# Modeling the flood risk impact: a regional SAM analysis

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**Abstract.** Recent natural disasters have had significant regional economic impacts. Especially flash floods which are disastrous over the economic development. These effects can be estimate throughout technical and economic modeling. A technical model build *ex-ante* can provide strong loss estimation results witch can be integrate into an economic model. This paper advances a regional SAM analysis in order to underline the flood risk impact over some economic sectors. We illustrate some of these contributions in a case study of the PACA region (south east of France) after the historical flood of December 2003.

**Keywords:** SAM analysis, technical modeling, economic modeling, flood risk.

## Introduction

Flash floods are one of the most dangerous natural event disasters in the world. The economic impacts estimations of natural risk such as floods are receiving an increasing attention by the economic community (Penning-Rowsell E. et al. [2006][1]). In this way, several recent assessments of research on natural risk have stressed the importance of improving economic loss estimation (Rose A. et al. [2002][2]). Thank to new computing methods supported by powerful new generation of computers and software, economists are able to expand loss estimation throw several mix economic models in order to improve the public decision in term of mitigation procedures. Indeed, the recent natural disasters happened in the PACA region have had significant impact on the regional economy. Thus it is important to study the effects of goods or services disruptions on the economic development. Previously,

[1] Penning-Rowsell E. et Wilson T. [2006]. Gauging the impact of natural hazard: the pattern and cost of emergency response during flood events. *Royal Geographical Society*, NS 31 pages 99 – 115.
[2] Rose A. et Lim D. [2002]. Business interruption losses from natural hazards: Conceptual and methodological issues in the case of the Northridge earthquake. *Global Environmental Change Part B: Environmental Hazards*, volume 4, numéro 1, pages 1 – 14.

Rose A. et al. [2005][3] have analysed the sectoral and the regional economic impact of a disruption into the Portland Metropolitan Water System aftermath a major earthquake. Tatano and al. [2007][4] study the economic consequences of a disruption in the transportation network for Niigata and Kanto regions in Japan. This paper seeks to advance the estimation of business interruption losses on several fronts. First, we clarify the technical losses estimation method used for our case of study. This includes the study area and the technical method result analysis. Second, we present a regional social accounting matrix (SAM) table in order to analyze the potential impacts of a flash flood. Indeed, Input – Output framework continues to be a popular modeling approach among the economists (Rose A. [1995][5]). We have generalized our method for the construction of a regional SAM table and propose a way to integrate data from technical economic losses estimation method.

## 1. Technical economic losses estimation methods: overview and French tools theorical background

Several methods are available in order to estimate the potential economic losses after a natural risk occurrence. The quantification of economic losses needs to gauge the individual and the community vulnerability, to evaluate the worthiness of mitigation decisions and to determine the appropriate level of disaster assistance (Knocke E. T. et al. [2007][6]). In that way, we can't avoid the state of the art of modeling business interruptions method.

### 1.1 Modeling business interruption method: an overview

Rose A. [2000][7] clarifying basic economic principles of loss estimation and summarizes major modeling approaches. One of the basic loss estimation methods is to collect data through survey, interview and phone investigations. Even if those methods are commonly used, the questionnaire approach has been somewhat limited because of its costs. With a well

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[3] Rose A. et Liao S. Y. [2005]. Modeling regional economic resilience to disasters: A computable general equilibrium analysis of water service disruptions. *Journal of Regional Science*, volume 45, numéro 1, pages 75 – 112.

[4] Tatano Hirokazu et Tsuchiya Satoshi [2007]. A framework for economic loss assessment due to seismic transportation network disruptions. *Natural Hazards*, DOI 10.1007, pages 1 – 13.

[5] Rose A. [1995]. Input-Output economics and computable general equilibrium models. *Structural Change and Economic Dynamics*, volume 6, numéro 3, pages 295 – 304.

[6] Knocke E. T. et Kolivras K. N. [2007]. Flash flood awareness in southwest Virginia. *Risk Analysis*, volume 27, numéro 1, pages 155 – 169.

[7] Rose A. [2000]. *Natural hazard loss estimation: Fundamentals and complications*. Department of Energy, Environmental and Mineral Economics, the Pennsylvania State University, University Park, PA.

knowledge of the natural risk studied, Cochrane H. [1997][8] is able to include both exploratory analysis, such as correlation, and causal analysis, such as regression. The aim of that work is to help the prediction or quick loss estimation of other natural risk in more formal data transfer function. By the way, macroeconometric models and more elaborate versions of statistical models are used to forecasting futures economic growth of a region from external shocks (Ellson R. et alii. [1984][9]). The final idea is to integrate technical data as a parameter in economic models. For example, at the microeconomic level, we include engineering-economic analysis (White J. et alii. [1997][10]). Indeed, the last category is stochastic simulation analysis. It refers to the application of Monte Carlo or various other methods to avoid the lack of data or uncertain data (Taylor C. et alii. [2001][11]). This previous approach is commonly used and can be applied to various aspects of hazard loss process, including the original physical stimulus (flood, hurricane, earthquake, etc.), the working of the built environment, vulnerability analysis, direct physical loss estimation, direct economic loss estimation, etc. In that way, deterministic simulation analysis involves the use of mathematical models, such as Input – Output or linear programming (Cochrane H. [1975][12]). The Indirect Economic Loss Module of the HAZUS (FEMA [2008][13]) allows to simulate natural risk occurrence and focus on production interdependencies makes it especially well studied to examining how damages in some sector can ripple through out the economy studied.  This approach has dominated the literature on indirect loss estimation, though it can also be used to estimate the direct loss estimation (Rose et alii. [1997][14]).

## 1.2 Modeling the flood risk impact in south of France

### 1.2.1 Technical loss estimation method used

[8] Cochrane H. [1997]. Forecasting the Economic Impact of a Mid-West Earthquake. In B. Jones ed. *Economic Consequences of Earthquakes: Preparing for the Unexpected*. Buffalo, NY; MCEER.

[9] Ellson R., Milliman J. et Roberts R. [1984]. Measuring the regional economic effects of earthquakes and earthquake prediction. *Journal of Regional Science,* volume 24, numéro 4, pages 559 – 579.

[10] White J., Case K., Pratt D. et Agee M. [1997]. *Principles of engineering economic analysis*, 4th Edition. New York, NY; John Wiley & Sons.

[11] Taylor C., Werner S. et Jakubowski S. [2001]. The walkthrough method for catastrophe decision-making. *Natural Hazard Management,* Inc., Torrance, CA.

[12] Cochrane H. [1975]. *Natural Hazards and Their Distributive Effects*. Boulder, CO; Natural Hazards Research Applications Information Center.

[13] FEMA [2008]. Site Internet, informations générales sur le logiciel de prévision des risques naturels, HAZUS: http://www.fema.gov/plan/prevent/hazus/

[14] Rose A., Benavides J., Chang S., Szczeniak P. et Lim D. [1997]. The regional economic impact of an earthquake: Direct and indirect effects of electricity lifeline disruptions. *Journal of Regional Science,* volume 37, numéro 3, pages 437 – 458.

The French loss estimation method developed by the CEMAGREF (engineering-hydrologic-economic national research center) hold two components as definition of flood risk; the vulnerability and the hazard. Hazard is the natural phenomena, the probable event and the vulnerability is human and economic constrains. The so-called *Inondabilité* method seeks to estimate, quantitatively, the risk for a surface named *hydraulic storage* thanks to a quantifiable model, parallel and independent of the two variables, which are the hazard and the vulnerability (Davis S. A. et alii [1988][15]). Based on strong hypothesis, the aim of this method is to quantify the vulnerability and the hazard with a same unity of measure, that is to say, with the same physical parameter (Gilard O. [1998][16]). By the way, we call by *TAL* the hazard measure for a storage element. *TAL* is a single parameter showing the average return period of the flood studied. Until now, hydraulic models (under S.I.G[17]) and hydrologic models (with HSMF[18]) give a possible estimation of a spatial hazard repartition (*TAL*):

[15] Davis S. A., Johnson N. B., Hansen W. J. et Reynolds F. R. [1988]. National economic development procedures manual. Urban Flood Damage. IWR Report 88-R-2, U.S. Army Corps of Engineers.
[16] Cf. pages 19 and 20, Gilard O. [1998]. *Les bases techniques de la méthode Inondabilité*. Cemagref Éditions.
[17] Geographic Information System (Système d'Information Géographique). This software is able to draw a spatial representation of the French territory.
[18] Synthetic Single Frequency Hydrographs (Hydrogrammes Sythétiques Mono Fréquence).

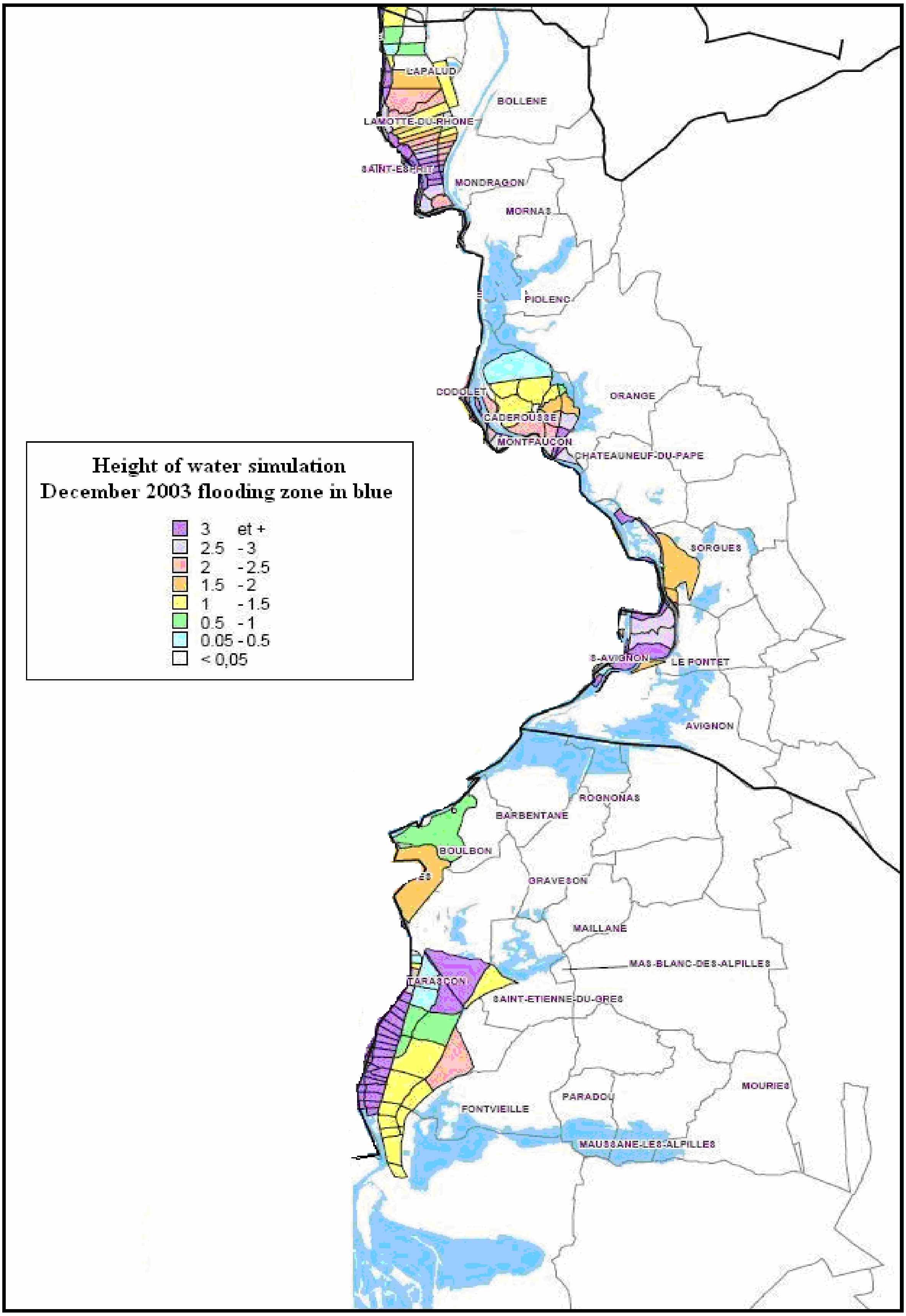



Figure n°1: Spatial hazard repartition.

Here we have a representation of the flood hazard for the Provence Alpes Côte d'Azur (PACA) region.

The vulnerability analysis has the same aim, that is to say a pertinent spatial representation according to the typology selected. Indeed, based on hydrologic model as *QdF* models[19], the vulnerability measure has to convert the couple of frequency – duration *(T,d)* and the triplet, frequency – duration – depth *(T,d,p)* to an equivalent variable said *TOP*[20]. *TOP* remain possible a negotiation in order to adopt an efficient level against flood disaster. In that way, the vulnerability estimation can be traduced as the "average annual cost of damages", calculated as the mathematic damages expectation like the equation below:

$$CMA = E(C) = \int_{0}^{+\infty} c \bullet f_c(c) \bullet d_c$$

With, *CMA*: average annual cost of damages,

*E(C)*: mathematic damages expectation,

$f_c$(c): density function of probability for the variable cost of damages C.

It's usually impossible to work on the basis of damages cost probability function but only on probability distribution of the water discharge. Damages cost is thus a function of the water depth and to the water discharge. These unities:

$$C = function(h) \quad , \quad h = function(q) \quad \Rightarrow \quad C(h(q))$$

With, *C*: damages cost,

*h*: water height,

*q*: water discharge for the corresponding height *h*.

We assume that the probability density of the damages cost is equivalent to those of the discharge. This yield:

$$CMA = \int_{0}^{+\infty} C(h(q)) \bullet f_q(q) \bullet d_q$$

With, *C*: damages cost for a height *h* given,

*h(q)* : height of water function to discharge,

$f_q(q)$ : probability density of the *q* variable.

With these functions, it is possible to valuate the damage cost.

[19] *QdF*, for discharge, duration and frequence.

[20] *TOP* for the protection target.

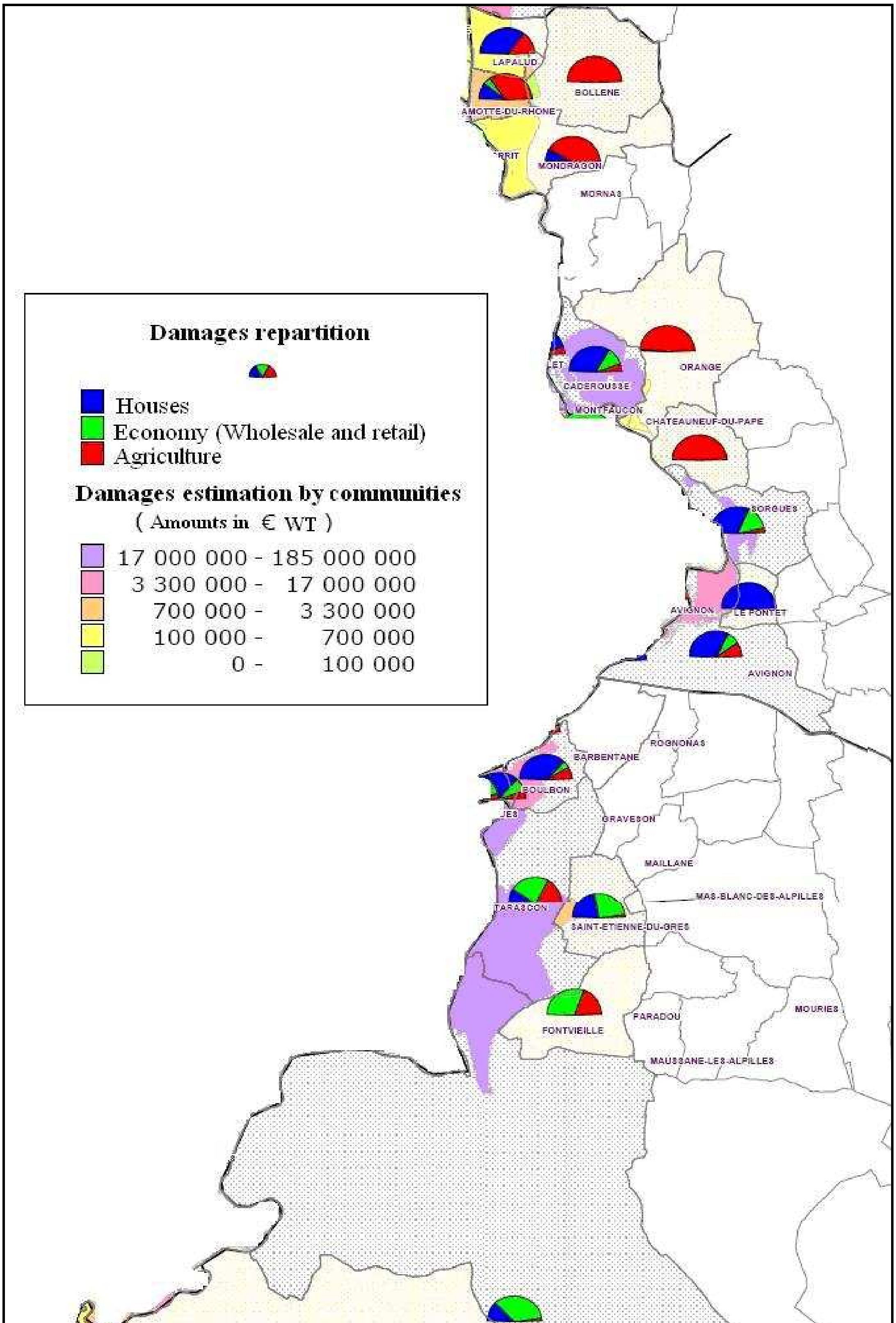



Figure n°2: Spatial vulnerability repartition.

The most important task is to represent the building vulnerability curves. These curves are function of parameters linked to the hazard (duration of submergence, height and velocity of water). For each level of damage, a percentage of physical damage is associated (Davis S. A. et alii. [1988][21]). In that way, we are able to estimate the corresponding damages curve for each categories of building and activities. Here we presented three damages curves of three different building categories:

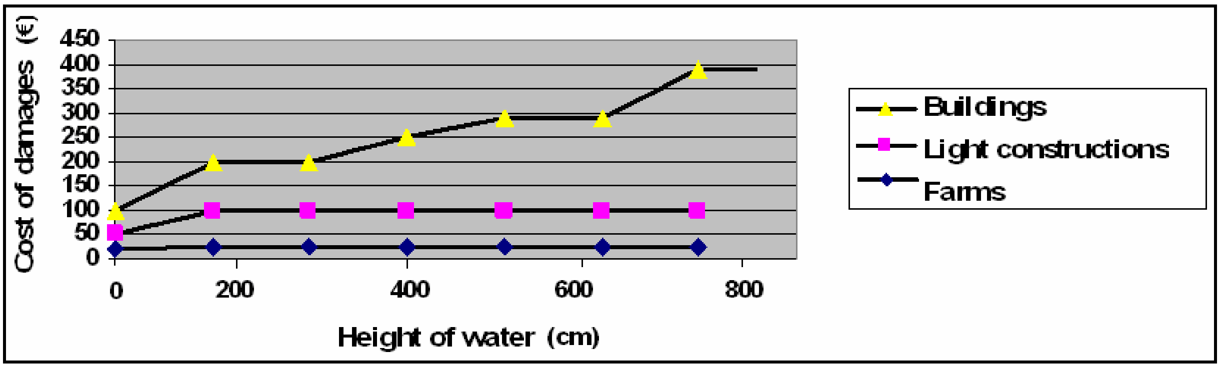



Figure n°3: Damages curves for 3 buildings categories (for 1m²).

Based on this theorical background, we adopt the technical valuation method to our case of study.

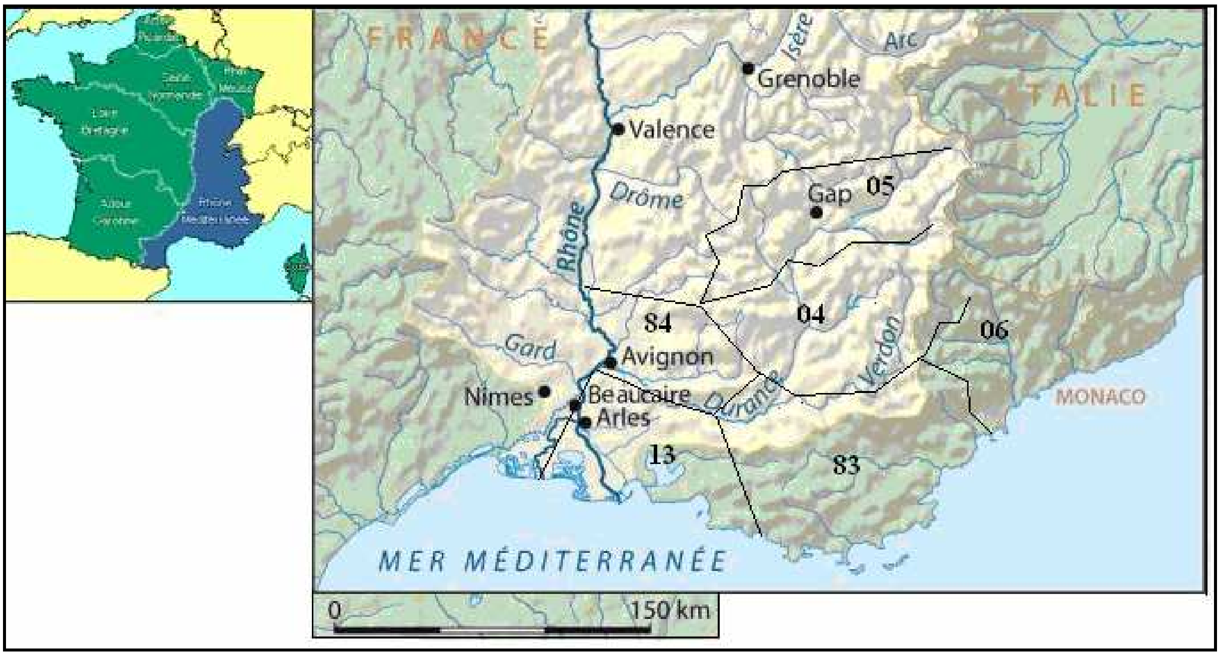
### 1.2.2 Study area

South-east of France is a both rural and urban region doted with small towns, cities and straddled by two most important cities: Avignon to the west and Marseille to the south-east. Flash floods can occur with intense rainfall associated with precipitation events, where the Rhône River and its affluent can usually spill in this study area. During autumn and winter, PACA region has known several cloudbursts and two of six PACA departments were touched by important floods. So far, the annual floods of September 2002 and December 2003 caused exceptional damages in these two departments; Vaucluse and Bouches-du-Rhône. Here (Table 1) an estimation of the December 2003 flood damages after an investigation procedure:

| | Amounts without taxes Low level | Amounts without taxes High level | Number of communes studied |
|---|---|---|---|
| Bouches-du-Rhône (13) | 331 846 058 € | 335 725 985 € | 17 |
| Vaucluse (84) | 15 201 752 € | 15 201 752 € | 12 |
| Total PACA | 347 047 810 € | 350 927 737 € | 29 |

Table n°1: Results of economic damages by departments, after investigation (amounts in euros).
*Source : DIREN de Bassin / DIREN Languedoc-Roussillon - CETE Méditerranée [2005], page 31.*

[21] Davis S. A., Johnson N. B., Hansen W. J. et Reynolds F. R., [1988]. Op cit.




<u>Figure n°4:</u> PACA Region and departments studied.

The map of the Figure n°4 shows the two departments studied and their situation among the Rhône River.

Two types of damages were taken into account: the direct damages and the damages linked to exploitation losses. The direct damages curve is the same of the one used for the buildings[22]. The exploitation losses were estimated in term of inactivity days in function of direct damages percentage compared to the turnover. As we can say above, thanks to SIG, the submersion map and the ground occupation, we are able to have both, global outlook and sound knowledge of the flooding zone as well as the corresponding weight of water. So far, with damages curves constructed, it is then possible to calculate the cost of each flood by adding the associated cost at the economic activity.

The results in Table n°2 are damages estimation for each *hydraulics storage* and aggregated at the departmental level:

[22] Cf. <u>Figure n°3:</u> Damages curves for 3 buildings categories (for 1m²).

| Damages by sector / Departments | Farmer sector | Economy sector – Trade, wholesale and retail | Households | Total by departments |
|---|---|---|---|---|
| Bouches-du-Rhône | 38 500 083 € | 177 970 315 € | 74 723 800 € | 291 194 199 € |
| Vaucluse | 6 029 513 € | 3 254 334 € | 34 614 835 € | 43 898 682 € |
| Total PACA | 44 529 596 € | 181 224 649 € | 109 338 635 € | 335 092 880 € |

Table n°2 : Damages estimation by the technical method (amount in euros).
*Source : DIREN de Bassin / DIREN Languedoc-Roussillon - CETE Méditerranée, [2005], page 47.*

As we can see on that table, the results are available only for three domains. Indeed, this technical method works for available damages curves. At present time, it doesn't exist in the economic model used, any damages curves which give the damages evaluation for several communication services or industrial equipments.

Nevertheless, the technical method introduced in this work, allows us to integrate the flood risk component into a process of economic losses estimation. That technical evaluation returns a good estimation of the hazard and the vulnerability variables and gives some interesting results[23]. The second part of this paper is to represent an integration method of these technical results into the whole economic table of PACA data.

## 2. A regional SAM table for data analysis

SAM modeling is commonly used in economic simulation. A SAM table shows the whole economic system of a country and can be calibrated at a small scale according to the simulation tested. We have to introduce our SAM model and develop a methodology in order to integrate data from technical model to the SAM regional table.

### 2.1 SAM table for PACA Region

The input-output model is the most widely used tool of regional economic impact analysis, and its application to natural risk dates back to the seminal work of Cochrane H.[1974][24]. I –

[23] Cf. Table n°1 and Table n°2.
[24] Cochrane H. [1974]. Predicting the economic impact of earthquakes. In H. Cochrane et al. eds. *Social Science Perspectives on the Coming San Francisco Earthquake*, Natural Hazards Research Paper No. 25, Boulder, CO; University of Colorado.

O is a static and linear model of all purchases and sales between sectors of an economy. Based on technical relations of production, I – O is mainly a model of production. Note that I – O requires the use of fixed coefficients where prices play no role (Rose A. [1995][25]). So far, I – O modeling provide an excellent organizational framework for data collection and display. It able to show a transparent view of the structure of an economy, and capable to integrate technical data (Rose A. [2000][26]).

Some refinements of the I – O methodology have been suggested that improve accuracy. Among that, Liew C.K. and al. [1991][27] introduce a multiregional, multiproduct, household interactive, variable Input – Output model. The aim is to capture the interactions and the optimizing behaviour of consumers and producers in the space economy. Concerning the applications to hazard loss estimation, Boisvert R. [1992][28] and Cochrane H. [1997][29] have developed methodologies for more flexible treatment of imports in the aftermath of an earthquake. Cole S. [1988][30] has improved the evaluation of the timeframe of regional impact. In general, Cole S. [1998][31] and Okuyama Y. et alii. [1999][32] have extended the area of coverage to account for economic ripple effects in regions adjacent and non-adjacent to where the natural risk occurred.

The methodology in order to build our SAM regional table has been to elaborate, in first, an SAM table for the French nation. The year of 2004 is selected for the French social accounting matrix construction. In two steps, we were able to build a *macro-SAM* and a disaggregated SAM for the French economy. The French *macro-SAM* is built on the basis of INSEE[33] statistic on-line accounting files. In that way, the national accounting matrix (NAM) can be done in order to obtain the corresponding *macro-SAM*. The NAM is constructed with

[25] Rose A. [1995]. Op cit.
[26] Rose A. [2000]. Op cit.
[27] Liew Chong K. et Liew Chung J. [1991]. A multiregional, multiproduct, household interactive, variable input-output model. *Annals of Regional Science*, volume 25, numero 3, pages 159 – 177.
[28] Boisvert R. [1992]. Direct and Indirect Economic Losses from Lifeline Damage. In *Indirect Economics Consequences of a Catastrophic Earthquake*, Final Report by Development Technologies to the Federal Emergency Management Agency.
[29] Cochrane H. [1997]. Op cit.
[30] Cole S. [1988]. The delayed impacts of plant closures in a reformulated Leontief model. *Paper of Regional Science Association*, numero 65, pages 135 – 149.
[31] Cole S. [1998]. Decision support for calamity preparedness: socioeconomic and interregional impacts. In M. Shinozuka et al. eds. *Engineering and Socioeconomic Impacts of Earthquakes: An analysis of electricity lifeline disruptions in the New Madrid Area*. Buffalo, NY: MCEER.
[32] Okuyama Y., Hewings G. J. D. and Sonis M. [1999]. Economic impacts of an unscheduled, disruptive event: a Miyazawa Multiplier Analysis. In G. J. D. Hewings et al. eds. *Understanding and Interpreting Economic Structure*. Berlin, Germany: Springer-Verlag.
[33] INSEE – Institut National de Statistique et d'Etudes Economiques.

the whole economic table[34] and the outputs – inputs table[35]. Susanna Santos[36] methodology was adopted in order to build the *macro-SAM*. The next level is to introduce a French disaggregated SAM according to our case of study. We decided to disaggregate the production factor account into two parts: the labour factor and the rest factor. The activity account is broken down into six production activities which are: farmers, industries and energies, building, wholesales and retails trade, financials and others services. The production account is also disaggregated into six products: framers products, industries and energies products, building working, wholesales and retails products, financials products and others services products. In order to introduce a balanced SAM, the cross-entropy method is adopted (Robinson S. and alii. [2000][37], Robinson S. and El-Said M. [2000][38] and Robinson S. and alii. [1998][39]) and compiled under GAMS.

A regional SAM can be build by adopting several ratios in order to estimate the economic weight of the PACA region in the French nation (Piet L. [2002][40]). The Regional Statistic and Economic Information Service and the Farmer Accounting Information Service give some pertinent data about the structural regional farmer accounts. The PACA regional room of trade and industry give data in order to identify the economic weight of different activities sector in the total of PACA production[41]. Finally, the regionalised public administration accounts structure available on the INSEE PACA website[42], help us to regionalise the institutional account.

Here the nomenclature adopted by account and the disaggregated SAM of the PACA region for the year 2004:

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[34] INSEE [2008]. *Tableaux Economique d'Ensemble*. Comptes nationaux annuels - Base 2000 ; http://www.insee.fr/fr/themes/comptes-nationaux/.

[35] INSEE [2008]. *Tableaux Entrées-Sorties*. Comptes nationaux annuels - Base 2000 ; http://www.insee.fr/fr/themes/comptes-nationaux/.

[36] Santos Susana [2006]. Constructing a database for economic modelling from the system of National accounts: A social accounting matrix for Portugal. Working Paper Series – SSRN Social Science Research Network.

[37] Robinson S., Cattaneo A. et El-Said M. [2000]. *Updating and estimating a Social Accouting Matrix (SAM) using cross entropy (CE) methods*. IFPRI. Discussion paper n°58.

[38] Robinson S. et El-Said M. [2000]. *GAMS Code for estimating a Social Accouting Matrix (SAM) using cross entropy (CE) methods*. IFPRI. Discussion paper n°64.

[39] Robinson S., Cattaneo A. et El-Said M. [1998]. *Estimating a Social Accouting Matrix (SAM) using cross entropy (CE) methods*. IFPRI. Discussion paper n°33.

[40] Piet Laurent [2002]. Spatialisation d'un modèle d'équilibre général calculable pour l'étude de la localisation des activités agricoles à une échelle infra-nationale. Thèse de Doctorat, spécialité Sciences de l'Environnement, ENGREF Paris.

[41] INSEE PACA [2007]. *Données Economiques et Sociales* - PACA 2007. Rapports chiffrés par secteurs d'activités.
 - Portail des Chambres de Commerce et de l'Industrie [2006]. *Tableau de bord de l'économie régionale en 2004*. Rapport d'étude chiffré. Chambres de Commerce et de l'Industrie, antenne Régionale.

[42] Cf. INSEE PACA [2008] – Section des comptes régionalisés. http://www.statistiques-locales.insee.fr/.

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|---|---|---|---|---|
| WF: Working factor | CBA: Construction and building activities | FP: Farmer products | FP: Financials products | FA: Financial account |
| OF: Other factor | TWDA: Trade wholesales and details activities | IEP: Industries and Energies products | OSP: Other services products | ROF: Rest of the France |
| FA: Farmer activities | FA: Financials activities | CBP: Construction and building products | CA: Current account | ROW: Rest of the World |
| IEA: Industries and Energies activities | OSA: Other services activities | TWDP: Trade wholesales and details products | KA: Capital account | |

| | WF | OF | FA | IEA | CBA | TWDA | FA | OSA |
|---|---|---|---|---|---|---|---|---|
| WF | | | 441,000 | 6148,416 | 13588,389 | 16397,807 | 6742,496 | 18367,804 |
| OF | | | 1373,000 | 5642,584 | 2443,000 | 4276,000 | 13915,504 | 13362,000 |
| FA | | | | | | | | |
| IEA | | | | | | | | |
| CBA | | | | | | | | |
| TWDA | | | | | | | | |
| FA | | | | | | | | |
| OSA | | | | | | | | |
| FP | | | 345,676 | 865,540 | 39,159 | 81,018 | 0,000 | 18,254 |
| IEP | | | 81,226 | 1519,396 | 179,174 | 308,179 | 105,115 | 195,897 |
| CBP | | | 178,135 | 3384,571 | 12214,994 | 1908,593 | 3588,155 | 4173,456 |
| TWDP | | | 150,818 | 7654,003 | 980,316 | 18362,066 | 6372,052 | 4185,192 |
| FP | | | 377,044 | 8946,237 | 1748,115 | 7643,720 | 12305,360 | 3256,293 |
| OSP | | | 24,305 | 586,029 | 62,114 | 418,592 | 478,005 | 1132,549 |
| CA | 62244,078 | 40468,922 | -26,110 | 1077,970 | 152,930 | 772,110 | 1499,460 | 253,640 |
| KA | | | | | | | | |
| FA | | | | | | | | |
| ROF | 52,144 | 3206,856 | | | | | | |
| ROW | 55,168 | 3392,832 | 0,000 | -1,273 | 0,000 | -1,008 | -2,109 | -0,805 |
| TOTAL | 62351,390 | 47068,610 | 2945,094 | 35823,473 | 31408,191 | 50167,077 | 45004,038 | 44944,280 |

**Figure n°5: PACA SAM for 2004 (in millions of euros)**

| | FP | IEP | CBP | TWDP | FP | OSP | CA | KA | FA | ROF | ROW | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WF | | | | | | | | | | 294,822 | 370,656 | 62351,390 |
| OF | | | | | | | | | | 2683,178 | 3373,344 | 47068,610 |
| FA | 2945,094 | | | | | | | | | | | 2945,094 |
| IEA | | 35823,473 | | | | | | | | | | 35823,473 |
| CBA | | | 31408,191 | | | | | | | | | 31408,191 |
| TWDA | | | | 50167,077 | | | | | | | | 50167,077 |
| FA | | | | | 45004,038 | | | | | | | 45004,038 |
| OSA | | | | | | 44944,280 | | | | | | 44944,280 |
| FP | | | | | | | 2035,309 | 129,083 | | 965,566 | 1425,000 | 5904,605 |
| IEP | | | | | | | 40705,287 | 9171,156 | | 1185,105 | 1749,000 | 55199,535 |
| CBP | | | | | | | 2160,552 | 4892,680 | | 0,000 | 0,000 | 32501,136 |
| TWDP | | | | | | | 6990,015 | 123,045 | | 7286,127 | 10753,000 | 62856,634 |
| FP | | | | | | | 5781,868 | 6933,520 | | 0,000 | 0,000 | 46992,157 |
| OSP | | | | | | | 42909,716 | 252,128 | | 33,202 | 49,000 | 45945,640 |
| CA | -374,724 | 6297,000 | 1092,945 | 510,041 | 1988,119 | 895,174 | 73565,001 | | | 0,000 | 850,000 | 191226,556 |
| KA | | | | | | | 8887,612 | 3445,000 | -625,000 | 13342,000 | 83,000 | 25132,612 |
| FA | | | | | | | | | 62536,000 | 0,000 | 20333,000 | 82869,000 |
| ROF | 1136,235 | 4457,062 | 0,000 | 4150,516 | 0,000 | 36,186 | 6727,001 | 0,000 | 6024,000 | | | 25790,000 |
| ROW | 2198,000 | 8622,000 | 0,000 | 8029,000 | 0,000 | 70,000 | 1504,195 | 186,000 | 14934,000 | | | 38986,000 |
| TOTAL | 5904,605 | 55199,535 | 32501,136 | 62856,634 | 46992,157 | 45945,640 | 191226,556 | 25132,612 | 82869,000 | 25790,000 | 38986,000 | |

**Figure n°5: PACA SAM for 2004 (in millions of euros)**

An assumption about the homogeneity of products is adopted in order to estimate the SAM production account cells. Indeed, at a regional scale, the estimation of each production sectors remains quite difficult to elaborate (Piet. L, [2002][43]).

## 2.2 Technical losses estimation data and PACA SAM: the flood risk impact

The combination of technical losses estimation method and SAM for PACA region remains possible a global outlook of the flood risk effects over the economic development. In that way, we focus over the PACA production block in order to modeling the flood risk impact. More over, as we have demonstrate before, we will take into account only two department of the PACA region. Indeed, the flood risk model takes as a start point a huge flood which hinted the PACA region in December 2003. This historical flood occurrence hinted two PACA departments among the Rhône River. An investigation procedure done after the disaster shows that the estimations results from the technical method are close to the reality:

| | Investigation results | Technical method results |
|---|---|---|
| Total PACA | 347 047 810 € | 335 092 880 € |

Table n° 3: Economic losses estimation (amount in euros).

Now we are able to simulate a scenario where two departments of PACA region: Bouches-du-Rhône and Vaucluse, are hinted by a flood. This causes important damages in two economic sectors: the farmer and trade sector, the wholesale and retail sector. Here a table which shows an overview of the data resulting from the technical losses estimation method. Thanks to the PACA SAM, we can estimate the output reduction after the flood risk simulation:

| | Farmer sector | Economy sector – Trade, wholesale and retail |
|---|---|---|
| Technical method results | 44 529 596 € | 181 224 649 € |
| Output reduction (%) | 1,51 | 0,36 |

Table n°4: Direct output reduction after the PACA flood risk by economic sector (in euros).

The simulation shows that the farmer activities are the most hinted economic sector after the flood. The output reduction can be estimate only in two economic sectors because the damages function is available. In terms of comparisons with the Rose-Lim loss estimation survey, they estimate the potential damages in all sectors when resiliency adjustments are

[43] Piet. L, [2002]. Op. cit.

included[44]. Further refinement could be the generalization of the damages function for other economic sector. The accuracy of our results can be improved by the integration of an I – O table for the production block. Because of a lack of data we assume the homogeneity of the product.

In addition, french economic losses estimation models lacks of powerful software like HAZUS in order to provide useful data on a real-time basis to guide responses in an on-going disaster recovery period.

## Conclusion

In this work, we have clarified the conceptual basis for a survey in order to estimate the potential economic losses after a flood disaster. We have shown that economic models are able to integrate data from technical losses estimation procedure. A hybrid method is developed in order to estimate the reduction of output in two economic sectors, on the basis of technical losses estimation results. In that way, we have explained the technical method used and applied it to a practical case of study. Indeed, after the flood disaster of December 2003, the technical method developed gives some pertinent results, not so far from the investigation procedure. Moreover, we have introduced a methodology in order to build a regional social accounting matrix from the national SAM of France for the year 2004. We have disaggregated the regional SAM for PACA region according to our simulation expectation. Finally, the results presented in this paper represent an interesting way for further refinements. In terms of research strategy, our results indicate in which way it is possible to integrate technical data through a SAM analysis and estimate the regional impact of flood risk disaster over the economic development.

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