

Flood management at the basin level in France: Sustainability of local risk-sharing policies

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1. Introduction

Flood risk is the most important natural disaster in France, in terms of the area at risk (20 000 km²), the number of people concerned (4.5 million) and the potential damages caused. According to Munich Re (Munich Re 2005), the number of climatic disasters, including floods, and the losses incurred from these disasters have dramatically increased worldwide over the last 50 years. This is explained both by a higher concentration of people and assets in flood-plains and a higher probability of extreme events linked both to climate change or to the fact that urbanisation, land use and development in rural areas result in greater rainwater runoff (OECD 2006). Since private insurance often chooses not to insure catastrophic risks, many countries, including France, have set-up a national solidarity scheme providing partial or total compensation to victims.

The consequence of rising flood risks is that public expenditures to control floods and to provide coverage of flood damages are increasing rapidly. It is thus urgent to find ways of reducing the costs of flood management and insurance.

Since 2002, France has promoted an integrated basin-wide approach by providing public financial support to so-called “Flood Prevention Action Programs” (introduced in 2002 under the name of *Plans Bachelot* and re-conducted in 2006 under the name *PAPI, Programme d’Action pour la Prévention des Inondations*). For the 2004-2008 period, PAPI programs were financed in 42 basins across France, covering about one quarter of French territory (OECD, 2006). A second call has selected another 15 catchments. Of these 57 programs, 48 were operational at the beginning of 2008, implying a total financial effort of over 1 billion euros (personal communication, Ministry of Sustainable Development. This covers financial contributions from all partners until 2013 and includes the *Plan Grands Fleuves*).

The backbone of these PAPI programs is to finance investments to recalibrate, relocalize or build new flood-defence infrastructure transferring flooding flows from high vulnerability areas (usually urban areas) to lower vulnerability areas (natural land and farmland) in order to reduce overall risks at the scale of the river basin. Other actions are financed by PAPIs (see below), but we focus on risk-reducing policies in the following. Eligible projects are therefore

projects of natural flood-plain restoration (for example the removal of embankments protecting farmland), or projects of farmland over-flooding (through the building of new embankments across the flood-plain, retaining water laterally, or hedges). Locally, the area concerned by these programs can be important. For example, in the case of the Oise-Aisne basin, 7 733 ha are planned to be over-flooded.

Such programs have two important consequences: the first one is that, by reducing overall damage costs, it should help to relieve the pressure on the national solidarity fund which was created by France in 1982 to provide coverage for natural disaster (*Cat-Nat* Fund). The second consequence is that it entails a new spatial distribution of risks at the local level, with potential losers located in rural and farming communities (who are exposed to more frequent and more intense flooding events) and potential gainers located in urban zones (who are better protected). The PAPI programs can then be described in a more theoretical setting as a mechanism which provides a public good: lower risks at the basin level benefit without rivalry nor exclusion to all contributors of the national solidarity fund since less compensation should be claimed. However, the burden to provide this public good is shifted from the national level to the local rural areas. It raises both practical and theoretical questions: should losers get compensation? How should existing compensation schemes be adjusted or reformed to take account of this reallocation of risks at local and national levels?

These questions are addressed in the next three sections. We first describe flood management policies and flood risk insurances in France (section 2). We then analyse the compensation systems that are set-up in the 48 catchment areas participating in the French PAPI flood-plain program (section 3). We finally discuss the limits of existing insurance and compensation systems and how they could best be adapted to this flood-management system (section 4).

2. Flood risk management and insurance in France

An important feature of flood risks is that hazards are of natural *and* of man-made origin (for example urban areas increase water runoff), and that vulnerability is determined by inherent characteristics *and* by human decisions (for example the choice to live in a flood-prone area). To some extent, flood risks are the “least natural” of natural disasters because they greatly depend on infrastructure and activities upstream of the basin. It is therefore increasingly acknowledged that flood issues should be dealt with through collective decisions at the basin level. In addition, the prevention and management of natural provides public benefits, justifying therefore intervention of state or local authorities (OECD 2006). The main issue is to decide the optimal level of public good provision: from the national level –for weather forecasts or for insurance for example– to the local level, when benefits are circumscribed to a given area or require specific information.

The three main tools of flood risk management in France are: Risk Prevention Plans; a national solidarity fund to compensate the victims of natural disasters and Flood Prevention Action Programs PAPIs.

2.1. Risk Prevention Plans

Risk Prevention Plans (RPPs or *Plan de Prévention du Risque – PPR*) are the main zoning instrument in France. RPPs are set up by the central government, through the responsibility of its local representative, the *préfet*. They identify the limits of flood plains and establish a mapping of different hazard zones, each of which is associated to specific regulatory restrictions. For example, new constructions are prohibited in the high risk areas, the *red zones*, and are contingent on the respect of threshold values in the medium risk areas, the *blue zones*. Other areas (yellow zones) impose special restrictions on rescue units or public hospitals. Although this mapping can be subject to negotiations with local stakeholders to

make it more acceptable, RPPs exemplify the top-down regulatory approach to flood protection in France.

2.2. National solidarity schemes for natural disasters

Compensation schemes are organized through public-private cooperation between the central government and insurance companies. Two main systems exist, depending on whether they apply to the agricultural sector or not. The so-called National Catastrophes (*Cat-Nat*) system applies to private buildings (including motor vehicles), professional buildings and trading losses. The FNGCA, National Fund for the Guarantee of Agricultural Losses (*Fonds National de Garantie des Calamités Agricoles*), and more recently the Multi-Risk Climatic Insurance (*Assurance Multi-Risques Climatiques*) apply to losses incurred by the agricultural sector. This public-private cooperation scheme is due to the low insurability of many natural disasters, especially flood risks. Indeed, the systemic component of flood risks is important, moral hazard is not easily controlled (insured people adopting riskier behaviour, i.e. moving to a flood-prone area where land prices are lower) and adverse-selection is preponderant (the insurer facing only those clients who are interested in insurance protection, i.e. individuals who are at risk).

The Cat-Nat system, established in 1982, embodies French national solidarity for catastrophic events. It is managed by three actors: the central government, insurances and the French public reinsurance company *CCR (Caisse Centrale de Réassurance)*. A fixed percentage of all property-damage insurance-premiums (12% since 1999) is levied for this solidarity fund. This fund is then used to compensate victims of all state-declared natural catastrophe, after application of a deductible that is fixed in the insurance contract. Only if individual action is not conforming to legal requirements (for example a prohibited construction in a high risk area of a Risk Prevention Plan), can this insurance guarantee be turned down. Insurance companies can reinsure themselves with the *CCR* and claim a governmental guarantee for catastrophes exceeding a certain size.

The agricultural solidarity fund (*FNGCA*) created in 1964 applies to all non-insured natural disasters striking agricultural production. It is based on intra-sectoral solidarity. 11% of agricultural building-insurance premiums are levied for this fund, matched by equivalent subsidies from the Ministry of Agriculture. Compensation is also conditional on a formal Declaration of Natural Catastrophe, issued by a commission composed of representatives of the farm sector, of insurance companies and of the Ministries of Agriculture and Finance), and based on local information collected by the decentralized services of the Ministry of Agriculture (*DDA*) and a Departmental Expertise Committee.

In order to be compensated, farmers have to incur minimum losses of at least 30% of the theoretical turnover of the concerned cultivation and 13% of the expected total turnover of their farm. Only 75% of total losses are compensated. Yet, in practice and due to numerous restrictions, the ratio of indemnification over losses remains low, at an average of 30%, therefore raising frustration and discontent among farmers. This is one of the reasons why the *FNGCA* is being progressively replaced by a new system relying on the private insurance sector: the multi-risk climatic insurance.

The multi-risk climatic insurance covers a wide range of climatic risks: hail, frost, drought, storms, floods and excess of water. It is a yield-insurance on cultivations, which has to be subscribed either for the entire farm area or for the entire area cultivated with a specific crop. Prices and yields are guaranteed on the basis of the (olympic) mean of the five previous seasons. During the testing phase (which is still running at the beginning of 2008), insurance premia are subsidised by public funds (at about 30%). With the multi-risk insurance, the damage payment is conditional on an expert report, which verifies the occurrence of the

natural disaster and the cause and effect relationship between the disaster and the yield. Only if some damages are not covered by the multi-risk climatic insurance can the farmer claim additional *FNGCA* payments. Otherwise he gives up the possibility to get compensation from *FNGCA*.

2.3. Flood Prevention Action Programs

Flood Prevention Action Programs, or *PAPIs*, promote an integrated basin-wide approach to flood risk management. Most often, *PAPIs* are developed and implemented by a water and flood management institution (called water manager thereafter) led by an elected group of representatives of all local councils in the basin. The programs include actions to improve local people's knowledge about floods, to set-up prevision and warning systems, to continue the protection of housing and the reduction of vulnerability with RPPs, to allow the local protection of urban areas with new infrastructure building and to promote the regulation of water flows within the flood plain through "dynamic flood retention" (*ralentissement dynamique*).

The last two points in particular may imply the over-flooding of certain areas. In many places, hence, farmers are exposed to more frequent or more intense flooding events after the implementation of *PAPIs*. The problem is that existing compensation systems cover quite badly this situation: the *FNGCA* compensation system does clearly not apply to "artificially" flooded areas and private insurers can exclude flooded and over-flooded areas on a case by case basis. The agricultural sector can thus be left without any protection. This is the reason why local water management authorities have tried to link negotiations on flood prevention with negotiation on compensation payment schemes.

In case of newly "over-flooded" areas, the national law (especially the 2003 Act) has foreseen the possibility to introduce compensation payments and gives water managers the right to impose easements on the use of land. When it comes to the restoration of natural flood plains, the law remains unclear about the right to compensation. In both cases, local authorities can design their own compensation rules.

Thus, although the 2003 Act does set a general framework for risk reallocation, local water managers are left with no guidance on important decisions: how should compensation payments be computed? Who evaluates the potential damage? Who finances the damage payments? Shall a local indemnification fund be created? What is the link between these local compensations and the existing national solidarity systems? What role should (re)insurances play in this system?

We have analysed the way those local compensation mechanisms are set-up at the basin-level, by conducting an exhaustive survey on all French *PAPI* programs. We are particularly interested by two issues: how are potential damages evaluated in the different river basins? How are local compensation systems embedded into existing national compensation systems? These points are discussed in the next two sections.

3. Compensation mechanisms at the basin level: a nation-wide survey

We conducted an exhaustive survey between November 2006 and April 2007 on the 48 river basins in France which had signed a Flood Prevention Action Program with the Ministry (cf. MEDAD 2007). Out of these 48 programs, only 27 projects had made sufficient progress to be able to respond to our questionnaire concerning their strategic choices in terms of protection and compensation. We also conducted four detailed surveys on four basins with in-field interviews of Flood Prevention Action Program managing structures, farmers associations, and governmental services.

Most local water managers point up the concept of solidarity (either upstream-downstream or rural-urban or both) to justify the implementation of Flood Prevention Action Programs and the risk redistribution they imply. Most people exposed to greater risks as a consequence of PAPI implementation (especially land owners, farmers, or representatives of agricultural associations) actually agreed with the general concept proposed in these programs. On the other hand, most local water-managers estimated that the better protected –urban– population should –and were willing to– contribute to these projects, either financially or politically. This solidarity is embedded into the organisation of water management institutions, which are financed by their members (communes and groups of communes). Each commune contributes financially to the water management institution according to a distribution key that is negotiated when it is created. In most cases, contributions are calculated according to the density of the population, the fiscal power of the communes and the relative impact of floods (see below).

One of the first conclusions of this survey was that river basin institutions lack guidance to design compensation schemes that are acceptable by farmers and that can be financially sustainable. Only eight river basins succeeded in signing a compensation protocol, in which a reference framework for the evaluation of damages and prejudice was clearly established at the basin level. In addition, only one basin had transposed the framework protocol into a local protocol, in which detailed conditions for indemnification payments are fixed. The following discussion summarises the main issues at stake in the different river basins and describes the range of agreements made in these eight basins.

The easiest solution for the local water manager would be to simply purchase (or expropriate) the land exposed to increased risks. Although this would entail a negotiation on the purchasing price or expropriation indemnity, it would have the advantage to eliminate the compensation issue for future flooding. This solution is sometimes envisaged for highly exposed areas but it cannot be generalized for several reasons: local water institutions have rarely the skills and equipment to ensure land maintenance and must therefore contract out the maintenance task (the most common solution is then to let the previous owner farm the land for a negotiated below-the-market rental rate); and landholders are often reluctant to sell their land. In some cases, the size of the area at risk is too big and it would be too costly for the local water institution to buy the land.

Compensations to landholders and farmers when land is not purchased or expropriated include two parts:

- An *ex-ante* indemnity compensates once-and-for-all both the face value of land (due to easements and increased risks) and the farming constraints imposed by easements (paid to the farmer when he is not the landowner).
- An *ex-post* indemnity paid to the farmer to compensate for damages to land and crops each time flooding –over the natural rate– occurs.

This damage compensation is of course the most controversial since it raises three issues: how to define over-flooding? How to value damages correctly and avoid moral hazard? What is the sustainability of locally created compensation funds?

- **The definition of over-flooding:** Theoretically only damages resulting from “over-flooding” should be compensated. The notion of “over-flooding” entails that the “flooding” situation is defined. Is it the flood occurring in the without-PAPI situation? Or is it the flood that would occur naturally in the absence of any human-made infrastructure? This second interpretation, which is the one retained in the 2003 law risk, should logically forbid farmers who are affected by projects of natural flood plain restoration to claim a compensation.

However, the choice of the reference situation remains controversial and most river basins have chosen to make distinctions, in their compensation schemes, between genuine over-flooding and restoration. The majority of them thus refer to the current situation when they define “over-flooding” and not to the “naturally occurring” situation. Still, the level of “over-flooding” is not easily defined. It entails to be able to calculate what would have been the flooding situation in the without-PAPI situation. Since a flood is described by many parameters (height, volume and flows at peak time, time length of the submersion etc.), it can become tricky to define the exact impact of the PAPI project or infrastructure because it will not affect all those parameters in the same way. None of the 8 protocols specifies a clear methodology to qualify “over-flooding” or to define the reference flood. Appreciation is left to experts who will be nominated by the basin committee after each flood.

- **Evaluation of damages and control of moral hazard:** Most protocols mention that damages should be evaluated by an independent expertise but they restrict the list of damages that can open a right to compensation: damages to crops are always included but some protocols include commercialisation losses (due to reputation loss or contract loss) and soil damages. The financial compensation is then either calculated on evaluated losses or on a fixed basis depending on the kind of crop cultivated, the type of soils, and the occurrence time of the flood. This second solution (evaluation on the basis of fixed damages) reduces the moral hazard problem associated with a full compensation system (i.e. farmers adopting a more risky behaviour than they would otherwise do) and can help the water manager to better anticipate compensation expenditures. It has the inconvenient, however, to be dependent on the first initial expertise. Two information sources are mobilized to evaluate fixed potential damage levels: the FNGCA list of damages and estimations from the agricultural profession. It has to be underlined that one river basin, which has not signed a protocol yet, is planning an entirely different system in which farmers would get a guaranteed annual subsidy, disconnected from the actual floods, and no further compensation. This system would transfer the whole risk on the farmer, who would then be responsible for his own insurance strategy.

- **Sustainability of the compensation fund:** In the most advanced compensation protocols, several clauses limit the risk supported by local water institutions. For example, the delimitation of the impacted area is an element of the protocol. Farmers outside this area cannot claim compensations. In addition, the amount of unitary damages is often explicitly mentioned so that the water-managers can calculate what they will have to pay in the worst case. Any revision of the calculus has to be accepted by both parties.

Very few water managers have a financial strategy to capitalize for the compensation fund. None of the protocols has planned an insurance system for the compensation fund. Disregarding what risk analysts would recommend, they are judging that their financial reserves are sufficient to cover an “average risk”, based on their estimations of the decennial flood. However, it is obvious that should floods occur with greater frequency, or should the protocols concern vast areas, they would soon have to face bankruptcy risks. The last section describes what could be done to avoid this.

4. What level of risk transfer?

In order to organise the risk transfer, we consider five different solutions involving the government, local water manager and insurers.

4.1. Reinforced national compensation funds for agricultural losses

One obvious solution is the reform of the national public fund, the FNGCA and its extension to areas that are over-flooded or re-flooded through the restoration of natural flood plains. However, the government has not planned to extend the fund to those cases, although they are

triggered by publicly supported programs which intend to reduce overall risks. This is explained by the fact that the FNGCA system is already facing fundamental problems of sustainability, recent droughts having seriously put to the test the French compensation system. The government therefore favours a re-orientation towards private insurances.

4.2. National insurance encompassing agricultural losses and other losses

An extreme solution would be the establishment of an entirely private insurance system, encompassing agricultural assets and non-agricultural assets and addressing simultaneously the rural and the urban sectors. The problem here remains the non-insurability of most natural disasters. Indeed, the possibility of risk-pooling is low because of an important systemic component of natural disasters, occurrence probabilities are not always known and premium calculation is difficult. Our survey has shown however that private insurers are not interested in designing flood-related contracts because “insured capital is relatively small relative to the necessary costs for surveys and studies” in order to establish a prevision of damages and to help calculate premia.

Rendering insurance contracts compulsory and mutualising rural and urban risks may probably mitigate somehow this problem by making the risk less catastrophic and more predictable and by addressing the adverse selection problem. But this would imply to reform the Cat-Nat system and to change the regulation over private insurance.

4.3. Locally managed basin-wide compensation funds for agricultural losses

This is the existing situation. The local water management authority sets up a basin-wide “compensation provision fund” which only applies to flood risks. This “fund” is essentially financed by the members of the authority, the different local councils. In fact, it is legally not allowed to manage a fund which could earn interests on the financial market because the water management authority is a public entity. The water manager can only estimate loss probabilities, and then set up provisions for exceptional charges. Expected losses are estimated either based on historical data or based on information given by the agricultural profession. Insurance experts may also be solicited. Average damages are seldom computed and not really of interest for the local water manager because his risk mutualisation capacity is weak.

It is not excluded thus that the water management institution runs into financial difficulties (i.e. if financial provision are run out by several years of exceptional damages) and cannot face its commitments in terms of compensation. This may depend on three elements: the delimitation of (restricted) responsibilities in the framework protocols, the accuracy of damage evaluation and the consideration of (a series) of flooding events, including low probability events occurring in the near future.

4.4. Basin-wide compensation funds for agricultural losses, managed by insurance companies

In this scenario, the insurance company plays the role of a re-insurer of the local water management authority. The local authority is in charge of defining the compensation system but it can re-insure itself against its own bankruptcy with an insurance company. This scenario has several advantages: For the insurance company, information asymmetries are reduced because of the detailed knowledge of local water managers. In addition, the costs of studies are less important for evaluating a risk of bankruptcy than for calculating a specific flood risk. Finally, the (re)insurance company can diversify its activities by covering not a climate risk *stricto sensu* but a risk of bankruptcy.

4.5. Private insurance for agricultural losses, subsidized by local water managers

This scenario describes a private insurance covering losses from flood risks and other risks in the agricultural sector, while being partly subsidized by the local water management authorities. In the case of over-flooding, the distinction between the idiosyncratic and the systemic risk is quite clear: before the implementation of the program, the individual is supposed to be outside the flooding area and is only subject to an idiosyncratic risk. After the implementation of the program, the artificial over-flooding exactly corresponds to the systemic risk he endures. Then, according to standard results in the literature (Raviv, 1979, Doherty and Schlesinger, 2002, Mahul, 2002), the optimal design of an insurance contract is based on the decomposition of risks into two elements: the non-diversifiable systemic risk and the diversifiable idiosyncratic risk.

With this decomposition, it is possible for the insurance company to use two different instruments to address the entire risk, notably participating policies and weather derivatives. This combination of contacts is optimal to cover combined idiosyncratic and systemic risks (cf. Enjolras and Kast 2007). Participating policies are already developed in life and car insurance. The main advantage of this instrument is that it reduces information asymmetries, because a large part of the responsibility lies with the insured. However, by construction, they are only designed for low-risks, not for catastrophic losses. Weather derivatives (or weather-risk contracts) may cover catastrophic losses. They are characterized by an underlying asset that is not traded, for example rain. Clearly, the market of weather derivatives is still marginal, and more easily accessible for insurance companies, but growth is regular and first applications to the agricultural sector are promising.

This combined policy could be interesting for the three types participants: the insured, the insurer and the local water management authorities.

The affected farms would benefit from a contract, which completely covers the risk they support. The insurers would minimize their potential losses by covering the idiosyncratic risk through a variable premium and securitizing the systemic risk on financial markets. They would also be confirmed as the main actors in the management of climatic events (setting the most appropriate premium etc.). The local authorities would limit their intervention to the subsidization of the insurance premia, a role they would probably play more easily than managing a fund. Moreover, their financial intervention could contribute to maintaining premia at a fair level.

Of course, this clear-cut distinction between individual and systemic risk is only possible for the very special case of over-flooding. But the principle can also work for other cases, where the initial risk exposure increases, for example through the restoration of natural flood plains.

4.6. Comparative advantages of the different systems

Each of the above policy options may be assessed with respect to the following criteria:

1. the long-run viability of the system,
2. the quality of risk coverage for the farmer,
3. the type of damages valuated and the costs triggered by the valuation,
4. the solidarity principle: who bears the costs of damage payments ?

1. The greater the financier's perimeter of intervention, the greater the scope for mutualisation of risks. Thus, a reinsurance company has greater chance to spread risks than a local water authority, an insurance company or the government. The question is whether a reinsurance company is interested in insuring a river basin manager –or a union of river basin managers.

On the other hand, the closer the financier to the local people, the better his information. For example a river basin manager may know every single concerned individual (or farmer) and may be able to evaluate his “type”. He may also be able to indicate naturally flooded and over-flooded areas quite precisely. Thus, he can address better the issue of adverse selection. This general fact may be attenuated when introducing more complex insurance tools, such as participating contracts in which the insured has an incentive to reveal his true “type”.

2. While insurance systems, compared to the FNGCA fund, have the advantage to offer a large coverage to the insured, there is still the risk that they choose to exclude some types of individuals from insurance, or only offer protection at prohibitively high prices. This is why a pure private insurance system should be rejected.

3. An important advantage of insurance companies compared to public decision makers is that they are able to reduce two sorts of costs: the costs of the management of funds and the costs of evaluating damages. Concerning the former, the insurance company may cover itself through weather derivatives or through re-insurance contracts to which other financing entities do not have access or for which they would not be able to compute the optimal investment. Concerning the latter, the insurance employs usually a network of experts and has created a database on the history of past catastrophic events and compensated damages, therefore generating economies of scale that are not easily matched by parallel evaluation systems. The insurance company has the role of a competent intermediary. The costs of hydrological and hydraulic studies in turn are probably lower for the public water management authorities, because they have already conducted and are able to model different types of floods and to evaluate the impact of particular protection infrastructure.

Both, insurance companies and local water management authorities currently tend to focus on direct damages and underestimate the impacts that are more difficult to value, such as environmental damages or stress. Yet, economic valuation methods exist which allow taking this type of damages into account (for example hedonic pricing, choice modelling or contingent valuation methods). It is probable that local water managers will tend to adopt these methods more easily than insurers as local managers are more interested in a holistic view of flood risk management than insurers (cf. Grelot 2004, Kast and Lapied, 2006 chapter 4).

4. In all of the above policy options, damage payments are born by a particular class of people. For example, it could be decided that the urban population bears the costs for the additional risk that is imposed on farmers. This could be realized through direct payments to a compensation fund, through increased contributions to the local water management authority or through an increase in a compulsory insurance premium. Hence, the above policy options have the same potential for implementing local solidarity.

5. Conclusion

This paper describes how France is currently trying to improve its flood management policy by financially supporting the setting up of action plans designed at the flood basin level to reallocate flood risks from the most vulnerable areas to the least vulnerable zones. The advantage of such system is to reduce overall flood damages in a given basin, and by the same token, to relieve pressure on the national solidarity fund which compensates victims of natural catastrophes. On the other hand, it shifts the risk burden onto the agricultural and rural sector, without setting-up the right mechanisms to ensure proper compensation of these new “victims”. This paper describes several solutions which could be mobilized in order to design a fair and sustainable risk-sharing policy. They range from a reinforcement of the existing system based on two national solidarity funds covering natural disasters, to a total

privatisation of risk insurance, including catastrophic risk. There are intermediary solutions which are worth exploring further because they maintain the concept of solidarity together with a safer coverage of damages.

Bibliography

Doherty, N. A. and H. Schlesinger (2002) Insurance Contracts and Securitization. *Journal of Risk & Insurance* 69: 45-62.

Enjolras, G. and R. Kast (2007) Using participating and financial contracts to insure catastrophe risk: Implications for crop risk management. Paper for the *EAAE Seminar "Management of Climate Risks in Agriculture"*, Berlin, Germany, July 5-6, 2007.

Grelot, F. (2004) *Gestion collective des inondations - Peut-on tenir compte de l'avis de la population dans la phase d'évaluation économique a priori ?* Thèse de l'Ecole Nationale Supérieure d'Arts et Métiers, Paris, 383p. + annexes.

Kast, R. and A. Lapiéd (2006) *Economics and Finance of Risks and of the Future*, Wiley-Finance)

Mahul, O. (2002) Coping with Catastrophic Risk: The Role of (Non-) Participating Contracts. Paper presented at the *29th Seminar of the European Group of Risk and Economists*, Nottingham, September 16-18, 2002.

MEDAD, French Ministry of Environment <http://www.ecologie.gouv.fr/-Inondations-.html>

MEDAD (2007) *Expertise des pratiques de compensation en cas de transfert d'exposition aux inondations* Brémond, P., Bretron, C., Enjolras, G., Erdlenbruch, K., Grelot, F., Kast, R., Thoyer, S. ed: MEDAD.

Munich Re (2005) *Topics Geo – Annual Review: Natural Catastrophes 2004*, Munich Re, Munich.

OECD Studies in Risk Management – France: Policies for Preventing and Compensation Flood-Related Damage, OECD 2006.

Raviv, A. (1979) The Design of an Optimal Insurance Policy. *American Economic Review* 69: 84-96.