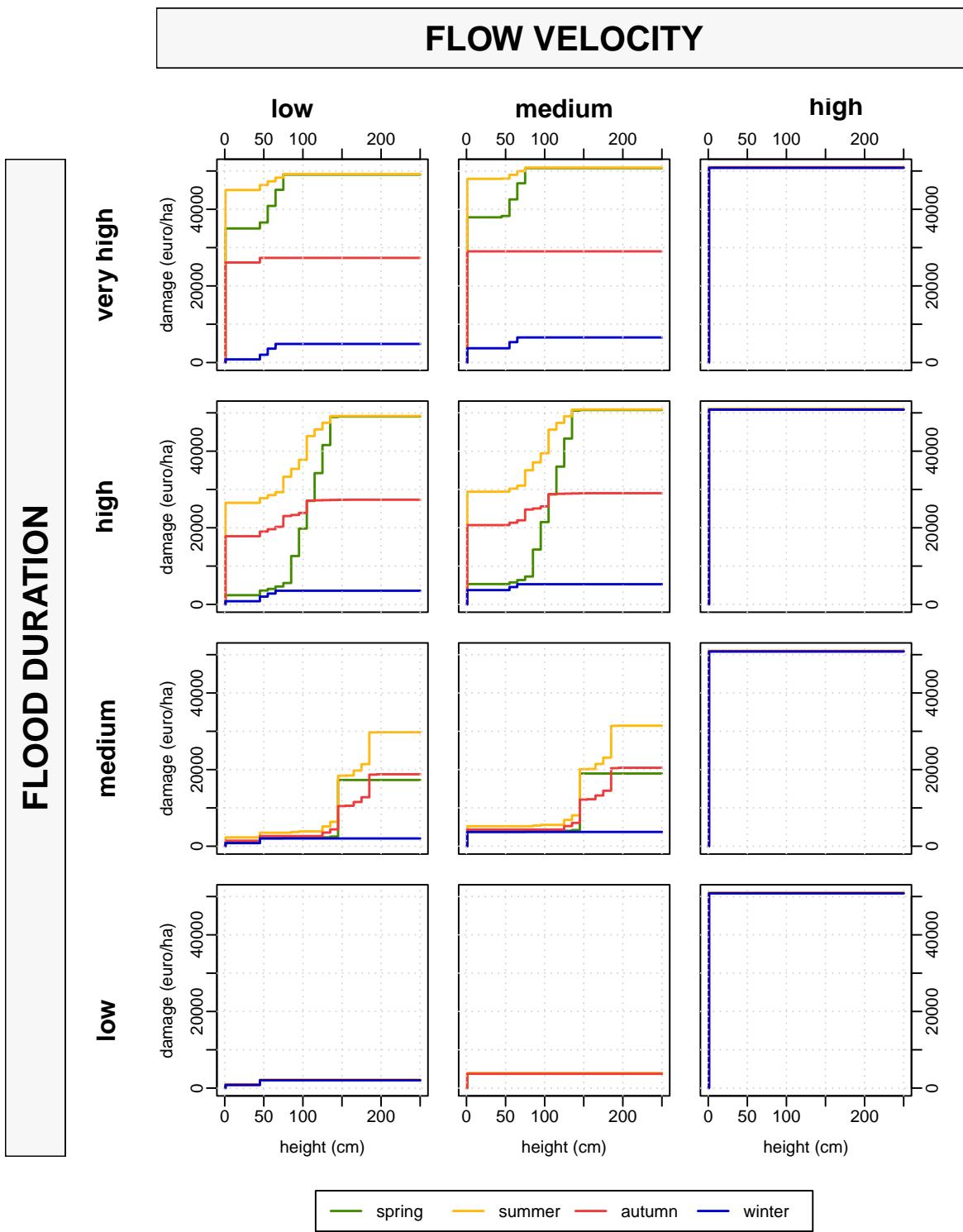


Figure 11. National flood damage function developed using for the category "Vineyard"

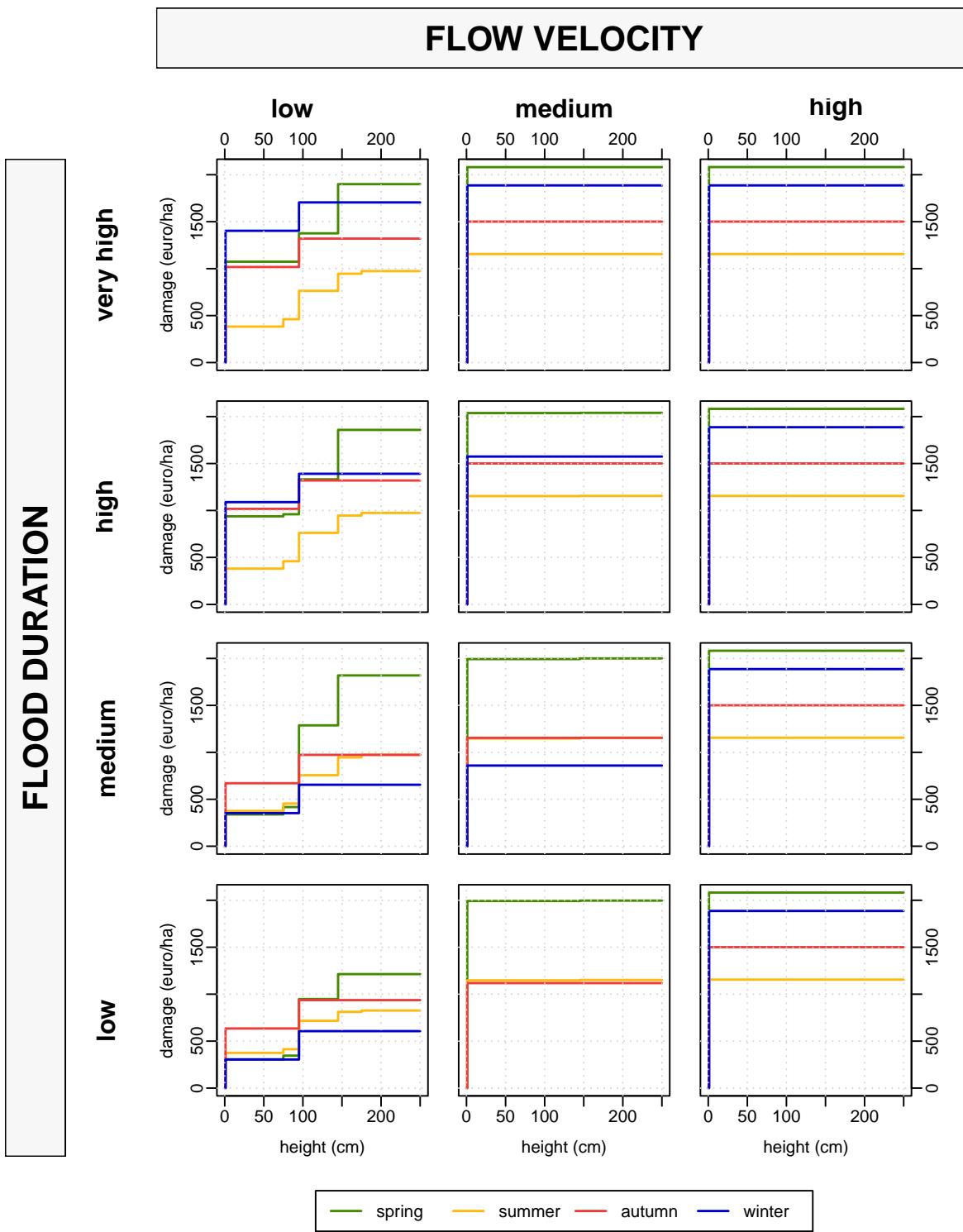


Figure 12. National flood damage function developed using for the category "Other industrial crops"

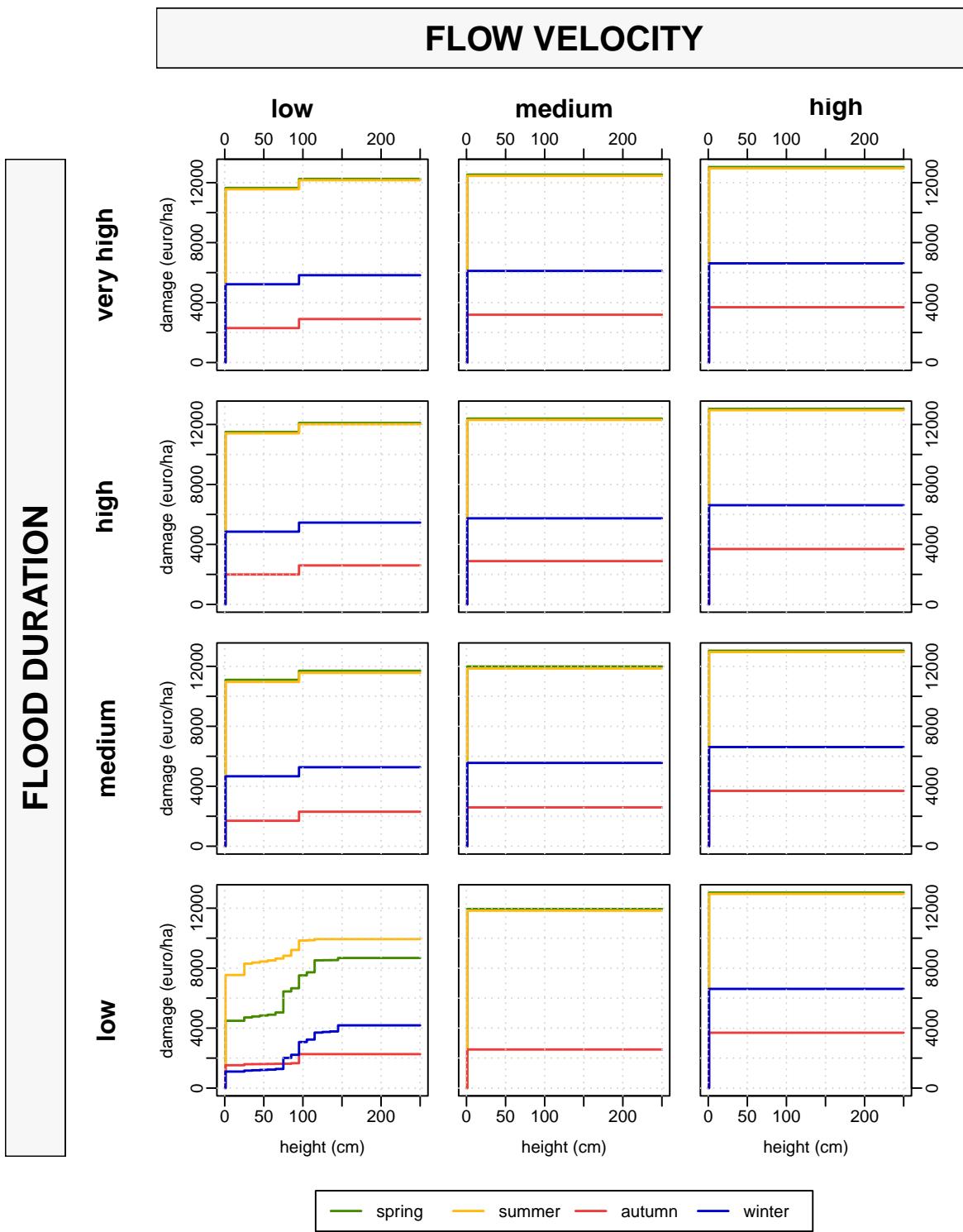


Figure 13. National flood damage function developed using for the category "Vegetables - Flowers"

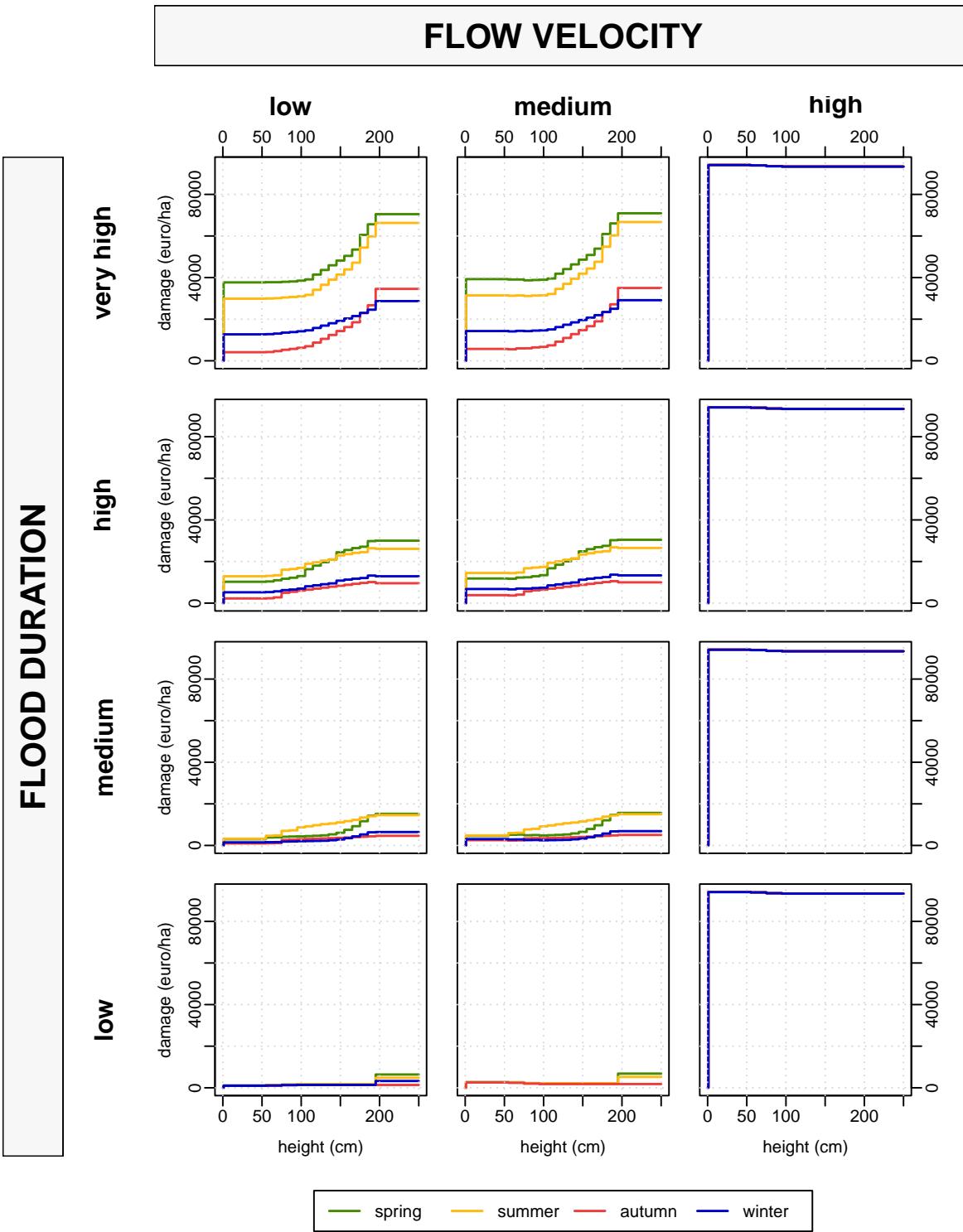


Figure 14. National flood damage function developed using for the category "arboriculture" and "Orchards"

25 **3 Supplement 3 – Focus Group of experts consulted to evaluate flood impacts on arboriculture**

Content of the supplement

This supplement contains, as an example, the recommendations for modifications of the damage functions that were identified during the focus group with the experts who were consulted on arboriculture. In total, five focus groups of an average duration of 2 hours were conducted. They brought together experts who had previously been interviewed 30 individually for their knowledge of the five crop families (grasslands, cereals, grapevines, arboriculture and vegetable crops). They resulted in the same type of recommendations as below.

Modifications made following the focus group of experts consulted in arboriculture

During the focus group, the following topics were discussed:

- the biophysical processes considered for each component,
- 35 – the ranges of yield loss in function of flood parameter,
- the determination of impacts for each components in function of flood parameter,
- the farmers' strategies for crop continuation,
- the additional or cancelled tasks and as a consequence the variation in crop expenses,
- the replanting strategies,
- 40 – the list of recovery tasks and their estimated cost (hours of work, equipment).

The following changes will be made to the arboriculture flood damage assessment methodology:

1. A cautionary note will be made that if orchards are planted on mounds, the mound height must be subtracted from the water height in order to use the proposed features.
2. The yield loss, in the absence of current, is modified to account for the following phenomena:
 - 45 – For apples at the flowering stage, because of the scab risk, if a treatment is delayed, whatever the height, the losses will start after 7 days of flooding. The total loss threshold (15 days) remains unchanged.
 - For apples and pears at the ripening stage, for a flood where the fruits are in contact with water (from 80 cm), the losses start after one day of flooding because of the risk of contamination.
 - For peaches and apricots, flooding during rest with the twigs in contact with water causes yield losses that start after 3 days and are total after 5 days. (The 36 h threshold is not used because the same damage was not observed in 1994).

– For peaches, the risk of development of monilia exists whatever the height of water, it can cause losses from 4 days of flooding which are total for 7 days.

55 – For apricots, the risk of development of monilia exists whatever the height of water, it can cause losses from 3 days of flooding which are total for 5 days.

– For peach and apricot trees, the height of the trunk is about 60 cm, and the damage is maximum from 2 m of water (the top can go up to 2.50 m).

– For cherry trees, the height of the trunk is 1.20 m with old varieties and 50 cm with new ones. The damage is maximum from 2 m of water.

60 3. For apple and pear trees, an effect on the quality of the fruit, and thus the selling price, is added when the flooding occurs at maturity and the fruit is in contact with water. Fruit that is not lost will be sold at a lower price because of its poorer storage potential.

4. The loss of plant material in the absence of current is modified when the water level is high. It is considered that mortality occurs about twice as fast for apple, pear and cherry trees when they are entirely in water. 65 Peach and apricot trees are more sensitive to this effect and mortality occurs as early as 15 days entirely under water during resting (7 days during vegetation).

5. Concerning the strategy of continuation of the itinerary (harvesting or not of the fruits), for peach, apricot and cherry trees, harvesting always takes place when there is more than 5% of fruits present (marketable or not) for reasons of sanitary risk. For apple and pear trees, if the percentage of unmarketable fruit is higher than 75% (flooding at maturity with water-fruit contact for example), the harvest will not be done and the fruit will be dropped with a chemical treatment. If the losses are lower than 90% and there is no unmarketable fruit (flooding early in the cycle and therefore classic work site), the harvest will be made.

70 6. Regarding the orchard replanting strategy, the production loss thresholds for replanting only the missing trees or the whole plot will be recalculated on the basis of an optimized economic profitability that will also take into account the amortization of the orchard (thus its average age). Higher uprooting costs will be considered when there is a trellis because it takes time to remove it.

75 7. Pruning and hand harvesting loads do not decrease or decrease little (not significant) in the years following the flood, even in the case of tree mortality.

80 8. An additional treatment will be made on peach, apricot and cherry trees if the flooding occurs during flowering, to limit the development of monilia.

9. Erosion: We will consider 3 levels of damage. The first two for weak and medium currents corresponding respectively to 0.5 and 1.5 days of work for two people with mechanization, or 215 and 645 / €ha. The last

level of damage corresponds to the formation of important gullies with the contribution of earth and the intervention of external service providers, and thus higher costs of approximately 1460 / €ha (2 days of work and contribution of earth).

85 10. Debris deposit and repair of the trellis, anti-hail nets and irrigation equipment: Debris deposition is a function of water height, as if water reaches the trellis or branches, the amount of debris to be cleaned will be greater. The damage to the trellis and irrigation equipment is a function of the current. The following values are proposed:

90

- for less than 80 cm of water with a weak current, the cleaning will take about 25 h/ha for one person with mechanization, or 750 / €ha.
- for more than 80 cm of water with a weak current or a medium or strong current whatever the height of water, the cleaning and the restoration will take 45 h/ha for two people with mechanization, that is 1890 / €ha.