NOTA DI LAVORO

92.2015

Improving Flood Damage Assessment Models in Italy

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Climate Change and Sustainable Development
Series Editor: Carlo Carraro

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Summary

Flood damage assessments are often based on Stage-Damage Curve (SDC) models that estimate economic damage as a function of flood characteristics, typically flood depths, and land use. SDCs are developed through site-specific analysis but rarely adjusted to economic circumstances in areas to which they are applied. In Italy, assessments confide in SDC models developed elsewhere, even if empirical damage reports are collected after every major flood event. In this paper we tested, adapted and extended an up-to-date SDC model using flood records from Northern Italy. The model calibration is underpinned with empirical data from compensation records. Our analysis takes into account both physical asset and foregone production losses, the latter measured amidst the spatially distributed gross added value (GVA).

Keywords: Flood Risk Management, Stage Depth Damage Curves, Economic Damage, Disaster Losses, Italy

JEL Classification: Q54

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Improving flood damage assessment models in Italy

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August 2015

Abstract
Flood damage assessments are often based on Stage-Damage Curve (SDC) models that estimate economic damage as a function of flood characteristics, typically flood depths, and land use. SDCs are developed through site-specific analysis but rarely adjusted to economic circumstances in areas to which they are applied. In Italy, assessments confide in SDC models developed elsewhere, even if empirical damage reports are collected after every major flood event. In this paper we tested, adapted and extended an up-to-date SDC model using flood records from Northern Italy. The model calibration is underpinned with empirical data from compensation records. Our analysis takes into account both physical asset and foregone production losses, the latter measured amidst the spatially distributed gross added value (GVA).

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1. Introduction

The EU Floods Directive (FD, 2007/60/EC) manifested a shift of emphasis away from structural defence approach to a more holistic risk management, with structural and non-structural measures having the same importance. The FD compels identification of areas exposed to flood hazard and risk, and adoption of measures to moderate flood impacts. A sound, evidence-based risk assessment should underpin public disaster risk reduction and territorial development policies. Stage-damage curves (SDC) are a customary tool used for assessing risk arising from the physical disruption of physical tangible assets (Genovese 2006; Messner et al. 2007; Thieken et al. 2009; Jongman et al. 2012), typically as a function of flood characteristics (primary water depth, in some cases speed and persistence) over different land use (LU) categories (Messner et al. 2007; Merz et al. 2010). SDC are either empirically determined from observed damage events or inferred from bibliographic sources. Most flood risk assessment studies employ empirical SDC models that are developed elsewhere and neither tested nor calibrated for the specific study area (Sargent 2013). The lack of practical corroboration compromises the reliability of the model results. In addition, the SDC models are afflicted by substantial uncertainties stemming from the variability of assets value and vulnerability (Messner et al. 2007; Merz et al. 2010; De Moel and Aerts 2011). To some extent, these uncertainties can be reduced if the damage models are designed to reproduce the economic conditions of households and businesses (Luino et al. 2009; De Moel and Aerts 2011). Different SDC models have been reported in literature, but most of them have been developed for site-specific application and are rarely tested for transferability. SDC based on empirical material from Italy are rare (Molinari et al. 2013; Scorzini and Frank 2015). This is despite the common practice of state compensation for households' (private) losses for which certified damage reports are collected. The SDC models also often assume that the potential damage is constant throughout the year. This does not hold for agricultural land, where the crop value varies depending from the crop maturity. Furthermore, SDC models address physical assets damage and hence are not able to determine output losses in terms of foregone production that arises from impairment of economic activities until after the production process are fully recovered. Spatially distributed economic and social variables such as population density and GDP can help to estimate impact on the economic flow from natural hazards. Different methodologies are employed for this purpose, such as econometric models (Noy and Nualsri 2007; Strobl 2010; Cavallo et al. 2012), Input-Output (IO) models (Jonkman et al. 2008; Hallegatte 2008; Henriet et al. 2012; Koks et al. 2014) and Computable General Equilibrium (CGE) models (Jonkhoff 2009; Bosello et al. 2012; Rose and Wei 2013; Carrera et al. 2015). These are useful to estimate the impact of a hazard on the economy up to the regional level, but require disaggregated data that is rarely available at lower scales. The availability of sound flood risk models appropriate for the Italian economic and social circumstances is essential for well-designed and informed flood risk management policies. In this paper we explore ways to improve the damage and loss assessments for the sake of a better risk assessment and management. Similar methods as those explored in this paper have been tested elsewhere at the national (Winsemius et al. 2013) and international scale (Ward et al. 2013).

The paper is structured as follows. First we test the applicability and transferability of up-to-date SDCs against household's damage declarations in the aftermath of the 2014 Modena flood in the Emilia-Romagna region. Successively, we describe a detailed crop-specific model for agricultural losses, better suitable for compensation claims (Forster et al. 2008; Tapia-Silva et al. 2011; Twining 2014). Ultimately, we explore the use of Gross Value Added (GVA) as an indicator of exposure for production losses (Peduzzi et al. 2009).

2. Study area

With the proposed methodology, we aim to simulate the impact of the flood event which hit the province of Modena province during 2014. On January 19th, a 80 meters wide levee breach occurred on the Secchia river, spilling 200 cubic meters per second in the surrounding countryside, covering nearly 6.5 thousand ha of cultivated land (figure 1). Seven municipalities were affected, with the small towns of Bastiglia and Bomporto suffering the largest share of losses. Both towns remained flooded for more than 48 hours. The total volume of water pumped out of the inundated area was estimated to exceed 20 million cubic meters (Fotia 2014). For the purpose of this paper we used the hydrological simulation produced by D'Alpaos et al. (2014). The extent of the simulated flood is nearly five thousand hectares, with an average depth of 1 meter. The bi-dimensional hydrological model employed to simulate the evolution of the flooding resolves the 2-D equations using finite-volume method. The flow volume at the breach is calculated using the 1-D model HEC-RAS calibrated on recorded observations from the event. The altimetry is deduced from a 1x1 m digital terrain model. The simulation takes in account the change in the breach size, as it increased from 10 to 80 meters by the end of the event (Vacondio et al. 2014).

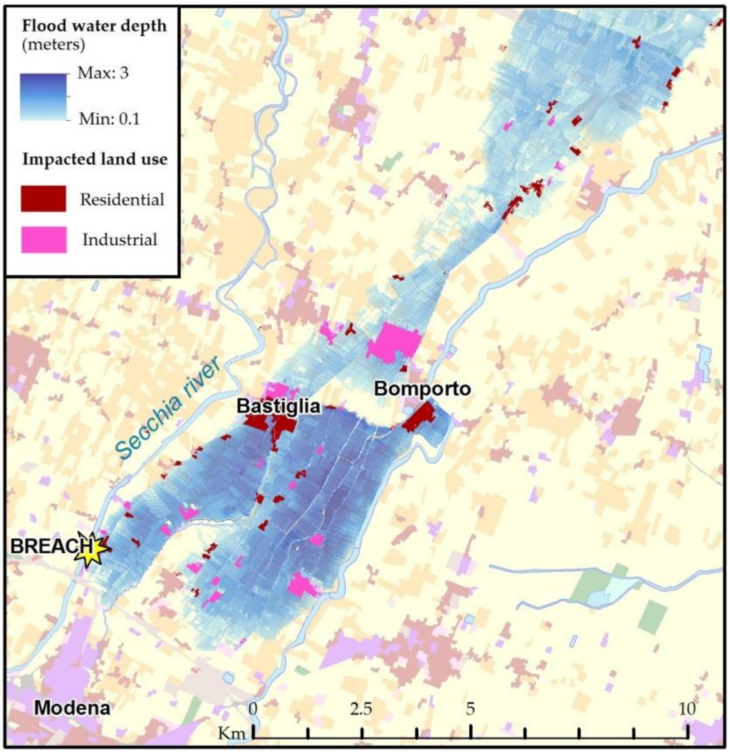

Figure 1: simulated max flood depth ensuing from the Secchia levee breach in January 2014 near Modena. Impacted areas are highlighted for residential and industrial land use.

3. Flood risk assessment methods

3.1 Methodology

Most commonly, *flood risk* **R** is determined as a function of *hazard probability* (**H**), *exposure* (**E**) and *vulnerability* (**V**): $R = H \times E \times V$ (Crichton 1999; Kron 2005; Messner et al. 2007; Barredo and Engelen 2010). Hazard is expressed as observed or modelled probability p (or return period RP = $1/p$) of river discharges exceeding the holding capacity of river embankments. Exposure represents the depreciated or replacement value of the tangible physical assets in hazard-prone areas. Vulnerability is the susceptibility to damage under different levels of flood submersion. The structural damage to physical tangible assets is also termed direct impact or damage on stock (Merz et al. 2010; Meyer et al. 2013). When productive capital is damaged, the impacts can also be valued in terms of production *losses* or foregone flows of production. Sometimes, flow losses are equated to indirect impacts or damage. This is misleading because production losses are an alternative manifestation of material damage to productive capital assets, one that contemplate the value of *output* (good and services) that would have been produced during the time of suspended production, rather than the depreciated value of the damaged asset. Flow losses are able to capture situations in which production is disrupted as a result of dearth of critical input with no material damage to productive capital, for example in case of lifeline disruption (Przyluski and Hallegatte 2011). Here we avoid this ambiguity by referring to damage in terms of partial or total physical asset destruction and losses in terms of foregone production flows. This is consistent with economic theory according to which the value of a stock is the discounted flow of net future returns from its operation (Rose, 2004). We estimate the flood damage both as *asset damage* using the SDC model and as *production losses* in terms of affected annual GVA (Figure 2). Agricultural losses are estimated using a complementary model that accounts for crop production cost and the value of yields (Thieken et al. 2009).

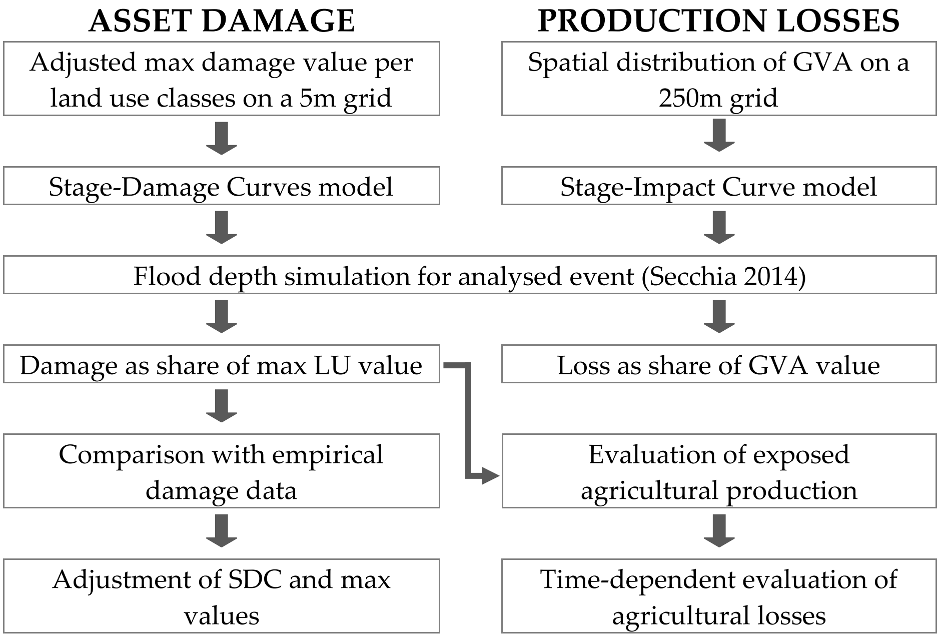

Figure 2: Flood damage assessment methodological approach.

3.2 SDC models for structural damage assessment

The SDC models have recently been tested for applicability in Italy by Scorzini (2015), who identified three models performing within a 10 per cent error margin compared to reported empirical damage: Damage Scanner (DS) (Klijn et al. 2007), JRC (Huizinga 2007) and RWS (Kok et al. 2005). A more detailed version of DS has been recently developed (De Moel et al. 2013; De Moel et al. 2014; Koks et al. 2014) including several sub-classes for residential, rural and industrial LUs (Tebodin 2000) and it represents the best effort to improve the accuracy of this method. These SDC models express the damage as a share of total exposed value, but they calculate it differently from each other. While the updated DS set (Figure 3 left, **SDC-1**) estimates the buildings’ impact separately from areas, the JRC curves (Figure 3 right,

SDC-2) returns an estimation for aggregated land use classes. In fact, in this set the maximum value for each of these main classes is built over the weighted sum of buildings and area, including both the structure and content. This approach is adapted to work in conjunction with low resolution LU maps at national scale. Depth resolution also varies among the two sets: SDC-1 takes steps of 0.1 m, while the other set has 0.5 m steps. All these curves are based on expert judgment and none of them have been validated on empirical damage data. SDC-1 and SDC-2 are the best available options up to date for transferability testing.

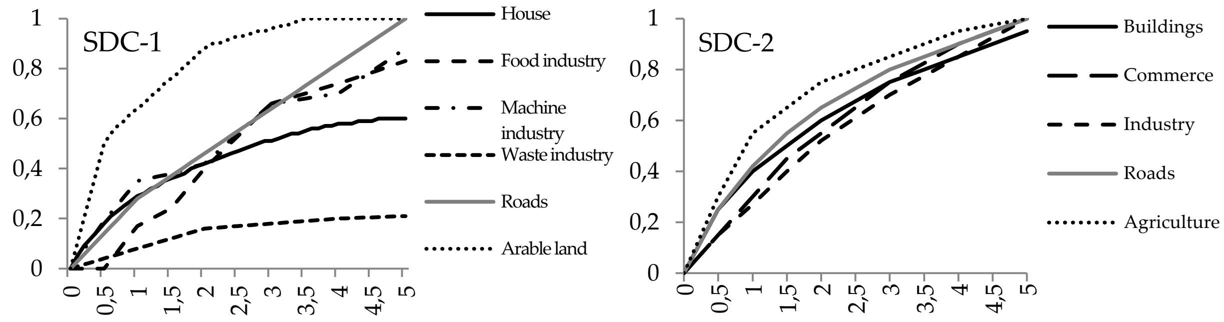

Figure 3: *two sets of SDCs from literature: SDC-1 (left) from DS and SDC-2 (right) from JRC-ITA.* (Huizinga 2007; Koks et al. 2014).

In SDC-1, the max damage value ($\boldsymbol{\lambda}$) associated to each LU class refers to the Netherlands during year 2012. Thus, it needs to be scaled to represent a different country in a different year, as shown in equation [1]:

$$\lambda_{max} = \tau \times \delta \times \lambda_{NLmax} \quad \text{[Equation 1]}$$

The scaling factor $\boldsymbol{\tau}$ (*0.92*) combines the IT/NL price level ratio for 2012 (0.91 from Eurostat) with the inflation rate of 1.011 from 2012 to 2014. SDC-2 is already available as scaled for Italy and others EU countries, and it only needs inflation adjustment. An additional factor ($\boldsymbol{\delta}$) is introduced to express the deviation from national λ mean value in the specific province. For residential areas δ is calculated as the ratio between the current average houses prices in the four flooded provinces and the national mean (*0.77*); for productive areas and buildings δ is the ratio between per capita local GDP and the national mean (*1.22*).We employ detailed land cover and use (LC/U) data combined with the description and location of buildings extracted from the regional spatial development plans (RER 2011). The LC/U typology is the same as in CORINE Land Cover (EEA 2006) but includes an additional, more detailed and accurate disaggregation level. The damage is estimated for urbanised spaces (that include residential and industrial areas) and agricultural land. A SDC is specified for each land use category. For residential damage we consider both the damage to physical structure of buildings and to their associated content. The model accounts also for damage to passenger vehicles based on statistical registers (ACI, 2014). The average price of used cars approximates the replacement costs. Contrarily, commercial vehicles are accounted as part of damaged fixed assets. Damage to roads is deemed negligible and not considered in the analysis. Damage to natural or semi-natural forests is neglected assuming that they are tolerant to occasional floods. Spatial analysis is conducted at high resolution (25 m^2) allowing the identification of single dwellings in sparsely developed residential areas.

The estimated damage using the province-scaled SDC method is compared to households-declared damage and approved compensations made available for the purpose of our work by the local authorities for the flooded municipalities of Bastiglia, Bomporto and Modena. The reported damage dataset distinguishes three categories of residential damage: the *housing* category includes registered damage to structural parts and installations of buildings; *mobile goods* includes furniture and common domestic appliances such as fridges, washing machines, TVs; *registered vehicles* refers to private cars and motorcycles. Mobile goods are compensated for up to 15,000 Euro based on the lower estimate between the sum of private expenditures and the sum of declared damage +10%. Registered vehicles are compensated for up to 25,000 Euro based on the cost of repair, when possible, or the full commercial value of the vehicle referring to official prices list (Eurotax). Compensation for damage inflicted to business enterprises has not yet been completed.

3.3 Agricultural losses

Expected losses in sparsely populated rural areas are often substantially lower than those in residential areas, since the density of exposed value is lower. For this reason, agricultural damage is often neglected or accounted for by using simple approaches with coarse estimates. Yet a thorough loss assessment is necessary in areas where agricultural production is the predominant activity (Messner et al. 2007) as it guides compensation where compelled by liability or granted in form of state aid (Forster et al. 2008; Tapia-Silva et al. 2011; Twining 2014). Standard SDC models are suboptimal for this purpose as they hardly account for the variety in cultivated crops values, yields, and the progressive distribution of production costs. The SDC typically assumes a constant economic value throughout the year, which is not consistent with the fact that the damage depends from when a flood occurs (Ward et al. 2011). In our enhanced model, we determine the representative full crop damage per hectare D_{MAX} as a weighted average of all major crops' values in the analysed area (equation 2) at any time during the growing session (equation 3 and 4).

$$D_{MAX} = \sum_{i=1}^{n} P_i \times Y_i \times \frac{UAA_i}{UAA} \quad \text{[Equation 2]}$$

where $\boldsymbol{i}$ denotes crop index, $\boldsymbol{P}$ the producer prices (per tonnes), $\boldsymbol{Y}$ the yield (in tonnes/hectare), and $\boldsymbol{UAA}$ the Utilised Agricultural Area[1].

D_{MAX} at any time t during the growing season can be estimated either by taking into account the end-of-the-season yield and producer price of crop i, minus production costs not exerted until the end of the production cycle (equation 3); or as a sum of all

[1] UUA comprises total area of arable land, permanent crops and meadows.

production costs exerted from the beginning of the growing season up to the damaging event, plus the land rent (equation 4). The best estimate of the crop value at the harvesting time is Gross Saleable Product[2] (GSP).

$$D_{MAX}^{t} = \sum_{i=1}^{n}\left(\left[GSP_i - \sum_{t}^{End} DC_i\right] \times \frac{UAA_i}{UAA}\right) \quad \text{[Equation 3]}$$

where DC are the direct production costs[3] and t a defined moment of the production cycle ($0 < t <_{End}$).

$$D_{MAX}^{t} = \sum_{i=1}^{n}\left(\left[TNI_i + \sum_{0}^{t} DC_i\right] \times \frac{UAA_i}{UAA}\right) \quad \text{[Equation 4]}$$

where TNI is Total Net Income calculated on the previous years' average, and DC a sum of crop specific production costs exerted until the damaging event.

The average yield, production cost and net income per hectare of arable and permanent crops are determined for different cultivation patterns in the Emilia-Romagna administrative region (RER) based on empirical observations (Altamura et al. 2013). The Farm Accountancy Data Network (FADN) database (INEA 2014) can be used to determine the same information elsewhere. The direct cost is calculated as a function of average cost of technical means (raw materials, machinery) and labour per hectare. These costs are drawn from data collected by agricultural consortia and are inclusive of transportation. Labour costs are split proportionally: half of the costs accounts for soil preparation, fertilization, sowing, and the setup the irrigation system, and the other half accounts for crop reaping and harvesting. Costs for technical means are distributed differently: costs of seeds and herbicides are ascribed to first stages of production, while costs of manure, pesticides and irrigation are applied during the growth of the crop. Direct costs that reflect labour and machinery costs are distributed over the growing season as follows: 50% during sowing period, 20% during crop growth period, and 30% during final production stage (Figure 4) (UOOML and PSAL 2009). A similar pattern (42/23/35%) is applied for vineyards and other permanent crops (see table 9 in the annexes).

	Growing season months												*Period*		*Costs*
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	1	sow	50%
Wheat	1	1	2	2	2	2	2	2	3	4	4	4	2	growth	30%
Maize	3	4	4	4	4	4	1	1	1	2	2	3	3	harvest	20%
Alfalfa	2	2	2	2	2	1	1	2	2	2	2	2	4	renewal	0%

Figure 4: *Allocation of production cost and the typical growing season for the most common cereal crops in the study area.*

Crops are characterised by different susceptibilities to harm when affected by flood. Permanent crops such as vineyards and fruit trees suffer from water stagnation and flooding can cause root rot and plant death. The sensitivity of the arable land depends from the type of crop and the duration of the flooding. According to Citeau

[2] The average gross income from the sale of the yield expressed in €/ha, not inclusive of direct costs.

[3] Sum of the costs for technical means and labour, excluding subsidies.

(2003), maximum tolerable inundation duration for cropland varies between three days in spring/summer to one month in autumn/winter. Germination stage is more sensitive because water can "flush" the soil and take away all the recently planted seeds. A flood that occurs right after sowing may lead to complete loss of seeds but the farmers may be able to limit the damage by sowing again.

A first appraisal of the flood impact completed by district authorities (Gazzetta di Modena 2014) quantifies the agricultural losses to 54 million Euro. About 300 farms have been affected, and most of the damage was related to rural buildings and their contents. Other analysis (Setti 2014) highlighted that the flooding occurred at a time when many field crops had not yet been planted. Wheat and alfalfa were the most commonly exposed crops, but the only physical harm reported was some occasional yellowing among crop fields. Vineyards and other permanent crops were in vegetative rest and apparently did not suffer any damage. The report on regional agricultural production for the year 2014 (OAA-RER 2014) does not revealed any substantial yield reduction. On the contrary, the average yield per hectare in 2014 were slightly higher than 2013.

3.4 Gross Value Added model for production losses

To estimate the production losses we use gridded *Gross Value Added* (GVA) (Peduzzi et al. 2009; Green et al. 2011) based on the statistical disaggregation of GVA at the *local market areas*[4] (in Italian S*istemi Locali di Lavoro* SLL) for three macro-economic branches: agriculture, industry and services (ISTAT 2013). We assume that within the SLL the GVA is uniformly spread, but only over the land use classes ascribed to each specific branch of economic activities. In the case of agriculture and industry, the GVA is attributed to respectively the UAA and total industrial area distinguishable in the land use/cover data sets. The GVA generated by services is distributed proportionally to the population density. The assumption behind this is that since services are multiple and dispersed, they are proportional to the number of residents served. A population density grid is produced based on the 2011 census tracks (ISTAT 2011), which is the most comprehensive source available. The GVA grid cell resolution of 250 × 250 meters is the highest possible given the nature of the data used. The expected losses as a share of GVA per cell are then calculated using a step function (Equation 5, Figure 5) (Carrera et al. 2015), inspired by literature on flood damage functions (De Moel and Aerts 2011; De Moel et al. 2012; Jongman et al. 2012; Saint-Geours et al. 2014). The curve assumes that the higher the water level, the more persistent is the productivity loss. This assumption is based on three principles: a) higher water-depths cause larger productive asset damage; b) larger asset damage typically requires longer recovery periods; and c) flood water retreat is a function of flood depth. The relation between water depth and persistence of the

[4] Local market areas (SLL) have been devised by the Italian Statistical Bureau as continuous territorial areas in which most of the daily work activity of resident people takes place. Typically a SLL is smaller than a NUTS3 unit and larger than a municipality.

impact is likely afflicted by uncertainty, however we assume the curve suited for our purposes.

$$Impact\ on\ GVA_{S,L} = \sum_{k=1}^{n} FC_{S,L\,k} \times c_k \qquad \text{[Equation 5]}$$

where *FC* is the flooded cell *k*, and *c* is the damage factor applied to each FC_k based on its water depth. *N* is the number of cells belonging to sector *S* for each system *L*.

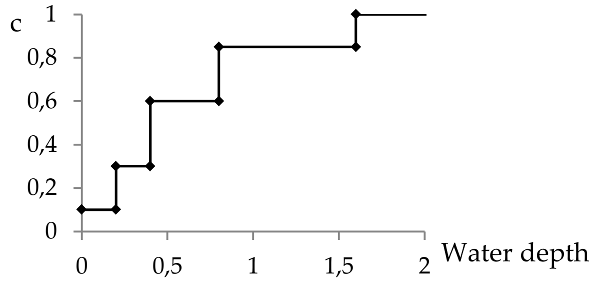

Figure 5: *Stage-impact curve for GVA losses.*

4. Results

4.1 Asset losses

We perform the loss assessment of the Modena flood with two SDC models (SDC-1 and SDC-2, as in Section 2.2). First we compare the results of the unadjusted models on the estimated hazard depths representing the Modena 2014 event, to test their original performance. As shown in Figure 6, the two models yield damage values that differ by 170 million, corresponding to one third of the SDC-2 estimate. Besides, there is a sizeable divergence in distribution of the estimated damage across the land use categories. The SDC-1 yields a damage that is more than two times higher than SDC-2 output for the industrial land use category. On the contrary, SDC-1 estimated damage is lower than SDC-2 by a factor 0.7 for the residential land use category and only one fifth for rural category.

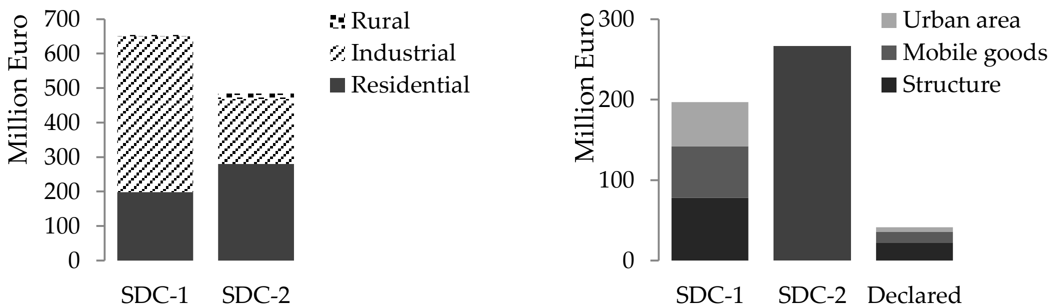

Figure 6: *(left) output of the damage model for the 2014 flood event among aggregated land uses; (right) comparison of SDC models output for urban areas against registered compensation requests from households.*

Figure 6 (right) shows the comparison of the SDC-1 and SDC-2 damage estimates with the empirical (reported) data on damage sustained. Overall, SDC-1 overestimates declared damage in residential areas by a factor 4.5, but for the urban area outside buildings (which includes shared spaces, squares, streets and parked vehicles) this difference peaks factor 9.2. SDC-2 results are even larger, 13 times greater than those observed. The damage shares between structure, mobile goods and private vehicles simulated by SDC-1 resemble[5] the ratios of declared damage. For the calibration exercise, we have chosen SDC-1 over SDC-2 because it is able to disaggregate structural and content-wise damage in isolated dwellings and built-up areas. Both estimated and declared damage are geocoded and aggregated in a 250 m grid.

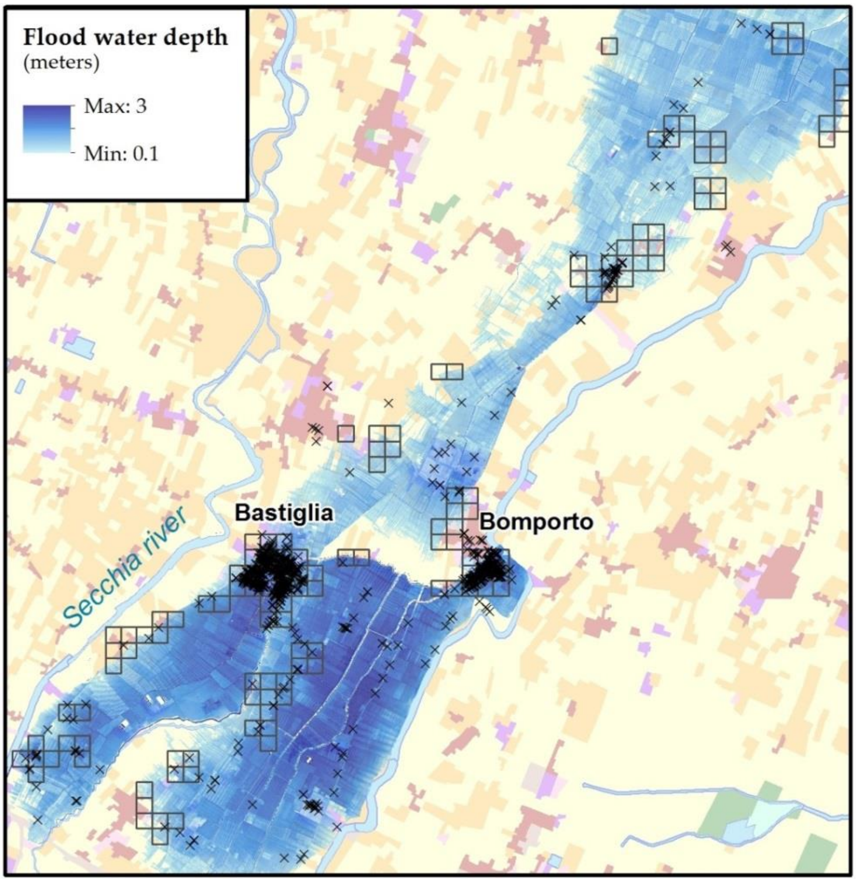

Figure 7: *location matching for residential land use between empirical (black Xs) and simulated damage (aggregated to 250 meters cells).*

There are 61 (out of 157) matching cells between simulated and empirical damage, which is less than 40% in terms of affected area but the matching cells account for 83% of simulated and 75% of the declared damage. As shown in Figure 7, this mismatch is caused mainly by uncertainty in the LU data for sparsely developed areas and in the extent of the flood boundaries, but the core damage areas of Bastiglia and Bomporto match well between recorded and simulated damage. The calibration hereafter is carried out only on matching cells using regression analysis under the hypothesis of linear relationship. For each land use category, the maximum damage value is individually adjusted using the *B* (slope) coefficients as scaling factor. Figure 8 shows the results of linear regression between SDC-1 output

[5] Simulated damage: 57/33/10%. Declared damage: 60/35/5%.

and empirical damage before and after calibration for *total* (A), *structural* (B) and *content* (C) damage categories.

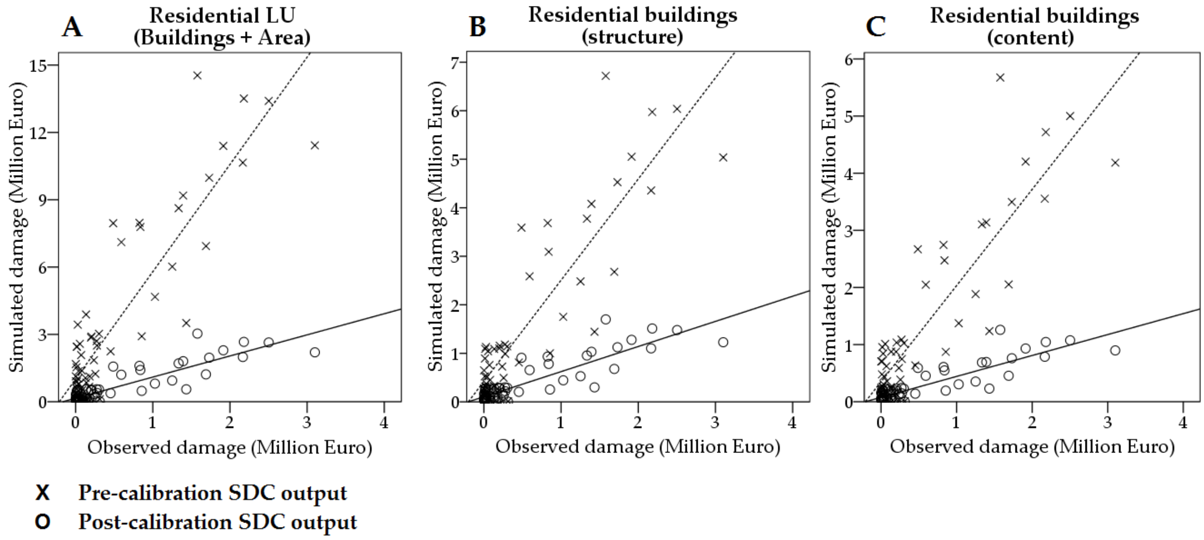

Figure 8: *Scatterplot showing empirical damage (X axis) and SDC results (Y axis) per grid cell using original land use values (cross indicator, dotted line) and calibrated ones (circle indicator, black line) for: A) total residential area; B) building structure; C) buildings content.*

The pre-calibration output overestimated the total damage in residential areas by a factor 4.5-7 depending on the within-urban land use category. The calibrated damage values are regressed with the observed/reported damage with good results (R^2=0.8) for all categories except for *urban area* where registered vehicles are assumed to be homogeneously distributed. This proven to be an over simplistic assumption. For buildings structure and content the coefficient (*B*) is close to 1.0, and the final output overestimate recorded residential damage by just 6% (Table 1).

Land Use		**Observed**	**Simulated**		
Description	Area (m^2)	Damage (million Euro)	Damage (million Euro)	R^2	B
Urban area (vehicles)	1,432,650	5,5	2,4	0.3	0.2
Buildings	234,950	36	41,9	0.8	1.0
Buildings structure		22,3	24,3	0.8	1.0
Buildings content		13,7	17,6	0.7	1.0
Total	1,667,600	41,5	44,4	0.8	0.9

Table 1: *Exposed area, observed and simulated damage inclusive of regression results for each calibrated land use category tested against empirical data.*

4.2 Agricultural losses

The area affected by the Secchia flood comprises predominately rural areas (43 km^2), with a prevalent share of arable crops (81% of UUA). The typical crops include cereals, in particular soft wheat and maize (40% of arable crops) and forage for livestock breeding (52% of arable crops). Other arable crops together cover less than

8 per cent. Vineyards and other permanent crops cover the remaining 19% of UAA. As shown in Figure 4, in January maize crops are fallow, while wheat is in its vegetative stage. This means that just half of cereal production is affected. Losses for wheat crops include all the initial costs, which amounts to 50 per cent of total value. Permanent crops are affected by 20% of annual production value. The maximum damage (total loss) to cropland estimated from these share using equation [2] is 343 Euro/ha, less than half compared to the max value used by SDC-1 (790 Euro/ha).

$$D_{MAX} = 0.81 \times \{0.4 \times [0.46 \times (2080 - 1409 \times 0.5)] + 0.5 \times (1281 - 853 \times 0.5)\} + 0.19 \times (9925 \times 0.2) = 343\ Euro/ha$$

This adjusted max value leads to a maximal estimated loss by SDC-1 of 375 thousand Euro over 4.2 thousand ha of crop land. In the end, empirical evidences on crop production (OAA-RER 2014) suggests that the assumption of total loss for exposed crops may be over pessimistic, since crop plants shown good tolerance to inundation (Setti 2014). Overall, an estimate based on case-specific empirical data should be preferred over unadjusted SDC values. Tables 3, 4 and 5 in annex show the direct costs, Gross Saleable Product and max values per hectare.

4.3 Production losses

The losses are calculated for each economic sector as a share of total annual production. The largest share of damage come from the industrial sector, affected for 434 million Euro, equivalent to 14% of its annual production (4.2% of total GVA for SLL Modena, see Table 2). The ratio between asset damage and annual GVA sheds light on the equivalence of structural damage and production losses as a function of the flood characteristics (Figure 9). For water depth around 1 meter, the linear trend describes an asset damage close to annual production losses (ratio of 1), similarly to the stage-impact curve assumptions in figure 5.

	Million Euro	Sector %	Total %
Agriculture	9,1	6,41	0,09
Industry	434.1	14,11	4,20
Services	147.2	2,07	1,42
TOTAL	590,4		5,71

Table 2: *modelled impact on GVA from the event of Modena 2014.*

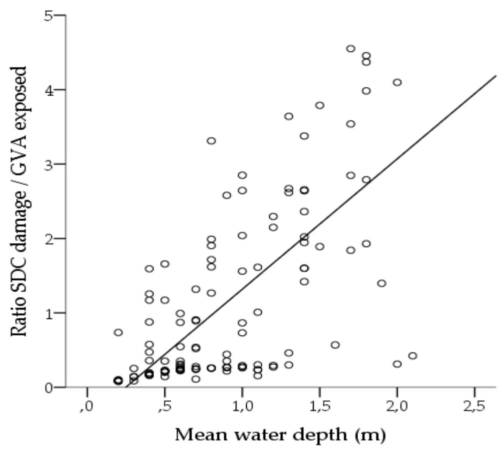

Figure 9: *Scatterplot of mean water depth (X) and ratio of SDC damage over exposed GVA (Y).*

4.4 Discussion

In this paper, we presented three ways to improve the current state-of-the-art of flood risk assessment models based on SDC. Major uncertainties in damage assessments are associated with the value of risk-exposed elements (i.e. maximum damage values) and the depth-damage curves (De Moel and Aerts 2011; Scorzini 2015). In Section 4.1 we have shown that by adjusting the maximum damage values for the specific conditions of the assessment area, the consistency of the model improves substantially. Prior adjustments, the tested SDC models overestimate the reported damage by a factor 4 to 13. After calibration, the maximum damage values for residential buildings are 4 to 4.5 times smaller than the original values and the simulation of total damage is very close to empirical observations. These considerations are consistent with those found by Scorzini (2015), who similarly stresses the importance of evidence-based SDC to perform a meaningful flood risk assessment. In Section 4.2 we considered the temporal variability in the agricultural sector using detailed crop yield data and local production patterns. This approach produces a different outcome compared to the conventional SDC estimate: the maximum crop-yield loss per hectare is less than a half of what is assumed by SDC-1; similarly, lower damage estimates using a time-dependent approach are found in Forster et al. (2008). Still, our estimate appears to be a pessimistic scenario compared to available evidences of small to no damage to crops production in our case study. Section 4.3 explains how the GVA approach can approximate output losses within the flooded area with relative ease, if economic data are available. We estimated that the production losses amount to around 600 million Euros, or 5.7 per cent of the annual GVA of the Modena SLL. Asset damage appears close to the annual GVA when the average water depth reaches one meter. However, these results are hardly comparable with empirical observations about production losses at the regional scale and thus cannot be properly validated.

5. Conclusion

Our analysis aimed at improving flood damage assessment modelling in Italy. The comparison of damage estimates made by SDC models with empirical recorded damage is key for this task. In this paper we tested two frequently used SDC models against reported flood damage after a major flood event in Northern Italy. Model calibration is proven mainly useful to improve the loss assessment in a specific event area, while it is yet to be studied how these calibrated curves can be adjusted for application in surrounding regions. The calibration here is carried out for residential land use categories only, while empirical damage records about industrial land use is awaited to complete the assessment in future research.

Further improvements can be achieved when a larger number of empirical damage evidences, typically collected by the Civil Protection Agency (CPA), is made accessible to academic community. Another research thread capable to improve the reliability of flood risk models by reducing the largest uncertainty in the definition of maximum damage values entail the spatially disaggregated socioeconomic data such as population, household income, cadastral value of property. With the growing availability of digital spatial data related to this variables, their implementation in an integrated model is a advisable step to improve the representativeness and reliability of flood risk assessment.

6. Acknowledgment

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 308438 (*ENHANCE - Enhancing Risk Management Partnerships For Catastrophic Natural Hazards In Europe*).

We are grateful to the Department of Civil Engineering, Environment, Territory and Architecture of the University of Parma for the provision of flood simulation of the 2014 Modena flood event.

7. References

Altamura V, Cesena C, Aldo P, Unibo B (2013) Costi di produzione delle principali specie vegetali in Emilia-Romagna 2013.

Barredo JI, Engelen G (2010) Land Use Scenario Modeling for Flood Risk Mitigation. Sustainability 2:1327–1344. doi: 10.3390/su2051327

Bosello F, Nicholls RJ, Richards J, et al (2012) Economic impacts of climate change in Europe: sea-level rise. Clim Change 112:63–81.

Carrera L, Standardi G, Bosello F, Mysiak J (2015) Assessing direct and indirect economic impacts of a flood event through the integration of spatial and computable general equilibrium modelling. Environ Model Softw 63:109–122. doi: 10.1016/j.envsoft.2014.09.016

Cavallo E, Bank ID, Galiani S, Pantano J (2012) Catastrophic Natural Disasters and Economic Growth. Washington DC, USA

Citeau J (2003) A new flood control concept in the Oise catchment area: definition and assessment of flood compatible agricultural activities. 1–19.

Crichton D (1999) The Risk Triangle. Nat Disaster Manag 102–103.

D'Alpaos L, Brath A, Fioravante V (2014) Relazione tecnico-scientifica sulle cause del collasso dell ' argine del fiume Secchia avvenuto il giorno 19 gennaio 2014 presso la frazione San Matteo.

De Moel H, Aerts JCJH (2011) Effect of uncertainty in land use, damage models and inundation depth on flood risk estimates. Nat Hazards 58:407–425.

De Moel H, Asselman NEM, Aerts J (2012) Uncertainty and sensitivity analysis of coastal flood damage estimates in the west of the Netherlands. Nat Hazards Earth Syst Sci 12:1045–1058.

De Moel H, Bouwer LM, Aerts JCJH (2014) Uncertainty and sensitivity of flood risk calculations for a dike ring in the south of the Netherlands. Sci Total Environ 473-474:224–234. doi: 10.1016/j.scitotenv.2013.12.015

De Moel H, van Vliet M, Aerts JCJH (2013) Evaluating the effect of flood damage-reducing measures: a case study of the unembanked area of Rotterdam, the Netherlands. Reg Environ Chang 1–14. doi: 10.1007/s10113-013-0420-z

European Environment Agency (2006) CORINE Land Cover.

Forster S, Kuhlmann B, Lindenschmidt K, Bronstert A (2008) Assessing flood risk for a rural detention area.

Fotia F (2014) Esondazione del Secchia. http://www.meteoweb.eu/2014/01/esondazione-del-secchia-evacuati-20-milioni-di-metri-cubi-dacqua/255270/. Accessed 29 Aug 2014

Gazzetta di Modena (2014) Alluvione: 54 milioni di euro di danni in agricoltura.

Genovese E (2006) A methodological approach to land use-based flood damage assessment in urban areas: Prague case study. Eur. Communities, DG-JRC, Ispra, EUR

Green PC, Viavattene C, Thompson P, Green C (2011) CONHAZ Report - Guidance for assessing flood losses.

Hallegatte S (2008) An adaptive regional input-output model and its application to the assessment of the economic cost of Katrina. Risk Anal 28:779–99. doi: 10.1111/j.1539-6924.2008.01046.x

Henriet F, Hallegatte S, Tabourier L (2012) Firm-network characteristics and economic robustness to natural disasters. J Econ Dyn Control 36:150–167. doi: 10.1016/j.jedc.2011.10.001

Huizinga HJ (2007) Flood damage functions for EU member states.

ISTAT (2013) Banca dati Italia.

ISTAT (2011) 15° censimento della populazione e delle abitazioni.

Jongman B, Kreibich H, Apel H, et al (2012) Comparative flood damage model assessment: towards a European approach. Nat Hazards Earth Syst Sci 12:3733–3752.

Jonkhoff W (2009) Flood risk assessment and policy in the Netherlands. In: OECD (ed) Green Cities new approaches to confronting Clim. Chang. OECD, Las Palmas de Gran Canaria, pp 220–240

Jonkman SN, Bočkarjova M, Kok M, Bernardini P (2008) Integrated hydrodynamic and economic modelling of flood damage in the Netherlands. Ecol Econ 66:77–90.

Klijn F, Baan P, Bruijn K de, Kwadijk J (2007) Overstromingsrisico's in Nederland in een veranderend klimaat.

Kok M, Huizinga HJ, Barendregt A (2005) Schade en Slachtoffers als gevolg van overstromingen.

Koks EE, Bockarjova M, De Moel H, Aerts JCJH (2014) Integrated direct and indirect flood risk modeling: development and sensitivity analysis. Risk Anal.

Kron W (2005) Flood Risk = Hazard x Values x Vulnerability. Water Int 30:58–68. doi: 10.1080/02508060508691837

Luino F, Cirio CG, Biddoccu M, et al (2009) Application of a model to the evaluation of flood damage. Geoinformatica 13:339–353. doi: 10.1007/s10707-008-0070-3

Merz B, Kreibich H, Schwarze R, Thieken A (2010) Assessment of economic flood damage. Nat Hazards Earth Syst Sci 10:1697–1724. doi: 10.5194/nhess-10-1697-2010

Messner F, Penning-rowsell E, Green C, et al (2007) Evaluating flood damages: guidance and recommendations on principles and methods.

Meyer V, Becker N, Markantonis V, et al (2013) Review article: Assessing the costs of natural hazards – state of the art and knowledge gaps. Nat Hazards Earth Syst Sci 13:1351–1373. doi: 10.5194/nhess-13-1351-2013

Molinari D, Aronica GT, Ballio F, et al (2013) Le curve di danno quale strumento a supporto della direttiva alluvioni: criticità dei dati italiani. 10–15.

Noy I, Nualsri A (2007) What do exogenous shocks tell us about growth theories? Santa Cruz Inst. for International Economics, Santa Cruz

Osservatorio Agro-Alimentare Emilia Romagna (2014) Il sistema agro-alimentare dell'Emilia-Romagna.

Peduzzi P, Dao H, Herold C, Mouton F (2009) Assessing global exposure and vulnerability towards natural hazards: the Disaster Risk Index. Nat Hazards Earth Syst Sci 9:1149–1159. doi: 10.5194/nhess-9-1149-2009

Przyluski V, Hallegatte S (2011) Indirect Costs of Natural Hazards - CONHAZ Report.

Regione Emilia-Romagna (2011) Coperture vettoriali dell'uso del suolo 2008. http://servizigis.regione.emilia-romagna.it/ctwmetadatiRER/metadatoISO.ejb?stato_IdMetadato=iOrg01iEnP1idMetadato76868. Accessed 1 Jul 2015

Rose A, Wei D (2013) Estimating the Economic Consequences of a Port Shutdown: the Special Role of Resilience. Econ Syst Res 25:212–232. doi: 10.1080/09535314.2012.731379

Saint-Geours N, Bailly J-S, Grelot F, Lavergne C (2014) Multi-scale spatial sensitivity analysis of a model for economic appraisal of flood risk management policies. Environ Model Softw 60:153–166. doi: doi.org/10.1016/j.envsoft.2014.06.012

Sargent DM (2013) Updating Residential Flood Stage-Damage Curves based on Building Cost Data. Reach. out to Reg. - SIAQ Conf.

Scorzini A, Frank E (2015) Flood damage curves : new insights from the 2010 flood in Veneto , Italy.

Setti G (2014) Recuperare i suoli dopo l'alluvione. Terra e vita 11:

Strobl E (2010) The Economic Growth Impact of Hurricanes: Evidence from U.S. Coastal Counties. Rev Econ Stat 93:575–589. doi: 10.1162/REST_a_00082

Tapia-Silva F-O, Itzerott S, Foerster S, et al (2011) Estimation of flood losses to agricultural crops using remote sensing. Phys Chem Earth, Parts A/B/C 36:253–265.

Tebodin (2000) Schadecurves industrie ten gevolge van overstroming.

Thieken a. H, Ackermann V, Elmer F, et al (2009) Methods for the evaluation of direct and indirect flood losses. RIMAX Contrib 4th Int Symp Flood Def 1–10.

Twining S (2014) Impact of 2014 Winter Floods on Agriculture in England.

UOOML, PSAL (2009) Linee guida per la sorveglianza sanitaria e la prevenzione dei rischi per la salute e la sicurezza nel settore cerealicolo.

Vacondio R, Aureli F, Mignosa P, Palù AD (2014) 2D shallow water GPU parallelized scheme for high resolution real-field flood simulations.

Ward PJ, Jongman B, Weiland FS, et al (2013) Assessing flood risk at the global scale: model setup, results, and sensitivity. Environ Res Lett 8:044019. doi: 10.1088/1748-9326/8/4/044019

Winsemius HC, Van Beek LPH, Jongman B, et al (2013) A framework for global river flood risk assessments. Hydrol Earth Syst Sci 17:1871–1892. doi: 10.5194/hess-17-1871-2013

8. Annexes

2012	Maize	Wheat	Alfalfa	AVG	AVG%	Sum%
Labour						
Soil preparation	330	310.5	377	339	31	52
Fertilization	118	94.4	40	84	8	
Sowing	90	61.4	52	68	6	
Irrigation system	86	86.9	53	75	7	
Reaping	797	311.2	452	520	48	48
Total labour	1421	864.4	974	1087	64	100
Technical means						
Seeds	201	115	220	179	29	84
Manure	327	243	238	269	44	
Herbicides	35	103	45	61	10	
Pesticides	30	82	4	39	6	16
Irrigation	120	0	0	40	7	
Total tech means	772	544	507	608	**36**	100
Direct costs	**2,193**	**1,409**	**853**	**1,485**	**100**	

Table 3: *average cost (Euro/ha) and relative share distribution for cereal crops production. The sum is made between crop start/end costs.*

2012	Trebbiano	SanGiovese	AVG	AVG%	Sum%
Labour					
Pruning	1,035	1,289	1,162	26	40
Soil preparation	161	554.5	358	8	
Fertilization	25	491	258	6	
Treatments	260	262	261	6	6
Weeding	25	0	12	0	
Harvest	2,466	2,425,7	2,446	54	54
Total labour	3,972	5,023	4,497	61	100
Technical means					
Machinery	1,061	952	1,007	35	55
Fertilizers	409	393	401	14	
Hale insurance	148.5	205	177	6	
Pesticides	968	954	961	34	45
Contingencies	320	320	320	11	
Total tech means	2,907	2823	2,865	39	100
Direct costs	**6,879**	**7,846**	**7,363**	**100**	

Table 4: *average cost (Euro/ha) and relative share distribution for vineyards production. The sum is made between crop start/growth/end costs.*

	Tech means	Labour	Direct cost	GSP	Avg. max value
2009-2012		*Arable land*			
Maize	772	1,421	2,193	2,500	2,100
Wheat	544	864	1,409	2,080	
Alfalfa	155	698	853	1,281	
Others			3,150	3,650	
2012		*Vineyards*			
Trebbiano	2,907	3,972	6,879	11,750	9,925
SanGiovese	2,823	5,023	7,846	8,100	

Table 5: *direct cost (tech means + labour) and Gross Saleable Product for the most common arable crops (avg. 1996-2012) and for two representative kind of vineyards (2012) in Eur/ha.*

CODE	Description	Structure max damage (€/m²)	Content max damage (€/m²)
110	Residential area	46	34
111	House	1,478	739
112	House shed	924	92
135	Sport	1,478	554
136	Other	924	92
150	Industrial area	37	-
151	Industry	1,662	1,108
152	Warehouse	1,108	924
153	Food industry	485	1,108
154	Crude oil refineries	1,159	1,108
159	Machine industry	485	1,108
162	Waste industry	2,078	1,108
167	Other industry	485	1,108
210	Horticulture	37	-
211	Greenhouse	92	-
220	Arable land	0.22	-
221	Barn/Stable	924	924
230	Pasture	0.1	-
240	Permanent cultures	0.74	-
340	Recreational area	0.03	-

Table 6: *max damage values adapted for Italy for exposed land use categories. Values are based on Koks, 2014.*

Regression analysis after calibration of LU max values

Residential land use (Buildings + Area) *COD 110+111*

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
,883	,780	,776	375730,872

The independent variable is OBS_110+111.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
OBS_110+111	,941	,065	,883	14,447	,000
(Constant)	158096,496	58590,843		2,698	,009

Residential buildings *COD 111*

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
,893	,797	,793	354400,843

The independent variable is OBS_111.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
OBS_111	,998	,070	,893	14,301	,000
(Constant)	165031,642	60526,986		2,727	,009

Residential buildings structure *COD 111S*

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
,895	,801	,796	207952,474

The independent variable is OBS_111S.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
OBS_111S	,952	,068	,895	14,024	,000
(Constant)	98612,192	37216,240		2,650	,011

Residential buildings content *COD 111C*

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
,836	,699	,693	180916,068

The independent variable is OBS_111C.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
OBS_111C	,959	,089	,836	10,779	,000
(Constant)	92945,665	31258,721		2,973	,005

Model Summary and Parameter Estimates for regression between SDC/GVA ratio and mean water depth

Dependent Variable: Ratio_GVA

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	,437	95,399	1	123	,000	-43,299	175,182
Power	,462	105,455	1	123	,000	85,003	1,306

The independent variable is WD_mean.

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