View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Research Papers in Economics

Modelling farm vulnerability to flooding: towards the appraisal of vulnerability mitigation policies

Pauline Brémond[*1], Frédéric Grelot[2], Géraldine Abrami[3], Céline Blanc[4]

*1. Corresponding author, pauline.bremond@cemagref.fr

PhD Student in economics at UMR G-EAU, Cemagref

361 RUE J.F. BRETON BP 5095

34196 MONTPELLIER CEDEX 5

2. UMR G-EAU, Cemagref , frederic.grelot@cemagref.fr

3. UMR G-EAU, Cemagref , geraldine.abrami@cemagref.fr

4. UMR G-EAU, Cemagref , celine.blanc@cemagref.fr

hal-00553472, version 1 - 7 Jan 2011

Contributed Paper prepared for presentation at the 2009 EAAE PhD Workshop, Giessen, Germany, September 10-11, 2009

Abstract (max. 200 words)

In France, two new kinds of flood management policies are promoted: floodplain restoration and vulnerability mitigation. Few experience feedback exist on these policies but they may have strong impacts on farms. Flood management on Rhône River is highly illustrative of these policies and local authorities would like to appraise the efficiency of these policies with an economic tool (Cost-Benefit Analysis) to help decision making. But the current methods of flood damage modelling do not make the appraisal of these policies possible; mainly because they do not take into account the organizational and temporal dimensions of damage formation and propagation at farm scale. After a presentation of the Rhône River context and policies, we review existing methods of flood damage modelling for agriculture and show the interest to focus on the farm scale instead of land plot scale. Once the theoretical frameworks for systemic approach presented, we detail the construction of our conceptual model of farm vulnerability before presenting a case study that shows how the model can be implemented to compute flood damage at farm scale. Finally, the outlooks concerning the use of the model to appraise vulnerability mitigation policies and its application at regional scale are developed.

Keywords

Vulnerability, UML modelling, flood, farm

Copyright 2009 by [Bremond et al]. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

1 Introduction

Recent catastrophic flood events such as Elbe in 2002 or Rhône in 2003 (850 m € (SIEE, 2005)) have shown limits of flood management policies relying on dykes protection: worsening of flood impacts downstream, increased damage by dykes rupture. Those events, among others, contribute to radical changes of flood prevention philosophy and to the promotion of new orientations to mitigate flood exposition. Two new trends may have significant impacts on rural areas: floodplain restoration and vulnerability mitigation.

The Rhône River program is a contract of objectives signed between French Government and local authorities which aims at promoting an integrated management of the watershed on several points: environment, flood, culture...The flood management promoted in the Rhône River program is highly illustrative of the new policies presented above and their impact on agricultural sector. In this program, it appears that areas to be concerned by floodplain restoration are agricultural ones, because their supposed vulnerability to flood is expected to be less important than urban areas. As a consequence, agricultural sector is particularly concerned by planned actions on mitigation of assets vulnerability, an important part of the program (15 out of 310 m € for the period 2007-2013). Mitigation of agricultural assets vulnerability reveals proves particularly interesting for the local authorities for the two following reasons. Firstly, it is a way to maintain agricultural activities in floodplains, without promoting flood protection. Secondly, in case of floodplain restoration, vulnerability mitigation is a way for local authorities to compensate over-flooding impacts. In practice, local authorities may financially support farmers for implementing measures to mitigate their farm vulnerability.

The Rhône River has already carried out an important work to characterize farm vulnerability to flooding and propose measures to mitigate it. More than 3 000 farms exposed to flood risk have been identified representing 88 690 ha of agricultural areas which is estimated to generate 400 to 800 m € of damage depending on the season of occurrence for a catastrophic flood. About 50 vulnerability mitigation measures have been listed. They can be: physical (equipment or electric power system elevation…), organizational (emergency or recovery plan…) or financial (insurance…).

These measures aim at decreasing the total damage incurred by farmers in case of flooding. For instance, if equipment is elevated, it will not suffer direct damage such as degradation. As a consequence, equipment will be available to continue production or recovery tasks, thus, avoiding indirect damage such as delays, indebtedness…

Meanwhile, decision makers and financial actors require more justification of the efficiency of public fund by economic appraisal of the projects. On the Rhône River, decision makers asked for the development of an economic tool that could enable to appraise the program of farm vulnerability mitigation they plan to implement. This entails identifying the effects of the farm vulnerability mitigation measures, and classifying them by comparing their efficacy (avoided damage) and their cost of implementation. This paper presents the methodological framework that has been designed to answer this request and the first results in terms of flood damage modelling at farm scale that will be useful to appraise vulnerability mitigation measures. Section 2 gives a review of the existing methods to appraise flood damage on agriculture and shows that they do not fit to appraise vulnerability mitigation policies. These methods focus at the land plot scale and only consider direct damage on crop when the measures to mitigate farm vulnerability mainly apply at the farm scale and improve organizational capacity. In section 3, we present the different theoretical frameworks that can

hal-00553472, version 1 - 7 Jan 2011

hal-00553472, version 1 - 7 Jan 2011

be used to model and formalize farm vulnerability with a systemic approach. In section 4, we present our conceptual model of farm vulnerability and proposed an implementation of the model over a case study. In section 5, the conclusions concerning the use of the model at the regional scale are developed.

2 Review and limits of existing methods for modelling flood damage in agriculture

2.1 Current models for flood damage modelling

Even if agricultural areas are often critically concerned by flood risk, flood damage modelling on this sector has been little investigated in Europe (FORSTER et al., 2008).
First work about impacts characterization of crops submersion collected by Poirée et al. (1973), were carried out in Hungary in 1950. In the United States, where economic project appraisal at the federal scale have had to be done since 1936 (Flood Control Act), some models were developed in the 1970's (LONGHINI, 1997). These models compute direct flood damage on crops functions for: the season only (MCDONALD, 1970), the depth of inundation and the season (LACEWELL et al., 1972) or the depth and duration of inundation (GOULTER et al., 1983). More recently, Forster (2008) presented an economic assessment of a flood retention area used for agriculture. They take into account direct damage on crop loss due to flooding and monetize it (FORSTER et al., 2008). The central point of their work is to propose a seasonally based method and to balance the monetary loss of agricultural product which is strongly seasonal by the likelihood of the flood which is also seasonal.
In the Multi Coloured handbook (chapter 9), the authors proposed to estimate impacts of flooding on agricultural productivity and to express difference in monetary values. (PENNING-ROSWELL et al., 2005).The impact of flooding is estimated by the yield variation in different field drainage condition. This work has mainly been developed on North European agriculture (England) and the hypothesis does not seem transferable to all climatic condition especially Mediterranean ones because the productions and the type of flood are radically different.
All these methods focus on a macro scale approach and consider agricultural land use as a group of land plots defined by the type of crop grown and without interactions between them.
In 1988, Morris et Hess introduced a systemic approach of the farm and developed a model which tries to emphasize the link between direct and secondary damage based on the example of the dependence of breeding on grassland production (HESS et al., 1988). But this approach is not transferable to all production type in particular Mediterranean ones such as arboriculture or market gardening. Lacewell who had already developed classical flood damage model on agricultural areas (LACEWELL et al., 1972), evaluated a flood management project in 2006 introducing secondary additional costs incurred by farmers (LACEWELL et al., 2006). But this model does not take into account the systemic dimension of farm. Moreover, since it has been developed in United State and relies on local farmer's expertise, it can not be transferred to our context.

2.2 Limits of existing method and interest of a systemic approach

To understand why the current models do not fit to appraise new flood management policies, it is important to remember the first two steps of the economic appraisal methodology (PENNING-ROSWELL et al., 2005). The first hypothesis to be defined is the spatial scale that will be investigated. Farm vulnerability mitigation policies imply single protection measures which will apply at individual farm level. Indeed, equipment elevation will be done and will have effects on a single farm. But, this kind of policy is planned to be applied at regional scale, as for instance the program on the Rhône River. This clearly shows that we need to evaluate effects at individual scale and to compute them at regional scale. As indicated by Messner et al (2007), it is necessary to have a micro scale approach concerning single protection measures. Resulting from this, the demand on accuracy is high so as the amount of input data required. The current models of agricultural flood damage have a meso scale approach. They consider agricultural land use type and compute damage based on a loss of yield due to flood without considering farm spatial organization. Moreover, they nearly always consider only direct damage on production and ignore pluri annual effects due to degradation of planting for perennial crops for example.

The second important step of project appraisal is to define what the objective of the project appraisal is. In this study, we focus on two kinds of policies which may highly impact agricultural area namely floodplain restoration and vulnerability mitigation. As there are few examples of implementation of these policies, above all measures to mitigate vulnerability of farm, project appraisal must reach two objectives: 1) to help decision makers financing these policies ensuring the efficiency of public funds; 2) to appraise socio economic impacts of the policies. First, the ex ante appraisal must help administrations to determine how financing these policies based on the proportion of avoided damages. So, this kind of appraisal requires high precision (MESSNER et al., 2007) and an in-depth understanding of damage generation on agricultural area. Since these projects may have important socio economic impacts on the particular sector of agriculture, as Brouwer proposed (2004), it seems important to carry out financial and economic cost benefit analysis. The authors of the FLOODsite project advocate another approach, considering economic evaluation rather useful to help decision making than financial one (MESSNER et al., 2007). Nonetheless, in the Multicoloured Handbook, Morris (2005) also propose to measure financial performance "given the uncertainty in the farming sector as farmers adjust to new policy and market conditions" (PENNING-ROSWELL et al., 2005). So, we think that it is central to lead at the same time economic and financial analysis above all in an evolving risk context. Economic analysis must help decision making and guarantee the efficiency of public funding. In depth focus on farms must allow to identify effects of the policy and to distinguish which one should be consider as economic costs or financial costs. Current models do not consider agriculture as an economic activity which would require developing an approach at the farm scale. The focus on the land plot scale limits the characterization of effects to physical loss of crops, which is not representative of the vulnerability of agricultural area. Moreover, public policies concerning vulnerability mitigation can not be evaluated using the approach at the land plot scale. In fact, vulnerability reduction mainly consist in protecting production factors (furniture, stock) which contribute to produce the yield but are not easily correlated to it. Some measures are also proposed because they are supposed to improve labour organization during the alert or after the flood. To encompass these kinds of effects a model of vulnerability to flood at the farming system scale which allow representing temporal, spatial and organizational is required.

Based on enquiries in France, Pivot (2002) shows clearly "that damage caused to farming areas by flooding should be considered both at field level and at farm level" and that there is a temporal propagation of damage to farm (PIVOT et al., 2002). As suggested in current models of agricultural flood damage, flood damage on crop production is function of the parameters of the flood and the characteristics of the land plot (plant cultivated species). Nonetheless, losses estimation at the farm level can differ considerably and added value loss depends on internal organization and availability of reproduction resources. These conclusions highlight the need to change the scale for flood damage on agriculture modelling and to develop a systemic approach (BREMOND et al., 2009).

hal-00553472, version 1 - 7 Jan 2011

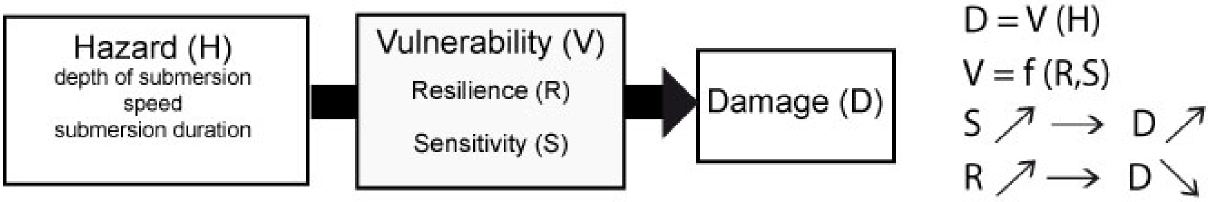
3 Modelling and formalizing farm vulnerability with a systemic approach

3.1 Link between flood damage, vulnerability, resilience and adaptation

Risk exposure can be divided in two components which are hazard and vulnerability. Blaikie et al (1994) define vulnerability as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impacts of a natural hazard" (BLAIKIE et al., 1994).

TURNER *et al* (2003) proposed a framework for vulnerability analysis that encompasses three concepts: exposure, sensitivity and resilience. The amount of damage incurred by a system will depend on these three concepts. The exposure is related to the hazard level that can affect the system and is positively correlated with the amount of damage. The sensitivity due to intrinsic characteristics of the system corresponds to its compounds propensity to endure damage (for example, the type of production and equipment for a farm). The sensitivity is positively correlated to the amount of damage. Finally, the resilience is the capacity of the system to recover after the event and it is negatively correlated to the amount of damage. As represented on figure 1, the damage resulting from a level of hazard (H) depends on the vulnerability of the system. The total amount of damage is a way to evaluate vulnerability.

Figure 1: representation of the link between hazard, vulnerability and damage



3.2 Theoretical frameworks for a systemic approach

In order to consider the different dimensions of vulnerability in the appraisal of the mitigation measures, we develop a methodology based on a systemic modelling framework. This framework uses concepts from the farming systems literature in agronomy and agro-economics and from the system's capital theory from development economics. It is formalized using the Unified Modelling Language.

3.2.1 Concept of farming system in agronomy and agro-economics

This literature concerning farming systems has been mainly developed by INRA SAD in the 80's (BROSSIER et al., 1990). Our framework relies on 4 concepts from this literature : farming system, crop management sequence, work organisation (simulation) and strategy.

Farming systems have been defined by Reboul (1976) as the set of resources which are farm's lands and workforce (farmer, family and employee) to produce animal or vegetal outputs. In our framework, the definition of the structure of a farm relies on this definition.

The crop management sequence is defined by Sébillote in 1978 (BROSSIER et al., 1990, p.23) as a "list of cultural techniques that allows to control the environment and to get a production". In our framework, this concept is used to represent the organizational dimension of the farming system.

The literature on work organisation (PAPY et al., 1988; BROSSIER et al., 1990, p.80) and the possibility to simulate it at farm scale (ATTONATY et al., 1990) was the basis for representing induced flood effects on work organization in our framework

hal-00553472, version 1 - 7 Jan 2011

hal-00553472, version 1 - 7 Jan 2011

Finally we use the concept of farmers strategies (AUBRY et al., 1998) to analyse and represent recovery after flooding.
The unique approach of farming system modelling using UML language we found has qualitative objectives close to ours but did not have economic evaluation perspective (HERVÉ et al., 2002).
The construction of the conceptual model of farm vulnerability to flooding also rely on the formalization of experts corroborations developed in France(BAUDUCEAU, 2001; BARBUT et al., 2004)

3.2.2 The theory of the system's capitals in development economics

On the other hand, we used a framework given by the development economics (GONDARD-DELCROIX et al., 2004) to analyse the several capital forms or production factors available at the farm scale to overcome and recover after flooding. The capital forms identified are:

- Physical capital (equipment, stocks, land plot)
- Financial or monetary capital (resources from saving or loan)
- Human capital (workforce)
- Social capital (mutual aid, economic partners).

3.3 Unified Modelling Language: a language to formalize complex system

The complexity related to the entanglement of the spatial, temporal and organizational dimensions leads us to choose Unified Modelling Language (UML) to formalize our conceptual model. UML is a semi formal language which enables to elaborate object-oriented models independently of any programming language. Since it has been designed to represent computer systems through the description of their entities, their activities and their interactions, UML proved an useful tool for systemic models conceptualization (ROUX-ROUQUIÉ et al., 2004). UML allows representing the elements of a system as classes whose attributes are the descriptive parameters and methods are the state transitions. Using the different views of UML it is then possible to create formal representations of the elements of a system and their interrelations, of the conditions and possibilities of state transitions or decision steps in a strategy, and of the sequencing of the activation of these entities under different scenarios. (HERVÉ et al., 2002).

4 Proposition of a conceptual model of farm vulnerability

We will present in the following sections the conceptual model we develop and a test bench implementation over a simple case study of flood damage evaluation at the farm scale.

4.1 General structure of the conceptual model of farm vulnerability

Figure 2 represents the structural and spatial dimensions of a farm in our conceptual framework. It describes a farm by its physical capitals located on spatial elements, namely:

- Agricultural land plots: soil, perennial trees and current production
- Buildings
- Equipment
- Stocks (inputs, harvest, finished products).

Figure 2: structural representation of the farming system (class diagram)

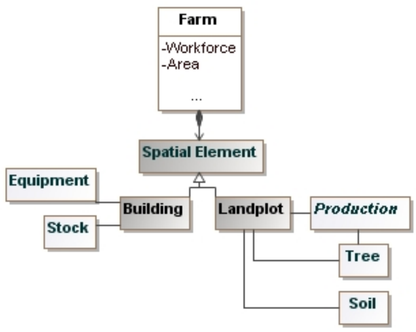


Figure 3: functional representation of the farming system (class diagram)

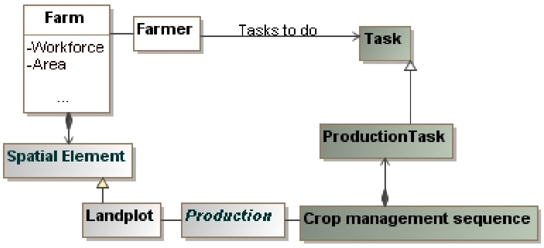
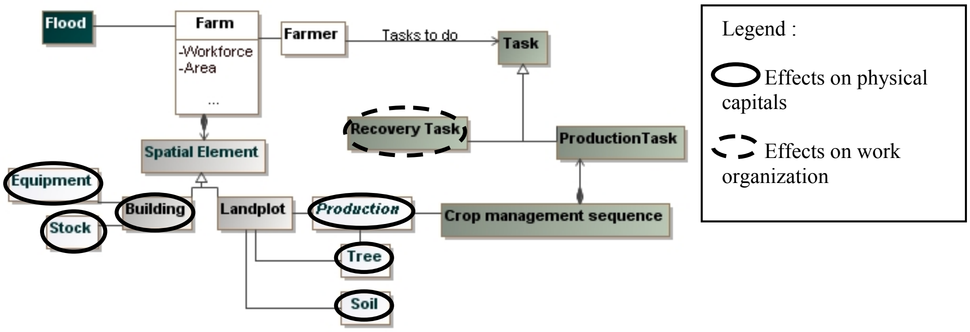


Figure 3 represents the organizational dimension of a farm: each production is related to a crop management sequence which is composed of tasks that can be accomplished by the farmer.

4.2 Modelling flood damage on farm

4.2.1 General framework of flood effects on farm

Figure 4: effects of flood on the farming system (structure and functioning)



The flood scenario is implemented with several parameters (height, speed, duration of submersion, season). As show on Figure 4, the effects of the flood on a farm can be broken down into two categories: effects on physical capitals and effects on work organization. First, the physical capitals (production, trees, soil, equipment and stocks) of the farming system can be damaged by the flood in function of the flood parameters and of their own sensitivity. The physical capitals will endure a temporary or a definitive deterioration. Except for the production that is definitively destroyed, the deterioration implies actions to recover (recovery tasks) that can be associated to a cost. The model then specifies which tasks must be done, their constraints (time and finance) and dependencies. Thus, we distinguish two kinds of tasks, the productions tasks defined by the crop management sequence and the production and the recovery tasks defined by the damage endured by the physical capitals. Each task is associated with a working time, a need of input and a cost. The decisional entity “farmer” has to manage the task achievement under the constraints of equipment and labour force availability and implement a strategy.
We will now focus on the modelling of the impacts of the farm physical capitals.

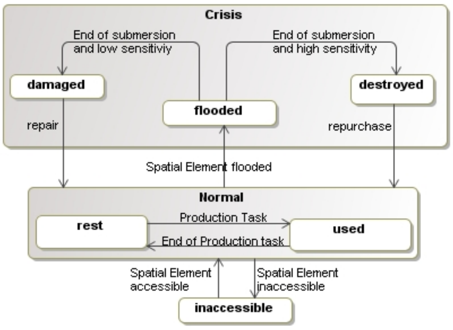
4.2.2 Modelling impacts of flooding on farm physical capitals

We defined for each physical capital the possible states that can be reached. For example, for the class “equipment”, five states can be defined: rest, used, damaged, inaccessible, and destroyed. The state diagram (Figure 5) enables to represent the transition and to set the implicit assumptions concerning the condition and the constraints of these transitions. Thus, the link between the direct consequences of the flood on farm and the work organization is provided by the concept of task.

hal-00553472, version 1 - 7 Jan 2011

hal-00553472, version 1 - 7 Jan 2011

Figure 5: State transitions of the class "equipment" (State diagram)

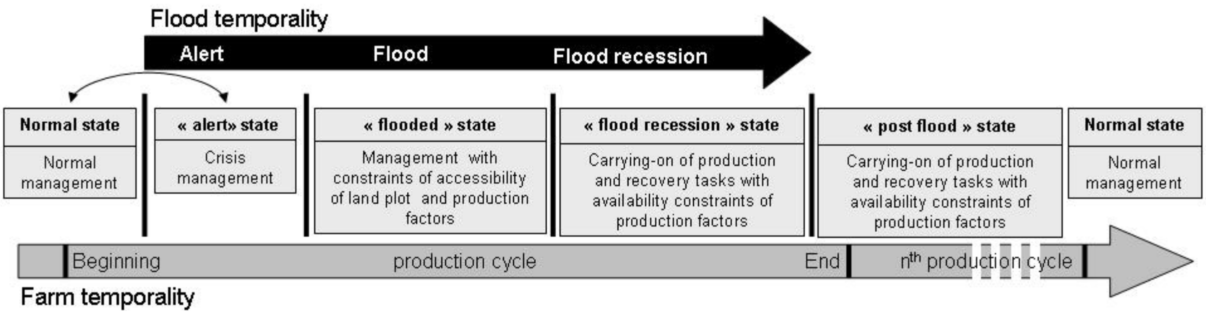


To recover from the state « damaged » or « destroyed », the tasks « repair » or « repurchase » must be done and during this period, it will be unavailable to do tasks for crop production. In the same way, damage to the soil of the land plot which is often dirtiness, needs to be cleaned before the crop management sequence can be restarted. Then, the link between the direct effects of the flood on farm and the effects on work organization is provided by the concept of "task" that must be done by the farmer. We will focus on these tasks and how they are spread along the flood and farm temporalities.

4.2.3 Global dynamic and strategies

Figure 6 shows that three temporalities are in interaction: the farm one, the flood one and the crisis management one. Farm temporality is related to crop management sequence. Flood temporality determines the degree of damage depending on the moment the flood occurs in the crop management sequence. The temporality of the crisis management results from the crossing between flood temporality and farm recovery evolution and leads to the sequences of five ways to manage farm presented below.

Figure 6: Periods after flooding and associated strategies



The difficulty results in crossing farm temporality and these disturbed ways to manage farm. It implies identifying the effects of the crisis management on the crop management sequence. This requires making assumptions on the tasks prioritization under several constraints (period, equipment and workforce availability). These effects we have named "induced effects" are presented in the next section.

The conceptual modelling enabled us to define a framework that is used in the following test bench to evaluate both direct damage on physical capitals of the farm (4.2.2) and induced damage due to the disturbance on organization at farm level.

hal-00553472, version 1 - 7 Jan 2011

5 Implementation of the conceptual model for a case study: a test bench of the framework for small farms in arboriculture

5.1 Study site and request of the operational authority

Our study site is located on the Rhône River downstream as shown on the Figure 7. 3000 farms have been identified as potentially exposed to flood. On this area, agriculture is an important activity and the productions are diversified. They can be grouped in five categories which are: arboriculture, market gardening, viticulture, cereals, grassland and livestock. The main category in the studied area is farms specialized in arboriculture (Figure 8). Within this category, small familial farms are supposed to have smaller financing capacities and as a consequence should benefit first from the subsidies to implement efficient measures to mitigate their vulnerability to flooding. We chose this type of farm as an implementation test bench over a particular flood scenario for our framework

Figure 7: study site and flooded area during the flood of the Rhone River in 2003

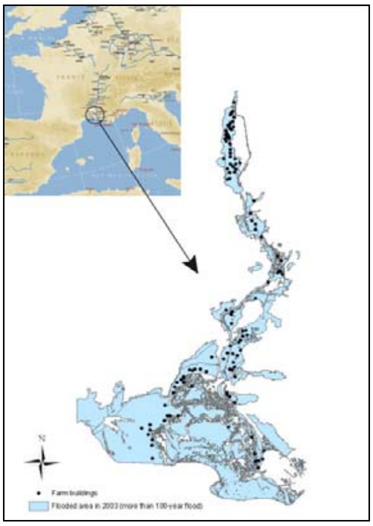
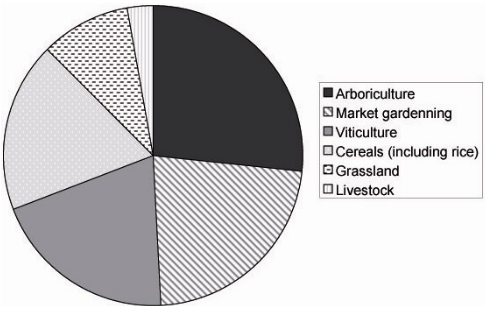


Figure 8: reparation of the number of farms by categories of production



5.2 Presentation of the farm type: familial structure specialize in arboriculture

According to French national data on farm structure (2000), in the five departments of our study zone, 4300 farms can be related to the group of arboriculture production. We split these farms in two groups (less than 15 hectares and more than 15 hectares). As specified above, we focus on small farms and we defined the characteristics of a type farm (Table 1).

Table 1: characteristics of the farm type specialized in arboriculture with a area of less than 15 ha

Type of production	Average area (ha)	Average workforce (men/farm)	Average yield (kg/ha)	Average price (€/kg)	Gross product (€/ha)	Costs of production (€ /ha)	Gross margin (€/ha)
Apple (Royal Gala)	8	2	43000	0.5	20300	12600	7700

Sources: RGA 2000 and "technical and economic references of arboriculture in Vaucluse" (CA84, 2005)

Since a crop management sequence has to be defined to estimate induced effects, we focused on an apple production (Royal gala) which is the most spread production in this area.

5.3 Characterization of damage evaluation

The implementation of our conceptual model to evaluate flood damage on farm encompasses two steps: 1) the characterization of flood damage on physical capitals of farm (production, soil, trees, building, equipment, and stocks), 2) the characterization of induced damage on the farm (loss of product or increase in cost production).

hal-00553472, version 1 - 7 Jan 2011

For each physical capital we characterized the damage endured and then monetized it. The damage endured by the physical capitals fit with the economic cost (in contrast with financial cost) of the actions needed to recover. The damage is, most frequently, estimated by the cost of repairing or repurchasing. For the agricultural production that can not be repaired, the damage is estimated by the gross product or the gross margin.

The induced effects that we considered will be developed in section 5.6.1. They are:

- Impossibility to shift forward a task planned in the crop management sequence
- Unavailability of equiment
- Unavailability of labour force
- Financial repercussions (indebtedness due to loss of product or increase in cost production).
- Contractual repercussions (loss of label or contracts).
- Replantation of trees (induced loss of production). We have included these costs in the damage endured by the component "tree".

5.4 Flood scenario chosen

For the simulation, we defined a theoretical scenario which could have been observed during the last flood that occurred on Rhône River in December 2003. The parameters of this scenario are presented in the Table 2.

Table 2: Flood scenario parameters

Scenario parameters	Chosen level
Period of occurence	December
% SAU flooded	100
Height of flooding on landplot and buildings	]0,20] ;[20,50[;[50,100[;[100,∞[
Duration	7 days
Speed	Medium

5.5 Evaluation of damage on farm type physical capitals

The degree of damage depends on the intensity of flood parameters. In the Table 3, we summarize the methods we develop to estimate damage and to monetize it. The fourth column gives the result of the evaluation for a specific scenario. For example, damage to soil is relatively low because in this specific scenario, trees do not need to be replanted after flooding. In our study, we simulate damage evaluation for several scenarios.

Table 3: example of damage simulation for a specific flood

Physical capital	Estimation	Monetization
Production	% of loss of harvest (gross product)	Gross product : 20300€/ha
Soil	Time of cleaning Land terracing	Cost of workforce (12 €/h) Mechanization costs
Trees	Time of cleaning New planting Maintenance costs during 3 years Loss of harvest during the 3 years following the New planting	Cost of workforce (12 €/h) 21 800€/ha 6100€/ha Gross margin : 7700€/ha/y
Buildings	Time of cleaning	Cost of workforce (12 €/h)
Equipment	Repairing or repurchasing costs	% of equipment value (depending on age)
Stock input	Repurchasing costs	Cost of input

Table 4 presents the cost of the damage on each farm component in function of the height of submersion. These costs include all economic costs that can be considered at farm scale. The first result is that even if there is no damage at this period on production, the damage on other components can be high specifically on trees due to the destruction of the planting. This result confirms the assumption that it is not sufficient to consider only direct damage on crop to evaluate flood damage on agricultural area.

Table 4: cost of damage for a flood in December on 100% of the farm type during 7 days

Height (cm)	Production	Soil	Trees	Buildings	Equipment	Stock input	Total
0-20	0	14160	0	576	195	0	14931
20-50	0	14160	0	576	5140	4775	24651
50-100	0	35736	0	960	28825	9550	75071
>100	0	14832	40800	1344	70000	9550	136526

5.6 Evaluation of induced damage after flooding

The characterization of induced damage requires the following preliminary steps:

- To shift the tasks in the crop management sequences on land plots that have been flooded taking into account the duration of submersion and of recovery on land plot and buildings. This allows identifying tasks that cannot be shifted.
- To build a calendar of equipment unavailability that will enable to know which task needs to be done by a service provider. When the task is done by a service provider we assume that it will relieve some workforce.
- To build a balance on workforce availability that will enable to know which tasks require workforce employment.

5.6.1 Induced damage considered: causes and consequences

In order to evaluate the global flood damage, we characterized induced damage on farm. As explained with the conceptual model, direct damages of farm structure and organization entail some disturbance during the recovery. We classified them in four groups described in Table 5 and proposed a way to estimate them. The cost can be a loss of product or an increase of production cost.

Table 5: induced effects considered in our methodology

Effects	Cause	Estimation
Impossibility to shift forward a task planned in the crop management sequence	Duration of submersion and of recovery (cleaning) of soil and building too long and the task can not be shifted	% of loss of yield of the production of the year of the flood
Unavailability of equipment	Lead time for the repairing or the repurchasing	Task done by a service provider (increase in cost of production)
Unavailability of labour force	Time required to achieve the tasks higher than the workforce available on farm because of recovery tasks and the shifting of the crop management sequence	Employment of workforce
Financial repercussions	Loss of harvest or stock of end products Increase in costs of production (service providers, additional workforce)	Indebtedness Personnal ressources

5.6.2 Time-lag of the crop management sequence and induced damage due to impossibility to shift task

During the submersion and the time needed to clean the land plot and building, we assume that no task can be done on flooded land plot. We have shifted forward the crop management sequence considering this period of recovery. The period of recovery encompasses building

hal-00553472, version 1 - 7 Jan 2011

hal-00553472, version 1 - 7 Jan 2011

and soil cleaning. The labour time required for each task that have also been shifted to the next month.
Nevertheless, for some tasks it does not make sense to shift a task. In this case, we apply a damage function elaborated with experts that enables us to estimate a percent of loss of yield due to the undoing of the task.
In the case of a flood in December, the only task to do on the farm type is pruning. This task can be done between December and must be achieved at the end of February. As a consequence, this task can be shifted and it results no induced damage due to task shifting. This result would be different for a flood that would occur in May.

5.6.3 Induced damage due to equipment unavailability

The period of unavailability of the pieces of equipment has been defined by enquiries with experts and farmers. We can see Table 6 that there will be no induced effects due to equipment unavailability for this scenario because the piece of equipment needed for pruning is available whatever is the height of water.

Table 6: table of equipment unavailability

Equipment	]0,20[	[20,50[	[50,100[[	[100,∞[
Tractor	0	0	3	8
Field crop sprayer	0	3	8	8
Fertiliser ditributor	0	3	8	8
Roller chopper	0	3	8	8
Equipment for tillage	0	3	3	3
Trailer	0	0	2	4
Equipment for pruning	0	0	0	0

5.6.4 Induced damage due to labour force unavailability

Figure 9 shows the monthly repartitions of labour time, in standard situation and with the chosen flood scenario. We can notice that the disturbance on work organization last until February. According to the enquiries done with farmers, we defined two levels of workforce on the farm. In standard situation, we assume that the two employees work together 320 hours per month in standard situation and 480 hours per month in crisis situation. In December, January, February, the labour time is higher than the workforce available in standard situation. Nevertheless, we assume that induced effects due to employment of workforce will only occur when labour time required is higher than the workforce in crisis situation. This hypothesis is consistent with the reality observed in the field by enquiries. The induced costs relative to employment are financial costs for the farm. As a consequence, in the scenario we chose, we considered that 300 hours of additional workforce are needed which correspond to a cost of 3600 €.

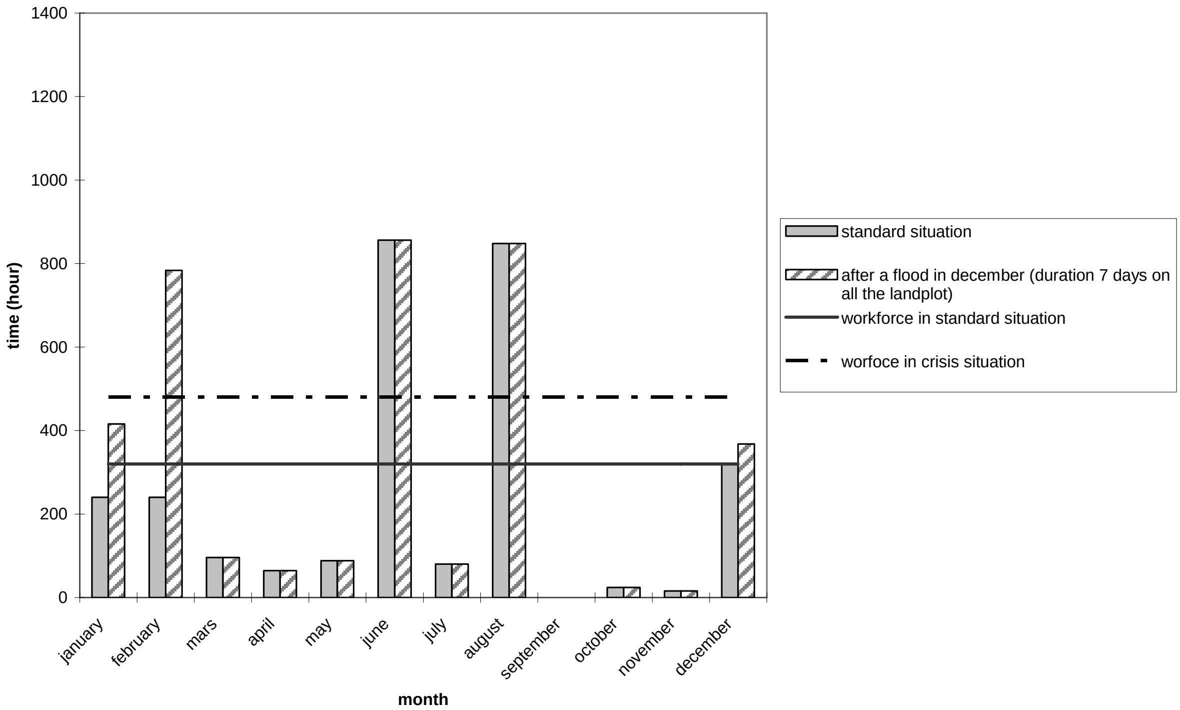


Figure 9: comparison of labour time in standard situation and consequently to the flood scenario chosen (December, 7 days of submersion, 100 % of land plot flooded, 80 cm on land plot, 40 cm in buildings, medium speed)

6 Conclusions and discussions

The research program presented is articulated around the operational request of the decision makers of the Rhône river basin to develop an economic evaluation method of their program to mitigate farm vulnerability. In this paper, we proposed a methodological approach to improve appraisal of flood management policies specifically vulnerability mitigation policies. The global approach to appraise a vulnerability mitigation program requires the execution of five steps:

- The development of a methodology of flood damage modelling at the farm scale which account for direct and induced damage
- The comparison of a farm in a standard situation with a farm where measures to mitigate vulnerability have been implemented
- The implementation of this model on farm type representatives of the agriculture activity
- The comparison of mean annualised avoided damage and cost of implementation (applying a discount rate)
- The regionalization of this approach at watershed scale

To achieve the first step, the conceptual model of vulnerability developed at the farm scale enabled us to characterize the formation of direct and induced damages. This in-depth characterization has been formalized in UML in order to make the set assumptions transparent and to be repeatable on each farm type. Moreover, by UML modelling we succeeded in representing the crossing and the relation between the dimensions of the farm vulnerability namely spatial, organizational and temporal ones. Specifically, UML has been useful to clarify the complexity due to the crossing between the different temporalities (flood, farm

hal-00553472, version 1 - 7 Jan 2011

management and crisis management) and the effects resulting from the disturbance on the farming system.

We are now able to compute flood damage on a farm type for several scenarios in terms of period of occurrence (September, December, May), height, duration, speed. We proved that computing damage on crop only was not representative of the global damage on farm. Moreover, we have identified the induced effects on farm functioning at mid term and we proposed methods to evaluate them economically. The next step will be to use this methodology of flood damage modelling to appraise the measures to mitigate farm vulnerability. We will compare the damage incurred by farms which have or have not implemented measures to mitigate vulnerability. We will test two contrasted situations: a farm exposed to flood with frequent but low heights of submersion and a farm rarely exposed with high heights of submersion. It is expected that the measures to mitigate vulnerability are more efficient in case of frequent and small flooding. The cost benefit analysis consists in comparing the cost of implementation and maintenance of the measures and the mean annualised avoided damage that will be computed thanks to the framework presented. Another prospect is to consider the impact of induced effect on farm accountancy in order to take into account longer term effects, especially financial ones (indebtedness).

7 References

Attonaty, J. M., M. H. Chatelin, et al. (1990): L'évaluation des méthodes et langages de simulation In: J. Brossier, B. Vissac and J. L. L. Moigne (Eds.): Modélisation systémique et systèmes agraires. INRA, Paris. 119-133.

Aubry, C., F. Papy, et al. (1998): Modelling decision-making processes for annual crop management. In: Agricultural Systems 56(1): 45-65.

Barbut, L., N. Bauduceau, et al. (2004): Vers une évaluation de la vulnérabilité des activités agricoles aux inondations. In: Ingénieries Eau-Agriculture-Territoires 39: 29-41.

Bauduceau, N. (2001): Eléments d'analyse des répercussions des inondations de novembre 1999 sur les activités agricoles des départements de l'Aude, des Pyrénées Orientales et du Tarn. In: Rapport technique de l'Equipe pluridisciplinaire Plan Loire Grandeur Nature. 111.

Blaikie, P., T. Cannon, et al. (1994): At Risk: Natural Hazards, People's Vulnerability, and Disasters. Routledge, London.

Bremond, P., F. Grelot, et al. (2009): De la vulnérabilité de la parcelle à celle de l'exploitation agricole : un changement d'échelle nécessaire pour l'évaluation économique des projets de gestion des inondations. In: S. Becerra and A. Peletier (Eds.): Risques et environnement : recherches interdisciplinaires sur la vulnérabilité des sociétés. L'Harmattan, Paris. 231-244.

Brossier, J., B. Vissac, et al. (1990): Modélisation systémique et système agraire - Décision et organisation. INRA, Paris.

Brouwer, R. and R. Van Ek (2004): Integrated ecological, economic and social impact assessment of alternative flood control policies in the Netherlands. In: Ecological Economics 50(1-2): 1-21.

Forster, S., B. Kuhlmann, et al. (2008): Assessing flood risk for a rural detention area. In: Natural Hazards and Earth System Sciences 8: 311-322.

Gondard-Delcroix, C. and S. Rousseau (2004): Vulnérabilité et stratégies durables de gestion des risques: Une étude appliquée aux ménages ruraux de Madagascar. In:

hal-00553472, version 1 - 7 Jan 2011

hal-00553472, version 1 - 7 Jan 2011

Développement Durable et Territoires 3 (Les dimensions humaine et sociale du Développement Durable).
Goulter, I. C. and D. R. Morgan (1983): Analyzing Alternative Flood Damage reduction Measures on Small Watersheds Using Multiple return Period Floods. In: Water Resources research 19(6): 1376-1382.
Hervé, D., D. Genin, et al. (2002): A modelling approach for analysis of agro pastoral activity at the one-farm level. In: Agricultural Systems 71(3): 187-206.
Hess, T. M. and J. Morris (1988): Estimating the value of flood alleviation on agricultural grassland. In: Agricultural Water Management 15(2): 141-153.
Lacewell, R. D. and V. R. Eidman (1972): A General Model for Evaluating Agricultural Flood Plains. In: American Journal of Agricultural Economics 54(1): 92-101.
Lacewell, R. D., R. Freeman, et al. (2006): Update of estimated agricultural benefits attributable to drainage and flood control in Willacy County, Texas In. 32.
Longhini, M. (1997): Analyse micro-économique de la vulnérabilité aux inondations - recherche d'un cadre théorique : cas agricole. In. 82.
McDonald, G. T. (1970): Agricultural Flood Damage Assessment: A Review and Investigation of a Simulation Method In: Review of Marketing and Agricultural Economics 38(03): 105-120
Messner, F., E. Penning-Rowsell, et al. (2007): Guidelines for socio-economic flood damage evaluation. In. 181.
Papy, F., J.-M. Attonaty, et al. (1988): Work Organization Simulation as a Basis for Farm Management Advice (Equipment and Manpower, Levels Against Climatic Variability). In: Agricultural Systems 27 295-314.
Penning-Roswell, E., C. Johnson, et al. (2005): The benefits of flood and coastal risk management: a handbook of assessment techniques. Middlesex University Press.
Pivot, J.-M. and P. Martin (2002): Farms adaptation to changes in flood risk: a management approach. In: Journal of Hydrology 267(1-2): 12-25.
Poirée, M. and C. Ollier (1973): Assainissement agricole : drainage par tuyaux ou fossés, aménagement des cours d'eau et émissaires. EYROLLES, Paris.
Reboul, C. (1976): Mode de production et systèmes de culture et d'élevage. In: Economie rurale 112: 55-65.
Roux-Rouquié, M., N. Caritey, et al. (2004): Using the Unified Modelling Language (UML) to guide the systemic description of biological processes and systems. In: Biosystems 75(1-3): 3-14.
SIEE (2005): Inondations du Rhône et de ses principaux affluents de Décembre 2003 en aval de Viviers dans les départements de la Drôme, de l'Ardèche, du Gard, du Vaucluse et des Bouches du Rhône. In: Rapport technique pour la DIREN de bassin / DIREN Languedoc Roussillon. 137.
Turner, B. L., R. E. Kasperson, et al. (2003): A framework for vulnerability analysis in sustainability science. In: National Academy of Sciences (Ed.): Proceedings of the National Academy of Sciences, Washington, 100, 8074–8079.