

Risk-sharing policies in the context of the French Flood Prevention Action Programmes

K. Erdlenbruch^{(1)*}, S. Thoyer⁽²⁾, F. Grelot⁽¹⁾, R. Kast⁽³⁾, G. Enjolras⁽⁴⁾

(1) Cemagref, UMR G-eau, 361 rue J.F. Breton – BP 5095, 34196 Montpellier Cedex 5 France.

(2) Montpellier Supagro, UMR Lameta, 2 place P. Viala – 34060 Montpellier Cedex 1, France.

(3) CNRS, UMR Lameta, 2 place P. Viala – 34060 Montpellier Cedex 1, France.

(4) UMR Lameta, 2 place P. Viala – 34060 Montpellier Cedex 1, France.

* Corresponding author: Tel: +33467040387, Fax: +33467166440, e-mail : katrin.erdlenbruch@cemagref.fr

Abstract: This article analyzes the consequences for risk distribution of the French Flood Prevention Action Programme (PAPI). By redirecting floods from the most vulnerable to the least vulnerable areas, PAPIs expose farmers to greater flood risks. This has led local water management institutions to introduce compensation payments. The article outlines the results of an exhaustive survey of all PAPI programmes in France, which examined the way the compensation policies are set up locally. Results of the survey showed that the proposed policies may be financially non-viable. Several more viable risk-sharing solutions are then discussed, involving insurance schemes, state intervention and local institutions.

Key words: flood risk management, flood storage, washland creation, risk transfer, compensation payments, insurance, floodplain restoration, over-flooding, damage assessment.

1. Introduction

Over the last 50 years, the costs of flood damage have steadily increased (Munich Re). This may be explained by the higher concentration of people and assets in floodplains, and by increased rainwater run-off linked to urbanisation (OECD 2006). As a consequence, public expenditure to control floods and compensation paid for damage are also increasing steadily and governments are looking for more efficient flood risk management methods¹. Because human activities have a direct impact on flood risk, it is increasingly acknowledged that flood issues should be dealt with through an integrated, basin-wide approach. In addition, more “natural” flood risk reduction measures are now being promoted in many European countries: instead of building additional prevention infrastructure, recommendations are to learn to “live with floods” and to “make space for water” (Johnson et al. 2007, Hansson et al. 2008).

This integrated approach is also reflected in the 2007 European Directive on the Assessment and Management of Floods: in addition to the assessment and mapping of flood hazards and flood risks, it recommends the use of Flood Risk Management Plans which include non-structural protection measures, for example the restoration of floodplains and wetlands (Directive 2007/60/EC, Evers 2008, Kenyon et al. 2008).

The European Flood Risk Management Plans are mirrored in the French “Flood Prevention Action Programmes”, also called PAPI². The main purpose of the PAPI programmes is to

¹ This mainly concerns the reduction of economic and financial costs, but also better management of the social impacts of flooding which in turn trigger costs.

² *Programme d'Action pour la Prévention des Inondations*. The 2003 Act on Risks has strengthened the main ideas of PAPI programmes.

reduce overall risks at the scale of the river basin³. PAPI programmes provide financial support to projects which are environmentally sound, based on collective decision making, and cost efficient. However, the French government does not use explicit cost-benefit or scoring rules to select projects, contrary to the practice in other European countries, for example in England (Johnson et al. 2007). A variety of policies and tools are eligible for PAPI programmes, as long as they are adapted to the local situation (see section 2 for a more detailed description of PAPI programmes).

One important part of the PAPI programme is to transfer flood flows from highly vulnerable areas – usually urban areas – to less vulnerable areas, such as natural land and farmland. The implementation of these programmes entails a new spatial distribution of risks at the local level, with potential losers located in rural communities and potential winners located in urban zones. In addition, existing national compensation systems for natural disasters (see section 2) may no longer apply where PAPIs are implemented. This has led local water management institutions (hereafter referred to as WMI) to organize a new – purely local – compensation system which is the main focus of this article.

Different authors have discussed the impact of flood storage policies in England and Scotland (Johnson et al. 2007; Kenyon et al. 2008; Morris et al. 2008 and Posthumus et al. 2008) or the impact of more natural flood prevention policies in Europe (Evers 2008, Hansson et al. 2008, Moss and Monstadt 2008). Morris et al. propose an evaluation method to measure the impact of the creation of washland on agricultural activity. Hansson et al. propose a general framework for the evaluation of national flood prevention policies, including the interaction between re-naturalisation policies and compulsory insurance schemes. Johnson et al. (2007) take a slightly different approach by discussing the *fairness* of different flood risk management policies in England. Our article concerns the creation of washland in France. In contrast to the existing literature (Hansson et al. or Morris et al. 2008 for example), it focuses on the role of *local* compensation mechanisms and the interactions between *local* and *national risk-sharing policies*.

The implementation of PAPI programmes shifts the solidarity burden from the national to the local level. This raises both practical and theoretical questions: how should losers be compensated? Is a local compensation fund financially viable? How should the existing national solidarity fund be adjusted to account for this reallocation of risks at local and national levels? How can private insurance companies be drawn into the compensation schemes?

These questions are addressed in the next three sections. Section 2 gives an overview of the main public flood management policies and the flood risk insurance system in France, including the PAPI programme. Section 3 describes the results of an exhaustive survey of the 48 water basins in the French PAPI programme and analyses the new local compensation systems that have been set up at basin scale. Section 4 discusses how new local and existing national insurance and compensation systems could best be combined. In the final section, some conclusions are drawn.

³ Flood risk assessments and hazard and flood risk maps already exist in France.

2. Flood risk management and insurance in France

Among the main flood risk management tools in France, three are of particular interest for the present study: Risk Prevention Plans, Flood Prevention Action Programmes, and the national solidarity systems to compensate the victims of natural disasters. RPPs and PAPIs are prevention tools *strictu sensu*, solidarity systems mainly operate after a disaster has occurred. Other existing tools, such as weather forecasting or crisis management, are not described because they are less directly related to the risk-sharing issues discussed here.

2.1. Risk Prevention Plans

Risk Prevention Plans (RPPs or *Plan de Prévention des Risques – PPR*) are the main zoning instrument in France (see Barnier Act 1995, Pottier et al. 2005). They identify the limits of floodplains and define different risk zones, each of which is associated with specific regulatory restrictions: for example, building is prohibited in high risk areas. The main purpose of zoning policies is to limit the number of vulnerable persons and assets in risky areas, and consequently to control possible expenditure associated with damage compensation. Where they have been implemented, RPPs have strictly limited the extension of urban areas in floodplains. Flood prevention policies can therefore focus on better protecting *existing* urban hazard zones which is the objective of the PAPI programmes.

2.2. Flood Prevention Action Programs

Introduced in 2002 under the name of *Plans Bachelot* and renewed in 2006 under the name PAPI, (*Programme d'Action pour la Prévention des Inondations*), Flood Prevention Action Programmes, are policy packages which are designed locally and selected for financial support by the government following competitive bidding. PAPIs promote an integrated basin-wide approach to flood risk management⁴.

At the beginning of 2008, PAPIs were being financed in 48 catchments across France, for a total investment of about 750 million euros (Ministry of Sustainable Development, personal communication)⁵. Selected catchments are scattered throughout France, and cover a wide range of flood risks: from small (< 100 km²) to large catchments (> 10 000 km²), from very urbanized zones to rural areas, from rapid floods to floods with slow dynamics.

Each PAPI is managed by a local water management institution (WMI) which is most often a self-selected group of local governments and municipalities whose territory is concerned by flood risk. The WMI's budget is paid by the local taxpayers: each municipality (or *commune*) contributes financially to operating costs and to the compensation budget of the WMI according to a distribution key that is negotiated when the WMI is created. In most cases, contributions are calculated according to the density of the population of each *commune*, the wealth of the *communes* and the relative exposure of each *commune* to floods. Investment expenditures are mostly covered by the government's financial allocation to PAPI programmes.

PAPI programmes include a variety of policies and actions designed to: improve local people's knowledge about floods, set up forecasting and flood-warning systems, reduce the

⁴ They are complementary to the *Plans Grands Fleuves*, which are designed for flood management of the main French rivers (Loire, Seine, Rhône, and Garonne).

⁵ In the period 2004-2008, 42 PAPI projects were financed, covering about one quarter of French territory (OECD, 2006). Another 15 projects were selected after a second call of projects in 2006, some of them being the extension of previously selected projects.

vulnerability within RPPs, offer local protection for urban areas with new infrastructure, and promote the regulation of water flows within the natural floodplain.

The last two points are achieved primarily through “over-flooding” of certain areas, i.e. an increase in flood hazard and/or flood intensities, compared to the existing situation. Two types of “over-flooding” policies should be distinguished: the *restoration of natural flood plains*, for example the removal of embankments protecting farmland, and projects of *deliberate farmland flooding*, e.g. planting hedges or building embankments across the floodplain to retain water laterally. The distinction between these policies is crucial. *Deliberate flooding* implies that a *new hazard* is created, whereas *floodplain restoration* implies that existing infrastructure is adjusted to *return to the baseline situation*. The baseline is theoretically the level of risk that would prevail in the absence of infrastructure. Of course, it is technically and legally controversial to define such a level, especially in basins where many structural interventions have been made in the past to redirect flood flows. The area concerned by these actions can be big at the local scale: for example, in the case of the Oise-Aisne basin, 7 733 ha are planned to be over-flooded.

2.3. National solidarity schemes for natural disasters

When flood damage occurs, victims can be partially compensated through financial schemes resulting from public-private cooperation between the central government and insurance companies. Two main systems exist in France: the National Catastrophe System (*Cat-Nat*) covers all insured households and assets which are not linked to agricultural production; the National Fund for the Guarantee of Agricultural Losses (*Fonds National de Garantie des Calamités Agricoles*, FNGCA) applies exclusively to losses in the agricultural sector (agricultural production, stock, etc.). The FNGCA is currently being reformed and replaced by a private system: the Multi-risk climatic insurance.

The *Cat-Nat* system, which was set-up in 1982, embodies French national solidarity in the face of catastrophic events. It is managed by three actors: the central government, private insurance companies 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. The fund is then used to compensate victims of all state-declared natural catastrophes, after application of a deductible that is specified in the insurance contract. Only if an individual action does not conform with legal requirements (for example prohibited construction in a high-risk area of a Risk Prevention Plan), can this insurance guarantee be refused. Insurance companies can reinsure themselves with the *CCR* and claim a governmental guarantee for very big catastrophes.

The FNGCA was created in 1964 and applies to all non-insured natural disasters affecting agricultural production. It is based on intra-sectoral solidarity. Eleven percent of agricultural building insurance premiums are levied for this fund, matched by equivalent subsidies from the Ministry of Agriculture. Compensation is paid to farmers provided there is a formal Declaration of a Natural Catastrophe by a national commission. Farmers have to incur minimum losses of at least 30% of the average gross margin of the crop concerned and 13% of the expected total turnover of their farm. Only 75% of total losses can be compensated. Yet, in practice and due to a number of restrictions, the ratio of damages paid to losses incurred remains low, i.e. an average of 30%, leading to dissatisfaction and resentment among farmers. This is one of the reasons why the FNGCA is being progressively replaced by a new system that relies on the private insurance sector: multi-risk climatic insurance (Barbusiaux 2000; Ménard 2004; Mortemousque 2007).

Multi-risk climatic insurance covers several climatic risks together: hail, frost, drought, storms, floods and excess water. It is a crop-yield insurance. It can only be subscribed for the entire area cultivated with a specific crop (or for the entire farm but this is rare). Yields are guaranteed on the basis of the mean individual performance in previous growing seasons. During the testing phase (which was still underway at the time of writing), insurance premiums were still heavily subsidised by public funds (at about 30%). Damage payments are defined by the insurance expert, who checks that a natural disaster has actually occurred and evaluates the causality link between the disaster and the observed yield. Currently, multi-risk climatic insurance is run as a parallel system to the FNGCA but it is expected to progressively replace the FNGCA.

2.4. Reallocation of risk in PAPI programmes

In many places, farmers are exposed to more frequent or more intense flooding events after the implementation of PAPI programmes. In the case of *deliberately* flooded areas, the French law (in particular the 2003 Act) gives the WMI the right to impose easements on the use of land and has foreseen the introduction of compensation payments. Concerning the *restoration of natural floodplains*, the law remains unclear about the right to compensation. But locally, for acceptability reasons, the WMI also foresees compensation for farmers affected by the restoration of floodplains.

The main problem with the PAPI programmes is that existing compensation systems do not cover the situation satisfactorily. The FNGCA compensation system is not supposed to cover the risks incurred by “artificially” flooded areas, and private insurers are also free to exclude flooded (and over-flooded) areas on a case-by-case basis. Farmers fear being left without the usual protection, even if the WMI commits to pay for the *additional degradation* linked to the situation caused by over-flooding.

This is why farmers claim compensation for the entire expected damage. Although the 2003 Act does provide guidelines for risk allocation and compensation mechanisms, local solutions set up by WMIs may vary widely and have different consequences in terms of financial viability. The following section analyses the way the different compensation systems are set-up by WMIs.

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

3.1. The survey

We conducted a survey between November 2006 and April 2007, sending questionnaires by post and e-mail to the WMI managers of the 48 river basins in France that had signed a Flood Prevention Action Programme with the Ministry and that were operational at the time of the study (MEEDDAT 2007). We were particularly interested in two issues: first, how potential agricultural damage is evaluated in the different river basins, and second, how local compensation systems are embedded in existing national compensation systems. The questionnaire was in two parts: the first part aimed at describing the stakes in the catchments and identifying the technical solutions envisaged to reduce flood risk. The second part of the questionnaire addressed the issue of urban-rural compensation systems and their links with existing solidarity funds and insurance schemes. Only river basins with relatively advanced PAPI projects were able to answer the second part of the questionnaire.

All 23 river basins that were sufficiently advanced in their management plans responded to the second part of our questionnaire. The results of this survey are therefore representative of all the PAPI basins that were “operational” at the time of our study⁶. We also conducted detailed field surveys in four basins, selected because they illustrated the variety of situations encountered in France: Meuse (a large basin in the North of France), Isère (a large basin in a mountainous region), Touloubre (a small rural basin in the South West), and Lèze (a small urbanized basin in the South East). This part of the survey included interviews with water management structures, farmers and farm associations, local governments, governmental services, as well as insurance companies. A summary of the results of the two surveys⁷ is presented below.

3.2. Solidarity as a driver for risk-transfer

The questionnaire specifically addressed the issue of acceptability by asking water managers what kind of arguments they used to defend risk-transfer policies triggered by PAPI programmes. Although they could only give qualitative answers, their responses converged: most WMI managers put forward the concept of solidarity (either upstream-downstream or rural-urban or both) to justify the implementation of Flood Prevention Action Programmes and the risk redistribution they imply. As many interviewees stated, the concept of solidarity is in fact already embedded in the organisation of WMIs, which are financed by their members (local governments or municipalities).

Our field surveys confirmed that most people exposed to greater risks as a consequence of PAPI implementation (landowners, farmers, or representatives of agricultural associations) actually agreed with the general risk reallocation concept embodied in the programme. In addition, most WMI managers interviewed believe that better protected urban populations are willing to contribute to PAPI programmes, either financially or indirectly (by facilitating their implementation). We did not specifically address the issue of equity and social justice in this survey, but see Johnson et al. 2007 for a discussion of these concepts.

3.3. Policies to manage increased flood hazard

One of the most important conclusions of the survey is that WMI lack guidance on how to manage and administer areas with increased flood hazard.

The easiest policy for the WMI is simply to purchase (or expropriate) land exposed to increased flood hazard. Although this entails negotiation on the purchase price or on the expropriation indemnity, it has the advantage of eliminating the compensation issue for future flooding. In addition, WMIs can claim public subsidies for such buy-back policies. This solution is sometimes envisaged for highly exposed areas but it cannot be generalized for several reasons: first, WMIs rarely have the skills or the equipment to ensure land maintenance and would have to contract out this task (the most common solution is then to let the previous owner farm the land for a negotiated below-the-market rental rate); second, landholders are often reluctant to sell their land. In some cases, the area at risk is too big and it would be too costly for WMI to buy the land.

⁶ The following basins are represented: Agout-Thoré, Allan Savoureuse, Aude, Cens-Bionne, Combe de Savoie, Devoussat, Cagne Malvan, Dordogne Iotoise, Escaut-Hogneau, Essonne, Furan, Gardons, La Lézarde, Lèze, Loire amont, Mauldre, Orb, Ouvèze, Plaine de la Bassée, Saône, Savoie Pont Baudin, Savoie Hexapole, Siagne, Vilaine et Yerres.

⁷ The questionnaires, which are in French, are available upon request.

Another policy consists in subsidizing the construction of local – vulnerability reducing – protective measures. This solution only applies to buildings, never to agricultural land and is therefore quite marginal, as over-flooded areas are mainly agricultural areas.

The last policy is to compensate landholders who are exposed to greater flood hazards after the implementation of the PAPI programme. In theory, two compensation systems could be designed: either a once-and-for-all indemnity to cover the loss of land value due to its greater exposure to flood hazards or a compensation scheme to pay for damage to land and crops each time flooding occurs. In practice, water managers have favoured a combination of the two systems, accounting for the fact that landowners often lease their land and there is therefore a need to compensate both the landholder and the tenant.

The main issue is thus to decide what damage should be compensated and to define the rules for compensation. A system which defines *over-flooding* too narrowly would not be accepted by the farmers. On the other hand, a system which would guarantee unconditional total compensation could lead to additional risk-taking behaviour by farmers (this is one form of *moral hazard*, see section 4) and could encourage overstated loss declarations. Moreover, since financial provisions must be made to pay indemnities, the WMI needs to be able to make accurate estimations of expected payments.

As a result, WMIs have preferred a protocol-based approach which establishes the ex-ante rules according to which farmers will be allowed to claim compensation payments. It appears that all WMI have followed the same strategy: first defining a *global* protocol at basin scale – in which a reference framework for the evaluation of damage and damages is established – and then drawing up detailed conditions for compensation payments in *local* protocols. Only five river basins have succeeded in signing a global protocol, only two basins (Oise-Aisne and Meuse) have transposed the global protocol into local ones. We analyse these protocols in the following section.

3.4. Difficulties raised by the introduction of an ex-post indemnity

According to the existing protocols, an *ex-post* indemnity will be paid to the farmer to compensate for damage to land and crops each time flooding occurs over the natural rate. This *ex-post* damage compensation is of course the most controversial issue since it raises four important questions: How to define over-flooding? How to value damage correctly? How to limit the liability of the WMI? What is the financial viability of locally created compensation funds?

3.4.1. The definition of the reference situation

“Over-flooding”, be it deliberate flooding or the restoration of floodplains, implies that a greater hazard has been created in comparison with another situation, the “flooding” situation. But this requires that the “flooding” situation itself has been defined. Is it flooding that occurs in a situation with no PAPI? Or is it flooding that would occur naturally in the absence of any human-made infrastructure? The second interpretation, which is the one that was retained by the central government when the 2003 Act on Risks became effective, should logically forbid farmers who are affected by projects of natural floodplain restoration from claiming compensation. However, this choice of the reference situation remains controversial because many river basins have not been in a “natural situation” for decades. Our survey showed that most river basins choose to refer to the “without PAPI” situation when they define “over-flooding” and not to the “naturally occurring” situation. This implies larger compensation payments to farmers.

3.4.2. The evaluation of damage

All protocols include damage to crops; some protocols cover sales losses (due to damaged reputation or to the loss of a sales contract) and damage to the soil. The financial compensation is either calculated on estimated real losses or on a fixed standard – defined *ex ante*. In both cases, compensation depends on the type of crop, the type of soil, and the time and type of the flood. Most global protocols mention that damage should be evaluated by an independent expert. However, extended negotiation processes with local farm associations are conducted to define the most appropriate evaluation steps.

The evaluation of losses on the basis of fixed standards reduces the *moral hazard* problem (i.e. farmers adopting a more risky behaviour than they would otherwise do, increasing the uncertainty of the outcome) and can help the WMI to better foresee the compensation to be paid. However, it has the disadvantage of depending on the very first expertise.

None of the evaluations adequately account for changes in agricultural policies. For example, the 2003 reform of the Common Agricultural Policy established direct support payments paid to farmers independently of their choice of crop or yield. These direct payments can represent up to 60% of farm revenue (especially for farming systems with cattle or cereals), rendering the farmer much less sensitive to yield or quality loss. A well-designed protocol must leave enough flexibility in the calculation of the rules to adjust for such changes to avoid over-compensation (Morris et al, 2008).

In addition, evaluations currently tend to underestimate impacts that are more difficult to value, such as environmental damage or the annihilation of the sponge capacity of catchments. Yet, economic valuation methods exist to allow this type of damage to be taken into account (Hanley 2003; Grelot 2004; Kast and Lapied, 2006 chapter 4; Messner and Penning-Rowsell, 2006, Erdlenbruch et al. 2008). Specific methods to evaluate the financial and economic impacts of flood storage have also been proposed. (see Morris and Hess, 1987; Dunderdale and Morris, 1997; Penning-Rowsell et al., 2003), but were not yet applied at the time of writing.

3.4.3. Limited liability for the water management institutions?

The easiest way to limit the WMI's risk would be a narrow definition of the reference situation, which ensures that the WMI cannot be made liable for all the damage caused by a flood. As the survey showed, in practice, this is rarely the case. Other clauses are included in the compensation protocols to limit the risk faced by local water institutions: for example, the amount of "unitary" damages is stated explicitly so that the WMI managers can calculate how much they will have to pay in the worst possible case. For example in case of the Mouzon project, a 100-year return-period flood would generate around 102 000 € of indemnification payments if it occurred in spring, around 68 000 € if it occurred in summer, around 34 000 € if it occurred in autumn. This issue is all the more important for WMIs since their budget is limited and they are not allowed to earn interest on their available liquidities.

3.4.4. No financial viability of the compensation fund

In the most advanced PAPI basins, the local WMIs have set up a basin-wide "compensation fund", in the form of provisions for exceptional charges⁸. These provisions are mainly financed by the members of the WMI, local governments or municipalities.

⁸Since they are public institutions, WMIs are not allowed to manage a real "fund" or to earn interest on financial markets.

Disregarding possible recommendations of risk analysis, local water managers consider that their financial reserves are sufficient to cover an “average risk”, often based on the evaluation of historical floods. However, it is obvious that a WMI could run into financial difficulties: several years of exceptional floods, a severe flood in the first years of the “compensation fund” or a misevaluation of expected damage could jeopardize the system.

Our survey showed that none of the water managers included an *insurance system* for the compensation fund, although some had studied the feasibility of such a solution. Because this is one interesting solution, in the following section, we discuss the different ways an insurance system could be used.

4. Managing flood risks: Public organisation and/or private insurance?

In this section, we analyse the problem of flood risk coverage and suggest some solutions for innovative and integrated risk management policies.

Risk management has to deal with two aspects of risk: the first concerns the physical part, where management is about preventing the hazard, i.e. using devices to reduce its impacts on humans. The second aspect concerns the ex-post consequences of hazard in financial terms (damages), given the prevention devices used to reduce them ex-ante. Because prevention is costly, the two aspects cannot be separated in a global risk management scheme: there are cases when it is cheaper to compensate for losses than to invest in prevention measures, whereas in other cases, prevention may be enough to reduce financial claims sufficiently for individuals to manage them. It should be noted that prevention is usually undertaken at a collective level, whereas compensation, and more generally financial risk hedging, can be organized at an individual level. Furthermore, damage valuation is not undertaken with the same techniques in collective and individual decision making. The PAPI programmes aim at a mixture of the two approaches in order to improve the management of floods at the basin level, with some degree of coordination between basins. In this section we discuss at what scale the risk management policies would best be coordinated.

After a short review of the type of risks that occur in river basins that are subject to floods and over-flooding (subsection 4.1), we consider two forms of public-private cooperation for an integrated risk management in subsections (4.2) and (4.3).

4.1. Insurability of flood risks and over-flooded areas

Floods belong to the category of natural hazards that are considered as being catastrophic, i.e. they can cause a great deal of damage but the probability of flooding is not known and may be very small. As such, floods are not insurable because insurance contracts require risks to be independent and the mean of damages to be finite (i.e. not too high). Mutualisation of risks, organized at the basin level, does not reduce risks because they are not independent, but allows prevention costs to be spread and reduced.

Over-flooding upstream rural land to protect highly populated and industrialized areas downstream spreads the risk between the two parts of the basin and may transform uninsurable risks in the downstream part of the basin into insurable ones (if the flood levels are sufficiently reduced on average) while not exposing upstream areas to risks that become unmanageable. There will always be a catastrophic risk, but it will be less frequent than before the over-flooding system. Hence, this risk could be manageable via a re-insurance by national funds at a much lower cost than in the current national system.

On the other hand, agricultural risks that were previously partly insurable without over-flooding, will no longer be insurable once they are “over-flooded” because the risk that is created is not “random”, even though its outcome may be uncertain. This kind of risk is known as a *moral hazard*. It is clearly excluded by insurance policies to insure a risk provoked by the insured, or a risk that is known by the insured to be provoked by some other actor. However, if this actor - here the WMI - can deal directly with the insurance companies, a solution is possible: under the supervision of the WMI, the insurance company can set up appropriated contracts for the over-flooded individuals and with a specific contract binding the WMI and the insurance company.

As for the remaining catastrophic risk not included in the insurance contract, the water basin manager, or one of the national compensation funds, can insure its default risk (in the case of too high losses) with companies which are able to hedge this risk with financial instruments (reinsurance companies).

Three principles should be considered when discussing the risk management of areas concerned by PAPI programmes.

i) At the water basin scale, a limited number of farms whose structure and yields are well-known will suffer under the PAPI projects while a large number of individuals and activities with high potential losses are preserved. Therefore, a financial transfer from urban protected areas to rural affected areas should be considered.

ii) As over-exposure concerns a large number of river basins, it is reasonable to promote mutualisation between different independent basins. Indeed, not all the basins suffer from floods at the same time. It would thus be efficient to create a compensation mechanism at the national scale: when a flood occurs, preserved basins pay for affected ones. Compared to the former alternative, the mutualisation surface is much larger, which may generate savings for the premiums.

iii) Following this reasoning, it would be appropriate to imagine diversification of flood risks at an even greater scale, the global scale, by introducing hedging instruments on global financial markets. It is generally true that financial crises and natural disasters are not correlated. It is thus conceivable for investors to diversify their risks between securities and some financial assets whose returns depend on a particular natural catastrophe. So-called *catastrophe bonds* already exist whose returns are linked to earthquakes in California or Mexico. The same could be done with French flood-linked financial assets that could be traded on international financial markets.

These three arguments are clearly in favour of the development of (innovative) insurance and other hedging financial contracts designed for the coverage of over-flooding. Such developments can only be achieved through cooperative schemes between insurance companies, financial management funds (reinsurance companies) and public institutions in charge of flood risks. In the following, we describe and discuss some solutions involving the government, the local water manager and insurance (and/or reinsurance) companies.

4.2. One possible solution: the reform of existing national coverage systems

One solution would be to improve the existing national solidarity systems by applying them to all areas concerned by flood risk, including “over-flooded” areas. Here we focus on two main scenarios: The first consists in introducing a compulsory insurance, and the second extends the current reform of public funds (Cat-Nat and FNGCA).

4.2.1. Compulsory insurance mechanisms subsidized by the government

The first scenario consists in the introducing of a compulsory nation-wide insurance system for all sectors. This would improve the risk pooling efficiency by simultaneously addressing rural and urban sectors. The government could delegate the management of this insurance system to private insurers provided they guarantee a certain level of national solidarity by applying a maximum premium level. To this end, the government could subsidise insurance policies at the premium level, like in the US, thereby providing greater incentives to insurance companies to enter the market. Indeed, insurance premiums would be higher than the usual mean damages, given that risks would still be correlated and the insurance portfolio would be risky. Therefore, premiums would include an additional risk premium, paid in part by the national agencies. The still risky insurance portfolio could be managed by insurance and reinsurance companies, as the latter are specialized in the management of risky assets and could hedge the remaining risk through weather derivatives and other financial instruments.

4.2.2. Reformed public compensation funds

The second scenario concerns a reformed public fund system, taking into account that the Cat-Nat system and the FNGCA should *in fine* be financially linked⁹. Compensation for over-flooding losses would then be financed by the Cat-Nat regime, which would alleviate the financial pressure on the FNGCA. Insurance companies could handle the management and evaluation of damage. They usually employ a network of experts and have a database containing the history of past catastrophic events, thereby generating savings and economies of scale in information gathering that cannot easily be matched by parallel evaluation systems.

Both scenarios foreshadow how the current French solidarity schemes for natural disasters would evolve within the next ten years. However, both scenarios completely exclude the local water management institution (WMI) from the risk management. This is a disadvantage because the closer actors are to the insured, the better their information. For example, the WMI may know every single individual (or farmer) concerned and may be able to evaluate his/her “type”. Thus, the WMI is in a better position to address the issue of so-called *adverse selection*. The WMI may also be able to accurately delimit naturally flooded and over-flooded areas. Finally, the WMI may give reasonable estimates of the probability of flood occurrence and of the amount of “over-flooding”. This is why we now turn to solutions involving the local WMI.

4.3. The second possible solution: involving local water management institutions and insurance companies

This second approach takes into account the major role of the local WMI. Again, two scenarios are possible.

4.3.1. A private insurance scheme for farmers subsidized by the local WMI

In the first scenario, a private insurance company would cover losses caused by all natural risks in the agricultural sector (similar to the already existing multi-risk climatic insurance, see section 2.3). The WMIs could bring the insurance companies to cover “over-flooded” areas. In turn, the WMIs would make information on over-flooded areas available to insurance companies and subsidize the insurance premium, which they can do more easily than managing a fund. Hence, the affected farms would benefit from a contract that covers the risk they face or that provides at least strong assistance. For the insurance company,

⁹ Clearly, PAPI programmes will reduce overall government expenses for flood management but most savings will be realised in the urban sector, i.e. in the CatNat fund.

information asymmetries would be reduced because of the WMI's detailed knowledge about the local situation and local stakeholders. *Moral hazard* would be reduced by the WMI's responsibility for the occurrence of over-flooding. In addition, potential losses for the insurance company would be minimized by covering parts of the risk with public subsidies.

4.3.2. A basin-wide compensation fund involving reinsurance companies

In the second scenario, the WMI would be responsible for defining and implementing the compensation system. In counterpart, in the case of too high damages, it would be able to hedge its default risk with a financial institution: bank, national finance institution (*Caisse des dépôts et consignations*) or insurance company. For these financial institutions, the costs of evaluating the risk of bankruptcy would be lower than the costs of calculating a specific flood risk.

The introduction of insurance mechanisms has several advantages: for the WMI, it implies an advantageous transfer of risk or at least a relief from its responsibilities. Insurance companies could cover themselves through weather derivatives or re-insurance contracts, to which the local institutions do not have the same access, or for which they would not be able to compute the optimal investment. For the insurance company, the calculation of premiums would be facilitated if local water manager and insurance companies cooperate. WMIs, farm associations and insurance companies could collaborate to evaluate potential damage. The costs of hydrological and hydraulic studies are certainly lower for public water management authorities, because WMIs have already conducted such analyses and are able to model different types of floods and evaluate the impact of particular protection infrastructure.

5. Conclusion

We have seen how France is currently trying to improve its flood management policy by providing financial support for holistic programmes, so-called PAPI programmes, designed to reduce overall flood damage at the basin level in a cost-efficient, environmentally sound and user-friendly way. One part of the PAPI programmes consists in redirecting floods from the most vulnerable to the least vulnerable areas. By doing so, PAPI programmes relieve the pressure on the national solidarity fund that compensates victims of natural disasters. On the other hand, it shifts the burden of risk to the rural sector. Local water management institutions have consequently tried to set up mechanisms to ensure proper compensation of the new "victims" of risk reallocation. But, by limiting risk-sharing policies to a small geographical area, local compensation funds have little chance of being financially viable.

This article has summarized the results of an exhaustive survey of all PAPI programmes in France, in order to analyse how local compensation schemes are being set up at the basin level. We have shown that many WMIs are on the point of choosing financial compensation schemes which imply ex-post indemnification of flood damage. Because they do not define the situation of "over-flooding" narrowly enough and because national compensation schemes are not applicable to artificially created flooding, water managers will face very high financial claims in the case of severe flooding – and may face bankruptcy.

This is why it is crucial to design innovative risk management schemes involving insurance and re-insurance companies, local WMIs and the government. We have discussed several possible schemes which all imply a financially viable risk-sharing policy.

Given the fact that PAPI programmes have already shifted the risk to the local WMIs, the last two scenarios which include the local WMI appear to us to be particularly realistic. They are

also particularly relevant: they relieve the pressure on the local WMI and facilitate the acquisition of information and calculation of premium for the insurance companies. In addition, they are in line with the concept of locally adapted flood risk management policies, as promoted in PAPI programmes and in the European Framework Directive on Floods.

However, in order to make them applicable, a national framework for the cooperation between insurance companies and WMIs is needed. It is likely that a clear signal from the government would encourage insurers and local water management institutions to cooperate to ensure a better coverage.

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