Compensation Valuation Due to Hydraulic Constraints

Francesca Salvo(✉), Manuela De Ruggiero, and Daniela Tavano

Department of Environmental Engineering, University of Calabria, Via P. Bucci Cubo 46, 87036 Rende, Italy
francesca.salvo@unical.it

Abstract. This work aims to valuate the benefits and/or damages related to the apposition of hydraulic constraints, considering the economic aspects and the appraisal ones. From an appraisal point of view, the valuation of hydraulic damage considers the *ex ante* compensation: for the imposition of the hydraulic constraint and for the preventive compensation of future damages. The constraint can probably produce a loss in terms of income and assets, but also a decrease in hydraulic risk and consequent economic benefits. Compensation for future damage concerns random events and expresses the variation in the hydraulic risk for the land subject to restriction. If the change in hydraulic risk produces a reduction in risk (due to less probability and/ or less damage), then the measure of the damage is negative and it corresponds to a surplus value of lands. The proposed methodological process essentially aims to define the function of the *ex post* damage and to identify the criteria and the procedural process in order to valuate the damage caused to land as a result of the imposition of the hydraulic constraint and future damage avoided which have to be indemnified in advance (*ex ante*).

Keywords: Hydraulic risk · Hydrogeological constraint · Compensation appraisal

1 Introduction

Floodings are a central issue in public opinion and governance attention, both for an increased cultural emancipation and a more mature awareness of the related risk, and for the worsening of hydrographic basins instability caused by the lack of controls on the land use [1]. This phenomenon affects the territory at a widespread level, prefiguring the occurrence of risk situations almost everywhere. It is clear that the prevention of emergencies connected to the occurrence of flooding must be an imperative both under the socio-political profile, of the involvement of public institutions, and under the more strictly technical profile, in relation to the choice and planning of interventions aimed at flood defense [2–4].

Regarding the technical aspects, a fundamental role in the planning of the hydraulic works for rivers, streams, entire catchment areas, is played by the economic assessment of damage from flooding [5]. This is preliminary to the design of the interventions, since

O. Gervasi et al. (Eds.): ICCSA 2021, LNCS 12956, pp. 279–288, 2021.
https://doi.org/10.1007/978-3-030-87010-2_19

the works, in the absence of budgetary constraints, must be sized so that the marginal variation of the potential damage is equal to the marginal construction cost; and it is also preliminary to the economic evaluation of the interventions, matching the extent of the damage to the benefits obtainable with the implementation of the works, to be offset against the construction costs.

The problem of hydraulic risk mitigation is particularly significant in Italy. The Higher Institute for Environmental Protection and Research (ISPRA) report on the Italian hydrogeological instability provides a reference framework on the risk of landslides and floods on the national territory and on other risk indicators relating to population, buildings and cultural heritage [6].

91.1% of Italian municipalities are located in an area where the risk of hydrogeological instability is considerable. The surface of the areas classified as dangerous by medium-high landslides and/or medium intensity hydraulic landslides amounts to a total of 50,117 square kilometers, and is equal to 16.6% of the national territory. These are areas in which, following very heavy rainfall, landslides or floods, even of large dimensions, can occur. Considering that every year about a hundred landslides occur on the Italian national territory, which cause victims, injuries, evacuations and damage to buildings, cultural assets and infrastructures, it can be said that these are not only isolated events caused by particular atmospheric conditions or seismic events.

The report shows that over 7 million Italians reside in vulnerable areas, but potentially the number could be higher. Analyzing the risk from the point of view of the population, it turns out that 2.2% of the Italian population (from 2011 Istat census), resides in areas deemed to be at high and very high landslide risk, for a total of over one million inhabitants (1,281,970).

The population exposed to high flood risk is equal to 3.5% of the population (2,062,475 inhabitants), while those exposed to a scenario of average danger (with a return time between 100 and 200 years) reaches 10. 4% of Italian citizens (6,183,364 inhabitants).

The only way to reduce the damage caused by floods and landslides remains the most obvious, but also the least used: prevention. Prevention is possible by activating territorial monitoring and hydrogeological risk mitigation projects [7].

2 The Hydrogeological Constraint and the Hydrogeological Structure Plan (PAI)

The Italian law evolution about hydrogeological risk is extremely vast because of breadth and variety of all environmental cases.

The Royal Decree (R.D.) n. 3918/1877, still in force, among the others is the first regulatory interventions on specific restrictions for the protection of forests, summarized within the term 'forest restriction'. It defines the concept of hydrogeological constraint, which subjects land of any nature and destination to "constraint for hydrogeological purposes"(art. 1).

The main purpose of the hydrogeological constraint is to preserve the physical environment and therefore to ensure that all interventions that interact with the territory do not compromise its stability, nor trigger erosive phenomena, etc., with the possibility of damage. public, especially in hilly and mountainous areas.

The hydrogeological constraint therefore concerns land of any nature and destination, but is mainly located in the mountainous and hilly areas and may concern wooded or non-wooded areas. In this regard, it should be noted that the hydrogeological constraint does not coincide with the wood or forest one, always governed originally by the R.D.L. 3267/1923.

The hydrogeological constraint in general does not preclude the possibility of intervening on territory, but it makes interventions in these areas subject to the obtaining of a specific authorization (art. 7 of the Royal Decree no. 3267/1923).

The hydrogeological constraint has the nature of a "conformative" constraint of private property aimed at protecting a public interest (in this case the conservation of the good water regime, the stability and hydrogeological defense of the territory) and, that is, it can be imposed on all properties that have certain characteristics, with the consequence that it does not imply forms of compensation for the owners, as is the case for landscape, historical-artistic, park / protected area restrictions, etc.

The hydrogeological constraint does not entail the absolute urbanization of the area, so the interventions allowed by the urban planning instrument can be carried out if they do not damage or endanger the protected environmental values. The presence of the constraint imposes on the owners the obligation to obtain, before carrying out the intervention, the release of the specific authorization from the competent administration, in addition to the building permit.

In the Italian legislation, due to to Law Decree 11.06.1998 n. 180, the hydrogeological risk means both the hydraulic and the geomorphological ones; in simplified terms, the first is linked to a flood event in a watercourse, the second to the movement of a mass of earth, rock, or debris along a slope, both often caused by persistent precipitation of high intensity that characterize that particular area. Therefore, careful monitoring becomes fundamental in order to prevent and reduce the extent of these types of risk and to build adequate warning systems.

The hydrogeological risk assessment method has been identified in 1998 with Prime Minister's decree DPCM of 29.09.1998 [8]; it is structured in such a way as to allow a qualitative assumption of the essential risk factors, through which it is possible to reach a gradation in classes that depends on the combination of the danger of the area and related land use:

- R1: moderate risk;
- R2: medium risk;
- R3: high risk;
- R4: very high risk.

The purpose of this classification is essentially to identify riskier areas than others, even if they have the same hazard, depending on physical and anthropogenic elements found on them. In fact, according to the R level of risk degree, areas with a greater human presence are associated with high hydrogeological criticalities and, consequently, those to be defended as a priority. The identification of areas with different hazards, as well as the subsequent calculation of the risk, is instead essentially aimed at providing the basic elements for the subsequent planning and design activities of new construction in order to prevent the creation of new risk areas.

The identification of hydrogeological risk areas leads to the drafting of the hydrogeological risk map which is an elaboration foreseen in the excerpt planning of each Basin Authority. The hydrogeological risk map provides for the definition of some risk classes by crossing the hazard classes with the risk elements deriving from the land use map. The Hydrogeological Plan (P.A.I.) has essentially three functions:

1) the cognitive function, which includes the study of the physical environment and the anthropic system, as well as the recognition of the forecasts of urban planning tools and hydrogeological and landscape constraints;
2) the regulatory and prescriptive function, intended for activities related to the protection of the territory and water, the assessment of the hydrogeological risk and the consequent constraint activity in both extraordinary and ordinary regime;
3) the programmatic function, which provides the possible intervention methods aimed at mitigating the risk, it determines the necessary financial commitment and the temporal distribution of the interventions.

In the R4 risk areas, the PAI pursues the objective of guaranteeing hydraulic safety conditions, ensuring the free flow of the flood with a return time of 20 - 50 years, as well as the maintenance and recovery of the dynamic equilibrium conditions of the riverbed.

In the aforementioned areas all works and activities related to urban, territorial and building nature are prohibited, with the exclusive exception of those of demolition without reconstruction, adaptation or maintenance, making the assets and areas safe, practices for correct agricultural activity, provided that the morphology of the territory is not changed; there is greater flexibility for public infrastructures referring to essential and non-delocalizable services, but always subject to authorization by the Basin Authority.

In the R3 risk areas, PAI pursues the objective of guaranteeing hydraulic safety conditions, maintaining or increasing the flooding conditions with a return time of 200 years, together with the conservation and improvement of the natural environmental characteristics. In these areas all works and activities related to urban, territorial and building nature are prohibited, except all interventions allowed in R4 risk area, expansion interventions of existing buildings for hygienic-sanitary adaptation needs, of temporary deposits resulting from and connected to authorized mining activities, to be carried out in accordance with the procedures prescribed by the authorization devices.

In the R2 and R1 risk areas, the construction of underground and/or semi-terraced rooms for residential and commercial use is not permitted.

3 Methodology. The Damage Appraisal

The study examines the damage in its sense of *ex post* and *ex ante* valuation, with reference to the imposition of hydraulic constraints.

The topic of *ex post* compensation is proposed in the form of an income statement intended to quantify the reintegration for the loss resulting from the damage.

The valuation of the *ex ante* damage, in planning of hydraulic interventions, regards the imposition of the hydraulic constraint and the future damage avoided, to be compensated in advance. The appraisal of the *ex ante* damage, more specifically, concerns the evaluation of the indemnity, which means the measure of the damage linked to the variation in income and assets following the imposition of the constraint (land hydraulic arrangement land and related costs, loss of potential buildings, etc.)

The issue of compensation for *ex post* damage in private relationships is well stated in literature review [9, 10] and it follows the principle of reintegration of the property affected by the damage (once it has occurred). In the plumbing project, the preliminary valuation of the cost of compensation for any damage arises as a problem of the valuation of the *ex ante* compensation, paid in advance and one-off. The problem can be treated in terms of appraisal but it requires legal and political investigations for the justification of the indemnity.

Hydraulic damage has the following characteristics [11]:

- a harmful event that has occurred or to occur;
- the cause-effect link that allows the identification and delimitation of the damage;
- the presence of at least two subjects in antithetical garments;
- a situation prior to the damage (or initial);
- a situation subsequent to the damage (or final) that allows the differential measurement;
- the existing structure of property and use rights that attributes responsibilities and promotes compensation between private (or public in private relations) subjects.
- The damage exists only in the case in which the posterior situation is worse than the anterior one, otherwise there is an advantage.

3.1 *Ex post* Damage Appraisal

The compensation valuation follows a theoretical criterion that sets out the principle of reintegration of assets for the loss resulting from the damage, and a practical criterion that provides for the appraisal of the monetary amount [11].

The theoretical criterion considers the loss in value of lands submerged by water (temporary or permanent loss).

The practical criterion concerns the analysis of the events and responsibilities of the occurrence of damage, which can be sought in the following components:

- natural component, linked to the occurrence of the adverse event;
- administrative/technical component, attributable to poor management of resources and lack of or inadequate planning;
- management component, due to the presumed inefficient management of any hydraulic measures present;
- private component, linked to any conduct not aimed at containing the damage once it has occurred.

If we indicate with α the rate of damage caused by nature, β the rate of damage caused by political and technical contingencies, with γ the rate of damage caused by bad management and maintenance and δ is the rate of damage caused by the anomalous behavior of the owners, the unit damage is equal to:

$$Unitary\,damage \;=\; \alpha + \beta + \gamma + \delta \;=\; 1. \tag{1}$$

In summary, the problem of *ex post* compensation can be proposed in the form of an economic account Table 1.

Table 1. Ex post damage - Economic account

To give	To have
To private owners, according to the practical criterion for the rate γ	- from the natural component (natural adversity) for the α rate - from the administrative / technical component (political risk) for the β rate - from the management component for the disservice part for the rate γ; - from the private owners for the part of unsuitable practices for the δ rate

3.2 *Ex ante* Damage Appraisal

When planning hydraulic interventions, the valuation of damage caused to lands concerns the imposition of the hydraulic constraint and the future damage avoided, to be compensated in advance (*ex ante*).

Hydraulic Constraint

The theoretical criterion suitable to valuate the *ex ante* compensation for the imposition of hydraulic constraints regards the extent of the damage linked to the change in income and assets resulting from the imposition of the constraint. If this change results in a loss of income and/or capital value, then the relative measure corresponds to the permanent loss of market value of the asset, otherwise it is a capital gain. For the purposes of compensation, this means that this can be canceled or hypothetically give rise to a withdrawal. The loss of value is estimated from the difference between the condition prior to the project and the following one (the first ascertained, the second assumed).

The difference between the previous situation and the following one expresses the change in the value of the real estate assets following the imposition of the hydraulic constraint as perceived by the market (buyers and sellers).

The practical criterion for appraise the *ex ante* compensation for the imposition of constraints may concern:

a) the plant species, indicating R_a and R_p the net annual incomes respectively in the situations before and after the imposition of the restriction and with P_a and P_p

the current values of the multi-year annuities adjusted respectively in the situations before and after the imposition of the constraint [12]:

$$P_a = \frac{\sum_{s=1}^{m} R_{a_s} \cdot (1 + i_P)^{-s} \cdot}{1 - (1 + i_P)^{-m}}, \tag{2}$$

$$P_p = \frac{\sum_{s=1}^{q} R_{p_s} \cdot (1 + i_P)^{-s}}{1 - (1 + i_P)^{-q}}, \tag{3}$$

where m and q are the durations of the multi-year crop cycle respectively in the situations prior to and following the imposition of the constraint; i_P is the capitalization rate of tree crops;

b) the hydraulic works (for example, drainage ditches, drains) and the related costs C_s;
c) the loss of the land building potential; the permanent damage E for the loss of building potential is equal to the difference between the value of the building land in the previous situation and the value of the agricultural land in the situation following the feared damage:

$$E = \left[(p - c) \cdot e - p_A\right] \cdot S, \tag{4}$$

where p is the unit price of the building (€/m^3), c is the unit construction cost, e is the building index (m^3/m^2), S is the land area (m^2), p_A (€/m^2) is the unit price of agricultural land [13].

Future Damage

The theoretical criterion for the *ex ante* compensation related to future damages considers the extent of the damage linked to the variation of hydraulic risk in the area. This risk is related to the change in the probability of the adverse event and the change in the extent of the damage. If this variation results in an increase in risk (due to greater probability and/or greater damage), then the relative measure corresponds to the loss in value of the asset (temporary or permanent). If the change in hydraulic risk translates into a reduction in risk (due to lower probability and/or less damage), then the relative measure corresponds to a surplus value of lands. The loss or increase in value is estimated from the difference between the situation prior to the damage and the following one (the first ascertained, the second supposed).

The practical criterion for estimating the *ex ante* compensation for future damages may concern the losses of crop products and real estate assets following the occurrence of the damage:

a) the loss of the annual income of the herbaceous crops R_a and R_p respectively in the situations before and after the damage and the relative current values of the multi-year annuities P_a and P_p respectively in the situations before and after the damage;
b) the loss of land investments (for example rural and industrial buildings, roads, industrial buildings) and the related restoration costs C;

c) the loss of buildings (rural, industrial or residential ones) of value V_f.

At the time of the harmful event, the extent of damages D_a and D_p in the preceding and following situations is equal to:

$$D_a = R_a + P_a + C_a + V_{f_a}, \tag{5}$$

$$D_p = R_p + P_p + C_p + V_{f_p}. \tag{6}$$

At the present time, the amount of the damage related to the imposition of constraints and for future damages Δ is equal to conditions ascertained before and after the event:

$$\Delta = \frac{R_a - R_p}{i_R} + \frac{P_a - P_p}{i_P} + E + C_s - \left[\frac{D_a}{(1+i)^{n_a} - 1} - \frac{D_p}{(1+i)^{n_p} - 1} \right], \tag{7}$$

where i_R is the capitalization rate of herbaceous crops [14, 15], n_p and n_a the return times of the harmful event in the situations preceding and following the damage respectively.

According to the report, therefore, the damage is equal to the loss of income from agricultural crops and buildability and the cost of company accommodation, decreased by the reduction of hydraulic risk measured by the amount of the damage and its probability. The damage occurs if the loss of income and buildability is greater than the risk avoided.

In areas with little or no building susceptibility, if the implementation of the project involves maintaining the same crops and arranging the land at the expense of the institution, then it is possible to have net advantages if the hydraulic risk decreases. This means that there is an equilibrium point for which a certain rate of damage due to the imposition of constraints is offset by the lower hydraulic risk.

4 Conclusion

From an appraisal point of view, the valuation of the hydraulic damage in a hydraulic project takes into account the *ex ante* compensation: for the imposition of the constraint and for the preventive compensation of future damages.

The constraint can probably produce a loss in terms of income and assets but also a decrease in hydraulic risk and so that consequent advantages. The fact that the constraint places a burden on the landowners (losers) to the advantage of the external owners (gainers), requires that the advantage of the external owners is equal to or greater than the disadvantage of the imposition of the constraint on the owners of properties characterized by hydrogeological risk but also by potential advantages of proximity. The supply and demand of these lands considers the advantages and disadvantages of this position in the market price.

Compensation for future damage relates to random events and expresses the variation in the hydraulic risk for land falling within the risk area. This risk is related to the change in the probability of the adverse event and the extent of the damage produced. If the change in hydraulic risk translates into a reduction in risk (due to lesser probability and/or less damage), then the extent of the damage is negative and corresponds to a surplus value of the agricultural land of the area. It should be noted that there is likely to be a decrease in the hydraulic risk for the land outside the area due to the damage avoided. If the damage avoided to external land is greater than any damage caused to the land in the area, then there are the conditions to justify the hydraulic intervention project, and for the external owners to hypothetically compensate the owners of the area [16–18].

Finally, it should be noted that the realization of hydraulic protection works may entail compensation for the temporary occupation of the areas, intended for example to receive excavation and processing materials. In these circumstances, the compensation is equal to the loss of income for the period of occupation and the costs of restoring the areas intended to receive the material, referring to the end of the occupation.

References

1. Green, C.H., Tunstall, S.M., Fordham, M.H.: The risks from flooding: which risks and whose perception? Disasters **15**(3), 227–236 (1991)
2. Macchiaroli, M., Pellecchia, V., D'Alpaos, C.: Urban water management in Italy: an innovative model for the selection of water service infrastructures, WSEAS Trans. Environ. Dev. **15**, 463–477 (2019). ISSN 1790-5079
3. Driessen, P.P., et al.: Toward more resilient flood risk governance. Ecol. Soc. **21**(4) (2016)
4. Benintendi, R., De Mare, G.: Upgrade the ALARP model as a holistic approach to project risk and decision management. Hydrocarb. Process. **9**, 75–82 (2017)
5. Johnson, C., Penning-Rowsell, E., Tapsell, S.: Aspiration and reality: flood policy, economic damages and the appraisal process. Area **39**(2), 214–223 (2007)
6. ISPRA. https://www.isprambiente.gov.it/it/banche-dati. Accessed 27 Apr 2021
7. Brandolini, P., Cevasco, A., Firpo, M., Robbiano, A., Sacchini, A.: Geo-hydrological risk management for civil protection purposes in the urban area of Genoa, Liguria, NW Italy. Nat. Hazard. **12**(4), 943–959 (2012)
8. https://www.gazzettaufficiale.it/atto/serie_generale/caricaDettaglioAtto/originario?atto.dataPubblicazioneGazzetta=1999-01-05&atto.codiceRedazionale=98A11189&elenco30giorni=false. Accessed 27 Mar 2021
9. Bowman, M., Boyle, A.E. (eds.): Environmental damage in international and comparative law: problems of definition and valuation. Oxford University Press on Demand (2002)
10. Salvo, F., Morano, P., De Ruggiero, M., Tajani, F.: Environmental health valuation through real estate prices. In: International Symposium: New Metropolitan Perspectives, pp. 768-778. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-48279-4_72
11. Simonotti, M.: Introduzione alla valutazione del danno da inquinamento all'agrosistema, La Nuovagrafica, Catania (1982)
12. Ciuna, M., Pesce, S.: Il saggio di capitalizzazione della terra e dei miglioramenti fondiari, Rivista dell'agenzia del territorio, 1 (2008)
13. Ciuna, M., Pesce, S.: Il saggio di sconto variabile nella stima analitica delle colture arboree coetanee, Genio rurale - Estimo e Territorio, 2 (2003)
14. Simonotti, M.: L'analisi finanziaria del saggio di capitalizzazione, Genio rurale, 12 (1983)
15. Simonotti, M.: Ricerca del saggio di capitalizzazione nel mercato immobiliare, Aestimum, 59 (2011)
16. Kaldor, M.: Welfare propositions of economics and interpersonal comparison of utility. Economics J. **49**, 549–552 (1939)

17. De Mare, G., Nesticò, A., Macchiaroli, M., Dolores, L.: Market prices and institutional values comparison for tax purposes through GIS instrument. Lecture Notes in Computer Science, vol. 10409, pp. 430-440 (2017). https://doi.org/10.1007/978-3-319-62407-5_30
18. Hicks, J.: The foundations of welfare economics. Econ. J. **49**, 549–552 (1939)