



# Environmental reclamation of limestone mining sites in Italy: Financial evaluation, challenges and proposals for sustainable development

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## ABSTRACT

Currently the environmental restoration of former extraction sites of limestone materials to be used in construction sector is still an open issue, challenging the opportunities for a more sustainable development of local communities.

The present study evaluates the multiple causes underlying the abandonment of former limestone quarries and the lack of their reclamation as well as proposals to promote their environmental restoration.

We primarily frame the issue in both the European and Italian regulatory framework. Then, the present study applies an innovative Cost Revenue Analysis to a case study of a generic environmental restoration project of a former extractive limestone site. Such analysis deepens on investment and operating costs, revenues, Net Present Value and Revenue/Costs ratio. Results show that restoration activities, performed in agreement with current regulations, involving the creation of terraces in embankments by means of excavation materials from external construction sites or even acting directly on the existing quarry, are currently discouraging for entrepreneurs, since they do not generate enough revenues to cover the costs of restoration. As a result, we suggest some solutions to strengthen the current regulatory and political framework, to make the restoration activities more convenient in financial terms. Such solutions would be also beneficial for the society and environment.

## 1. Introduction

Limestone extraction is strategic for the provision of materials for the entire construction sector. The extraction activities are also source of huge impacts on the natural environment and the landscape as well as on human health (Clemente et al., 2004; Agboola et al., 2020). However, if such activities are performed according to the most recent legislation that requires the environmental recovery contemporary to the cultivation phase, the negative externalities on the environment could be strongly mitigated (Neri and Sánchez, 2010; Lai et al., 2021).

On the contrary, illegal quarry sites - as well as sites cultivated in the absence of an adequate national and/or regional regulations are difficult to restore. This is because these extraction activities only aim to the maximization of economic profits disregarding their environmental or social impacts and the need for a future environmental restoration. The results are high quarry fronts that in most of the cases entail vertical slopes.

Several scholars have already studied many problems related to

mining, as it has long been a key player in the development of multiple sectors: from the economy, to employment, to the supply of raw materials (Ali and Ur Rehman, 2020; Worlanyo and Jiangfeng, 2021).

Some authors have investigated the impact of this sector on sustainable development. According to Asr et al. (2019), the mining industry leads to positive and negative impacts on society, the economy, and the environment. For this reason, integrating sustainable development into mining industry means applying sustainability principles simultaneously and non-sequentially in the different stages of the mining life cycle. In this way, the positive impacts of the mining industry can be maximised, in so contributing to global development. Aznar-Sánchez et al. (2019) point out that the main challenge for the sector is to define approaches that balance economic, environmental, and social concerns. Furthermore, according to Monteiro et al. (2019), the mining sector has a large capacity to achieve the Sustainable Development Goals (SDGs), through the mobilisation of economic and technological resources.

Several authors have explored environmental and social issues in depth. For instance, Hou et al. (2021) evaluated the ecological damage

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associated to mining operations. There are in fact several impacts caused by the exploitation of limestone. These include: the destruction of wetlands with the consequent extinction of species (Beggs, 2012; Wassenaar et al., 2012); dust and particulate pollution (Silvester et al., 2009; Zobrist and Giger, 2013); potential geological, hydrogeological and slope instability hazards (Nysen and Vermeersch, 2010); high water consumption and contamination of surface waters (Phillips, 2016). For this reason, many studies have focused on strategies and solutions for restoring the ecosystems within abandoned limestone quarries. Wang et al. (2018) suggest the construction of an artificial slope using abandoned local building materials and provide restoration of the local ecosystem through appropriate revegetation. Jiskani et al. (2022) proposed pathways to promote green and climate smart mining, such as: strengthened research and development culture advancements; clear policies and processes; technological advancements etc. Gilardelli et al. (2016) studied the effects of vegetation restoration using different methods and provided valuable suggestions for limestone quarries, although they underlined that ecosystem restoration is a long and difficult task, because vegetation and soil layers are often completely removed during the mining process.

On the contrary, very few studies have addressed the economic and financial issues. In this respect, Lorite et al. (2021) proposed an economic assessment of ecological restoration options after extraction with reference to gypsum habitats. According to Monz et al. (2013), while it is crucial for mining entrepreneurs to have economic evaluations of mine site restoration interventions, very few studies are available in the literature, mainly focusing on the evaluation of the ecosystem services provided in terms of the value of fisheries or recreation. In addition, without an adequate assessment of the costs and effectiveness of different restoration options, managers often remain sceptical and consider ecological restoration economically unfeasible and even unrealistic. Damigos (2006) points out that two issues are crucial for the mining industry: the evaluation of projects through social cost-benefit analysis (SCBA) and the assessment of natural resource damage. Both issues require an analysis that allows a monetary evaluation of the loss of natural resources and the effects of environmental degradation on human health and well-being.

## 2. Structure and aim of the study

In this study we plan to stress regulatory issues and financial aspects related to the environmental restoration of quarries in Italy, with a particular focus on the Campania region, where the issue of environmental restoration is highly complex. Specifically, we investigate financial aspects related to the environmental restoration of limestone extraction sites, starting from an analysis of critical normative aspects. The current regulatory framework, while requiring the environmental restoration at the end of extraction activities, does not encourage its adoption in practice. Moreover, the penalty system is ineffective against illegal operators (Caserta environmental associations, 2004). The penalties are minimal for those who manage quarry areas without respecting the approved projects risk assessment required by the current regional legislation (Article 28 of the Campania Region Law no. 54 of 13 December 1985, "Cultivation of quarries and peat bogs") for all mining proposal. The administrations are actually unable to enforce the restoration at the expenses of those who cause the damages (Inter-University Research Centre for Territorial Economics, 2013).

As a result, the issue of environmental restoration of limestone extractive sites for construction arises differently depending on whether the site is:

- a. cultivated according to the most recent regional legislation;
- b. illegally cultivated and/or before the entering into force of the first regional regulations on mining.

In Campania Region (Southern Italy), the problem is more relevant

compared to the entire national context.

The case "b" refers not only to illegal sites, but also to those cultivated before the entry into force of Regional Law 54/1985. The latter law required the cultivation of extraction activities to be subject to a exploitation permit (Passalacqua and Rangone, 2011; Del Gaudio and Vallario, 2016). Before this law issuing, the activities were conducted in absence of a project planning, causing huge environmental damages on the sites and its surroundings, in so making highly complex the restoration activities (Law, 2014).

In order to better understand this issue, Fig. 1 distinguishes between the two cases and perspectives as mentioned above (case "a" and "b"). In the first case (Fig. 1a), the project for the extraction activities was designed in agreement with the specific legislation. The project entails the future restoration of the extraction site, as shown in the Figure. In this case, low and terraced fronts are created, with slopes that tend to respect those of the landscape (Italian Technical and Economic Cement Association and Legambiente, 2012). In this case, the recovery is generally carried out at the same time of the extraction phases, thus reducing the environmental impacts (Legambiente, 2017).

Fig. 1b evidences the second case, where the extraction activities have been conducted illegally or before the entry into force of the regional legislation. In these sites both the cultivation and restoration have not been carried out as in the first case. Here the restoration should be implemented on very high rock blocks, with almost vertical slopes as well as with the systematic absence of intermediate terraces. The case "b" constitutes a serious environmental problem in terms of landslide risk and hydrogeological instability, landscape damage, harmful effects on the health of the area, effects on local flora and fauna (Milgrom, 2008; Mouflis et al., 2008; Felice and Zorzea, 2019). It is important to underline that the case "b" occurs because operators mainly tend to exploit the quarry boundary up to the property limits. In this case it is not possible to move back the quarry fronts, that would be the only condition for creating terraces useful for re-establishing correct slopes and more appreciable landscape profiles (Province of Pesaro Urbino, 2004).

In this view, understanding the causes of illegal conduction of limestone extraction activities (Inter-University Research Centre for Territorial Economics, 2013) is essential to propose solutions aimed at addressing the issue and complementing the intervention of regional public administrations.

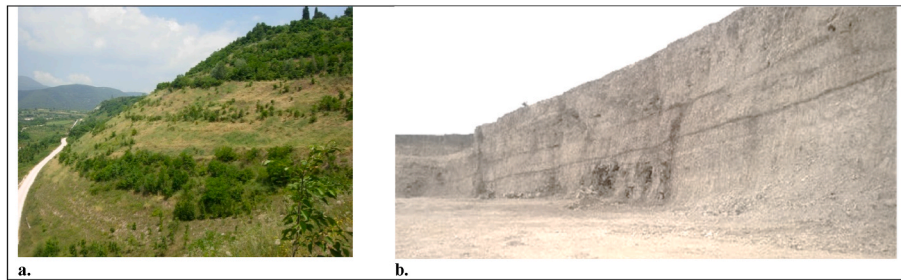
In the outlined context, the present study examines the environmental restoration for the case "b" described in the previous section 1, i. e. current sites illegally cultivated or sites cultivated before the entry into force of the first regional regulations on the subject.

To achieve this, we would like to answer the following research questions:

1. What are the characteristics of the extraction sites that are abandoned at the end of the quarrying activities?
2. What are the financial components and technical-regulatory factors that cause their abandonment without reclamation?
3. What actions can be implemented to favour a virtuous process of environmental restoration?

We will first evaluate how the relevant European and National legislation deal with this issue (section 3). Then, an assessment of the financial aspects that characterize the environmental restoration activities of production sites of limestone for construction (case "b") is performed, by implementing the principles of Cost-Revenue Analysis (CRA), in section 4. Section 5 details the different types of investment costs, operating costs and revenues for a generic environmental restoration case study of a former mining site of limestone materials for construction. The section provides the methodological background that guides the financial analysis in this research.

Section 6 shows the results of the financial analysis applied to a case study of environmental restoration in the Campania Region, to



**Fig. 1.** a. Rehabilitated modern mining site; b. Site cultivated illegally and/or before the entry into force of the first Campania region legislation.

understand to what extent creating embankment terraces through excavation materials from construction sites externally or even by acting directly on the existing quarry front (case b), is financially convenient. Section 7 explores if the current economic and regulatory context allow entrepreneurs in the sector to generate sufficient revenues that can cover the costs of the environmental restoration projects, in order to ensure that such projects are properly carried out. In section 8, solutions are proposed, aimed at guaranteeing an economic profitability to operators who actually intend to carry out the environmental restorations. These solutions concern changes in the regulatory framework, in order, on the one hand, to increase revenues for those who intend to carry out the environmental restorations and, on the other side, to reorganize the mining sector to prevent future problems. Section 9 summarizes the conclusions of the work, highlighting the main results achieved and the original aspects that arise from the implementation of the proposed financial evaluation. Conclusions also put into evidence the policy implications that these results could have and outline prospects for future research.

### 3. The current legislative framework

The European Union has adopted several directives aimed to improve the sustainability of the limestone materials mining sector in terms of reduction of environmental impacts, quality of the products offered as well as safety of the workers. In particular, it is worth mentioning:

- European Directive 85/337 of 27 June 1985 (on the assessment of the effects of certain public and private projects on the environment). This Directive conditions the opening of new mining sites to an Environmental Impact Assessment (EIA) procedure;
- European Directive 89/106/EC of 21/12/1988 (amended by Council Directive 93/68/EEC of 22 July 1993). The directive introduced the CE marking on construction materials produced by mining activities and proposes the distinction of aggregates according to their technical performance and no longer based on their origin (natural, artificial or from recycling)<sup>1</sup>;
- European Directive 92/104/EEC on Minimum requirements for improving the safety and health protection of workers in surface and

underground mineral-extracting industries (Directive within the meaning of Article 16 (1) of Directive 89/391/EEC)<sup>2</sup> and European Directive 92/91/EEC (Protection of the safety and health of workers in extractive industries),<sup>3</sup> implemented in Italy with the Legislative Decree no. 624/996. These are Directives that give to extractive companies an active role in the prevention and safety activities, through the adaptation of production structures, the introduction of new professionals, the adoption of prevention and protection services as well as of workers' training procedures;

- European Directive 21/2006 (on the management of waste from extractive industries and amending Directive, 2004/35/EC - Statement by the European Parliament, the Council and the Commission),<sup>4</sup> introduced in Italy with the Legislative Decree no. 117/2008. It requires the elaboration of a waste management plan. Furthermore, in order to limit emissions of polluting pathogens into the atmosphere, the Directive evidences the need for modernization of technologies and systems, as well as a greater attention to the recovery of production waste.

As advocated in the Communication from the European Commission COM (2000) 265 (Promoting sustainable development in the EU's non-energy extractive industry), in 2001 various trade associations set up the European Extractive Industry Council for Sustainable Development, with the aim of proposing solutions for the sustainable development of the entire extractive sector through coordination of sector policies and dialogue with all the stakeholders.

In 2011 the European Center of Nature Conservation, ECNC (independent European biodiversity expertise center for sustainable development) and the De Meent-Vleuten Consultancy drafted the European Action Plan on Biodiversity and Mineral Extraction. This document defines actions to be taken in the short, medium and long term, aimed at the sustainable development of the extractive industry, in terms of minimizing environmental impacts, conservation of natural resources and protection of biodiversity. In addition, the document supports investments in brownfield sites, through the promotion of future activities

<sup>1</sup> The framers work also includes the Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC OJ L 88 of 4 April 2011, available at: [http://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/construction-products\\_en](http://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/construction-products_en). Last accessed: 11/05/2021.

<sup>2</sup> Council Directive 92/104/EEC of 3 December 1992 on the minimum requirements for improving the safety and health protection of workers in surface and underground mineral-extracting industries (twelfth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC), available at: <https://op.europa.eu/en/publication-detail/-/publication/d13d49c8-3165-40a8-8bc6-8fea5a4164f4/language-en>. Last accessed: 11/05/2021.

<sup>3</sup> Council Directive 92/91/EEC of 3 November 1992 concerning the minimum requirements for improving the safety and health protection of workers in the mineral-extracting industries through drilling (eleventh individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC), available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:01992L0091-20070627>. Last accessed: 11/05/2021.

<sup>4</sup> Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC - Statement by the European Parliament, the Council and the Commission, available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006L0021>, Last accessed: 11/05/2021.

of collective interest.

With particular regard to the sustainable use of natural resources in the management of mining activities, the European Commission adopted the Communication COM (2003) No. 572: Towards a thematic strategy on the sustainable use of natural resources.<sup>5</sup> This communication preceded a series of European Union actions on the sustainable supply of raw materials:

- COM (2008) 699 (The raw materials initiative. Meeting our critical needs for growth and jobs in Europe)<sup>6</sup> and COM (2011) 25 (Tackling the challenges in commodity markets and on raw materials), also known as Raw Materials Initiative;
- Conclusions 6909 of the European Council of 10 March 2011 (Guaranteeing access to raw materials for the future well-being of Europe proposed European partnership for innovation concerning raw materials);
- COM (2011) 571, Roadmap to a Resource Efficient Europe;

It is also worth mentioning the documents concerning the European Union 2020 strategy:

- COM (2010) 614, An integrated industrial policy for the globalization era putting competitiveness and sustainability at centre stage;
- COM (2011) 21, A resource-efficient Europe. Flagship initiative under the Europe 2020 Strategy.

Taking up from the EU Directives and Communications, some industrial associations of category proposed specific guidelines. Important examples are the Reference Guide for Good Environmental Practices in the European Extractive Industry (Brodtkom, 2000) and the Guidelines for the design, management and recovery of extractive activities (Italian Technical and Economic Cement Association, AITEC), Legambiente (2017).

The analysis of the documents indicated so far shows that the EU directives only deal with aspects of a general nature, referring to national regulations for the discipline of more strictly operational aspects.

For Italy it is important to mention the Royal Decree 1443/1927 (Research and cultivation of mines), which regulated the mining sector until the regional regulations came into force at the beginning of 1980s. According to the Royal Decree 1443/1927, anyone could initiate a mining activity without an authorization by only submitting an execution complaint. It was therefore not necessary to present an intervention project or even communicate the volumes of material to be extracted. This has produced a large number of quarry sites that are difficult to restore, as they are only cultivated according to the maximization of the profits for the operators.

At the beginning of the 1980s, the first regional sector regulations slowed down and stopped the free mining, albeit unevenly between the different Regions. In Campania, the first regional law n. 54 of 1985 was issued, that still is the main legislative framework for mining activities nowadays. The main aspects of this law were the following:

- Introduction of the authorization and concession regime. As a consequence, today the extractive activities must be planned, providing for the contextual environmental restoration of the areas;

- Definition of penalties for illegal operators. However, the penalties have proved to be completely ineffective in stemming illegal activities;
- Definition of the Regional Plan of Mining Activities (RPMA) as a comprehensive regional planning tool for the sector. According to the law 54 of 1985 (Article 7), the Region had to prepare its own RPMA within 2 years from the entry into force of the law. However, in Campania Region, the PRAE was approved only in 2006. Unfortunately, the entire regulatory framework described above did not lead to the expected results, as it was unable both to force the operators to carry out environmental restorations contemporary to the extraction activities as well as to adequately punish those who caused the environmental damages.

In general, the Italian legislative system regulating mining activities over the last 30 years is missing a common intervention strategy for all regions (Legambiente, 2017). Currently, not all Regions have their own RPMA, even if all the Regions require that cultivation projects be inclusive of the restoration project at the end of cultivation. Instead, only a few Regions have a plan for the recovery of abandoned sites. In this regard, mention should be made of the Emilia-Romagna Region, which allocates part of the fees coming from the extraction activities to the restoration, recovery and enhancement of the landscape and the environment of such abandoned sites. Emilia-Romagna also monitors the progress of the rehabilitation projects.

So far mining activities in Campania Region (also after the introduction of the regional legislation) continue to be performed only taking into account the maximization of the profits, disregarding the environmental and social impacts of their activities. The cost-revenue analysis applied to a case study (section 6) will clearly highlight the main factors guiding the decisions of the extractive companies as well as will outline actions capable of incentivizing such companies towards taking into account other sustainability dimensions beyond financial ones.

#### 4. Materials and methods

From the framework outlined above, it emerges that the problems concerning the environmental restoration of former extractive sites (illegally cultivated or cultivated before the adoption of the first regional legislation) cannot be solved without considering the financial aspects that affect the profitability of the investments. Therefore, an in-depth study is required for this issue, which is the subject of this research. Such in-depth analysis can be conducted by using the principles of Cost-Revenue Analysis (CRA).

This section 4 introduces the essential aspects of the methodology driving the analysis. These aspects allow us to propose a general financial scheme (section 5), which validity has also been assessed by means of an application to a case study (section 6).

With the analysis of cash flows, the financial plan - or model of the investment is constructed, that is, a budget drawn up by the concessionaire of the extractive activities according to the principles of financial accounting. The model defines the financial needs of each production year and the capacity of the project to generate positive flows to cover the costs, including the loans and the technical depreciation rates of the works.

Basically, for each year of the analysis period, the financial plan compares the monetary revenues due to the sale of the goods and services produced by the project, with the monetary outlays corresponding to the value of the resources, goods and services used in the implementation and management of the intervention.

Costs and revenues, spread over the different life-years of the project and in order to be compared must be referred to the same year, generally that of the evaluation. In the ex-ante evaluations, it is a discounting operation. In financial analysis, the discount rate is determined on the market. It reflects the "opportunity cost", that is the return that can be derived from alternative uses and which the operator will give up in

<sup>5</sup> COM (2000) 265 final, Communication from the Commission Promoting sustainable development in the EU non-energy extractive industry, available at: <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2003:0572:FIN:EN:PDF>. Last accessed: 17/05/2021.

<sup>6</sup> Communication from the Commission to the European Parliament and the Council, The raw materials initiative — meeting our critical needs for growth and jobs in Europe. COM (2008) 699 final, available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52008DC0699&from=EN>. Last accessed: 17/05/2021.

order to allocate resources to the project under evaluation.

The CRA results are generally expressed in terms of the following indicators: Net Present Value (NPV); Internal Rate of Return (IRR); Revenue Costs (R/C) ratio. The NPV is defined as the positive or negative difference, or equality, between the discounted sum of revenues and the discounted sum of the project costs; the IRR informs about the performance of the project within the structural, economic and financial system in which the investment is included and it is equivalent to the discount rate that cancels out the NPV; the R/C ratio indicates the amount of money earned or lost for each money unit spent in the intervention:

$$NPV = \sum_{i=1}^n \frac{R_i - C_i}{(1+r)^i}$$

$$\sum_{i=1}^n \frac{R_i - C_i}{(1+IRR)^i} = 0$$

$$\frac{R}{C} = \frac{\sum_{i=1}^n \frac{R_i}{(1+r)^i}}{\sum_{i=1}^n \frac{C_i}{(1+r)^i}}$$

where  $R_i$  and  $C_i$  respectively represent revenues and benefits generated by the project on the  $i$ -th year;  $r$  is the financial discount rate and  $n$  the lifetime of the intervention.

The analysis must be placed over a sufficiently long period of time to evaluate the effects of the investment, considering both the degree of stability (uncertainty) of the scenarios (i.e., the likelihood of the forecasts), and the significance of the cash flows on the profitability of the project and the degree of risk related to the type of project.

The evaluation is often carried out at constant prices. This means that for each resource used up and for each good and service produced by the project in the analysis period, the same market prices are applied, those of the reference year of the evaluation.

### 5. Environmental restoration interventions of former limestone extraction sites for construction. Analysis of investment costs, management costs and revenues

Tables 1–3 summarize investment costs, annual management costs and annual revenues respectively for a generic restoration project of a former quarry area. For ease of reading, the income table recalls Fig. 2.

The data included in the Tables have been collected from surveys of extraction plant operators; analysis of projects actually carried out; results of studies and sector publications, regional and national reference price lists. As mentioned above, the sector publications are not very recent because there are few studies conducted in the field of the financial evaluation of the rehabilitation of quarry sites (Baliani and Valitutti, 2008; Italian Technical and Economic Cement Association and Legambiente, 2012; Campania Region, 2017; Campania Region, 2020; National Highway Agency).

Among the investment costs (Table 1), planning and preliminary investigation costs (including the costs for the Environmental Impact Assessment) are relevant. In fact, the long authorization times and the different professionals involved in the project often make the procedures very expensive. The Decree of the Campania Region Council n. 680 of 07/11/2017 (Transposition of the provisions on environmental impact assessment referred to in Legislative Decree 104/2017 and first organizational measures) requires, in fact, an EIA for all mining activities, regardless of both planimetric extension of the quarry sites and the volumes of aggregates extracted annually.

The costs for plant engineering, logistics and operating machines can also be huge. However, generally the operators who intend to carry out environmental restoration should already have: a suitable fleet of vehicles and equipment; inert processing and screening plants; the

**Table 1**  
Investments costs.

Investment costs			
Acquisition of areas	Acquisition of areas affected by cultivation and/or environmental restoration work	fixed basis	
Preliminary investigation and project drafting	Surveys and preliminary tests	fixed basis	
	Technical costs of drafting projects	fixed basis	
Investigation costs	Preparatory conference: preliminary services conference	fixed basis	
	Verification of eligibility for Environmental Impact Assessment (EIA)	fixed basis	
	EIA procedure	fixed basis	
	Decisional conference	fixed basis	
Preliminary actions	Unique Environmental Authorization/ Atmospheric emissions authorisation	fixed basis	
	Safety documentation (Operational safety plan; safety and coordination plan, etc.) Waste management agreements	fixed basis	
Plant engineering - logistics - machinery	Prefabricated monobloc for canteens, changing rooms, guardhouses, offices and infirmary rooms	each	
	Prefabricated monobloc for bathrooms	each	
	Prefabricated monobloc for administrative office	each	
	Purchase of operating machines (dumpers, excavators with breakers, trucks, shovels, etc.)	fixed basis	
	Supply and installation of weigh bridges	fixed basis	
	Construction of limestone mixture crushing and screening plant	fixed basis	
	Construction of mining facilities and installations	fixed basis	
	Costs of site preparation and preliminary works	Wire mesh fencing of the entire intervention area	m <sup>2</sup>
		Noise impact mitigation systems	fixed basis
		Dust and odour mitigation systems	fixed basis
Supply and installation of vertical signage		fixed basis	
Interception of existing aqueduct line for water supply		m	
Construction of artesian well for water supply		fixed basis	
Utility activation		fixed basis	
Supply and installation of water disposal system		fixed basis	
Setting up of processing waste storage area	fixed basis		

necessary logistics (offices, changing rooms, etc.) used in the previous phase of cultivation of the quarry. In this regard, however, the long cultivation schedules mean that a large part of the costs of the equipment already used in the extraction of the areas to be restored can be considered fully amortized.

With reference to the annual management costs (Table 2), which have a high impact on the financial results of the investment, the operations during both the extraction phase (re-profiling or stepping of the quarry faces) and the construction of artificial embankments have a particular weight. These are rock excavation and soils moving operations that require the use of expensive equipment, both in terms of usury and fuel consumption. Obviously, the hourly production, and therefore the unit costs, depend on the type of materials being processed. As this is usually limestone and soils and excavated stones, generally applicable average unit costs can be identified. For larger sites it may be

**Table 2**  
Annual management costs.

Management costs		
Area rent	Costs for renting the areas affected by cultivation and/or environmental restoration work	€/month
Costs at the extraction stage	Excavation in stone rock using a mechanical breaker	m <sup>3</sup>
Quarry charges	Payment: convention fee (ex-article 18, Regional Law. 54/1985.; environmental contribution, ex art. 19 Regional Law 1/2008)	m <sup>3</sup>
Environmental restoration costs	Construction of prequalification tanks	fixed basis
	Disintegration of quarry faces to be restored	m <sup>2</sup>
	Drainage of restoration embankments	m
	Company service roads, natural surface	m
	Construction of limestone cliffs to stabilise embankments	tons.
	Formation of restoration embankments with suitable materials	m <sup>3</sup>
	Excavation and/or resurfacing of ditches necessary for water regulation	m <sup>3</sup>
	Cut-and-cover excavation for the construction of lamination tanks	m <sup>3</sup>
	Supply and laying of topsoil	m <sup>3</sup>
	Establishment of the vegetation cover through seeding and covering operations	m <sup>2</sup>
	Supply and planting of native nursery shrubs	each
	Supply and planting of native nursery tree	each
	Supply and installation of fixed irrigation system	fixed basis
Creation of vegetation pockets on the conglomerate walls, which serve as a home for shrub species	each	
Management expenses	10% of total costs	fixed basis
Final obligations	Survey of final state for acceptance of works	fixed basis
	Restoration of neighbouring areas	€/ha
	Building site demobilisation	€/ha
	Final administrative tasks (Acceptance-Final reports)	fixed basis

**Table 3**  
Annual operativity revenues for the environmental restoration of the former quarry area.

Annual operating revenues		
Revenues in the extraction phase	Commercialisation of quarry boulders for making limestone cliffs and natural ballasts (Fig. 2a)	m <sup>3</sup>
	Commercialisation of limestone mixture to produce construction sub products (Fig. 2b)	m <sup>3</sup>
Revenues in the recovery phase	Charges for receiving excavation soil and rocks produced on external worksites (Fig. 2c)	m <sup>3</sup>
	Charges for the processing and arrangement for re-use of such materials (Fig. 2d)	m <sup>3</sup>

advantageous to carry out excavations with the aid of mines.

It should be noted that upon completion of the cost estimation phases (investment and management), it is often necessary to perform price analyses aimed at estimating in detail the unit amount of certain processes required in environmental restoration interventions. The price analyses include costs of labour, materials, vehicles and equipment. The Appendix details the analyses processed.

The annual revenues in operation (Table 3) consist of revenues for the extraction phase, deriving from the sale of the limestone material produced and revenues for the restoration phase, which requires the formation of artificial embankments.

With regard to the environmental restoration project under study, for which it is not possible to set back the quarry fronts, it is important to

underline that the calcareous materials capable of generating revenues are those produced by limited re-profiling and by improving the safety of the fronts. In this case the volumes produced are lower. Their selling alone cannot guarantee significant margins for the intervention, burdened by heavy management costs. In general, the sites that do not allow the terracing of the quarry fronts are abandoned to a spontaneous, slow and ineffective re-naturalization. Only where operations of the quarry fronts are feasible, and this is not the case examined in the present study, it is possible to obtain quantities of calcareous aggregates normally useful to guarantee sufficient margins for the recovery project.

## 6. Case study. financial analysis for the environmental restoration of a former limestone extraction site

The study concerns the environmental recovery of a former quarry site in the Province of Avellino (Campania Region, Italy). In the decade from 2005 to 2015, this site suffered a heavy environmental damage due to the extraction of limestone materials. In fact, the area was affected by illegal excavations with the formation of very high fronts and almost vertical slopes, characterized not only by the absence of terraces, but also by the concrete impossibility of creating terraces in the recovery phase. This leads the analysis back to a quarry site representative of a large number of sites in the region, currently severely compromised from an environmental point of view. In particular, the application refers to case “b” indicated in the introduction of the work (sites already illegally cultivated or cultivated before the entry into force of Regional Law 54 of 1985). In the case “b”, the impossibility of producing sufficient volumes of limestone material in the restoration operations means that an operator is not interested in carrying out the necessary environmental requalification. In this sense, our case study aims at highlighting how to create a virtuous process, useful for allowing restorations processes, while also ensuring the financial profitability to operators.

For the case study area, the Campania Regional Council - Provincial Sector of the Civil Engineers of Avellino - approved a restoration project, which involves the construction of a suitable embankment to mitigate the visual and environmental impacts of the superficial quarry fronts. Fig. 3 shows a section of the intervention project.

The hypothesis of intervention in the case study concerns the realization of the following works:

- Accumulation on the face of the excavation of any debris available on the bottom, in order to build an artificial embankment close to the bare rock wall, with the aim of guaranteeing partial masking;
- Scaling of the quarry face, mainly through the removal of unsafe and fragmented stones, in order to secure the fronts themselves for restoration work;
- Construction of an artificial embankment at the basis of the escarpment, with excavated soils and stones from external sites;
- Making pockets on the rocky front which, once filled with topsoils, are suitable for hosting shrubs and vines;
- Replenishment of topsoils on embankments, on squares, on small steps and in pockets;
- Enhanced hydroseeding on the wall, on the steps and on the squares, in order to favour the grass cover and the growth of shrubs;
- Planting of native trees, if necessary, with tall trunks, and climbing species on all project areas, in harmony with the existing landscape.

The project idea is the only feasible one, due to the fact that the quarry fronts cannot be pushed back because the excavations have reached the limit of the property. Unfortunately, this is a very frequent situation, due not only to the reaching of the property limit, but also due to the presence of road networks and/or buffer zones, or due to topographical conditions incompatible with the terracing.

In these situations, only the formation of artificial embankments, associated with naturalistic engineering works, can allow an effective re-



Fig. 2. a. Quarry boulders; b. Arid quarry mix (Tout Venant); c. Receiving excavated soil and rocks; d. Reuse of excavated soil and rocks in artificial embankment.

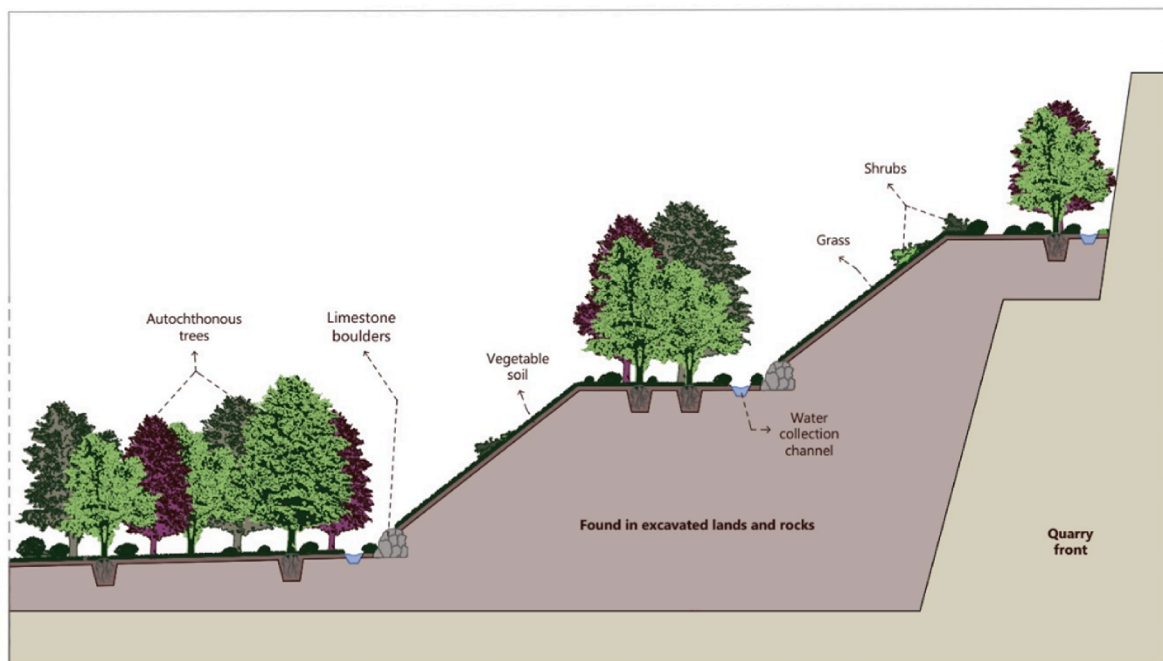


Fig. 3. Typical environmental restoration section for the former illegal mining area. Artificial embankments are foreseen due to the impossibility of grading the outcrops.

naturalization of the areas.

The planned investment determines the execution of an artificial embankment for about 300,000 m<sup>3</sup>.

The entire work must be performed in 4 functional batches. Each lot constitutes a working phase of 12 months, for a total duration of 4 years. The data on the main processes are shown in Table 4.

From a planimetric point of view, the area to be restored has an

extension of about 6 ha and does not fall within areas that are landscape constrained, nor are they subject to constraints belonging to the Natura-2000 network: Sites of Community Importance (SCI), Special Conservation Areas (SCAs) and Special Protection Areas (SPAs). The entire area, on the other hand, is subject to hydrogeological constraints, so in the financial analysis the preliminary costs for the hydrogeological release at the competent Mountain Community must be considered.

Table 4  
Technical project data.

Processing steps	Duration [months]	Volume extracted [m <sup>3</sup> ]	Recovered surface [ha]	Volume embankments [m <sup>3</sup> ]	Vegetable ground volume [m <sup>3</sup> ]
Phase 1	12	0.00	0.00	87,282.75	0.00
Phase 2	12	370.50	1288.00	82,687.43	6407.33
Phase 3	12	1753.05	2545.00	81,346.50	4321.95
Phase 4	12	18,540.30	4828.00	89,358.23	8998.65

Table 5 has been created taking into account the general schemes in Tables 1–3, with reference to the four processing phases (functional batches). The analysis of the unit costs of the individual processes are reported in the Appendix.

Table 5 shows the different types of costs and revenues, essential for the financial plan in Table 6, elaborated according to the principles of Cost-Revenue Analysis. In the financial discount operations, a 4.00% rate is used, namely a value suggested by the European Commission for the real opportunity cost of capital in the long run (European Commission, 2014). The discounting is carried out considering the individual annuities postponed. The last row of Table 6 evidences the sequence of discounted cash flows that the environmental recovery project generates.

## 7. Results of the cost-revenue analysis. Discussions

The financial plan elaborated in the previous section allows the estimation of the cash flows over the four years of the analysis period. This sequence is graphically shown in Fig. 4.

The Net Present Value of the investment is negative and equal to € –499.72. This result shows that to date, in case new volumes of aggregates cannot be extracted, the restoration of the former quarry area (illegally cultivated and/or prior to Regional Law 54/1985) is not economically convenient and it is difficult to make the area owners implement a mine reclamation. In this case, the environmental damage caused by the illegal cultivation is followed by the abandonment of the areas.

It is therefore evident that the investment's ability to generate positive cash flows is a key factor in environmental restoration activities.

In this regard, it is essential to identify those parameters that can make the intervention profitable. In the impossibility of extracting limestone aggregates to be sold in the market, the results of the financial analysis suggest that the profitability of the environmental recovery intervention depends mainly from the management of excavated soils and stones used for the formation of the artificial embankments. In fact, as indicated in Table 3, Fig. 2c and d, the excavated soils and stones produced in public and private construction sites can be transferred to the environmental restoration sites by paying two monetary amounts related to:

1. the conferment;
2. the re-use for the formation of embankments.

Today the solution to the problem should be found in the process of reuse of excavated soils and stones. In fact, this process is not well structured and does not favour the environmental recovery. In practice, the operator who has to carry out an environmental restoration is forced to find the excavated soils and stones from construction sites in the area, agreeing on the fees to be received for their acquisition and reuse. In many cases, this method forces the operators to accept inadequate remunerations that do not cover the high restoration costs.

Consequently, solving the problem requires the definition of a financially virtuous system for the management of excavated soils and stones to be used in the construction of artificial embankments. In our case the revenues must be increased in order to fully cover the costs of processing, while ensuring the right margin of profitability for the entrepreneur. Based on the real market dynamics, it is acceptable to consider a business profit of 10%.

Therefore, the financial analysis can be reformulated in Section 6 by increasing the revenues as in the following:

1. Charges for the conferment of excavated soils and stones produced on external sites;
2. Charges for the processing and re-use of the aforementioned materials.

Through the price analysis of the individual processes, developed according to the aforementioned logic aimed at fully covering expenses and guaranteeing a 10% business profit, the new minimum revenues are estimated, which are 4.00 €/m<sup>3</sup> and 5.50 €/m<sup>3</sup> for the two processes, as in Table 7. The Appendix provides details about the analysis of the prices.

At this point, we apply the new prices to the revenues in the financial plan. Table 8 and Fig. 5 respectively return the results and the new cash flows for each of the four years of the analysed period. Fig. 5 shows cash flows that are now positive in each of the four years. This results into a positive NPV and an R/C ratio greater than 1:

$$NPV = 296,76 \text{ €}$$

$$\frac{R}{C} = \frac{\sum_{i=1}^4 \frac{R_i}{(1+r)^i}}{\sum_{i=1}^4 \frac{C_i}{(1+r)^i}} = 1.13$$

## 8. Proposals for the intervention

As examined in the previous section, only an adequate increase of the revenues from the reuse of excavated soils and stones can guarantee the financial balance of environmental restoration interventions. As a result, in this section possible solutions are suggested to favour environmental rehabilitation that are profitable for operators. Below, each proposal is discussed in detail.

### 8.1. Virtuous system for the management of excavated soils and stones

To encourage the restoration of the areas, acceptable levels of profitability must be guaranteed for the acquisition and reuse of excavated soils and stones produced on external construction sites and necessary to build the embankments. This result can be favoured by:

- a. Adoption of a specific Register of sites having an authorization for environmental restoration;
- b. Definition of suitable procedures for the management of excavated soils and stones.

With regard to the point a, the Register must contain:

- the location of the site that should be recovered;
- the residual quantities of excavated soils and stones necessary to complete the restoration project;
- a minimum, although profitable, unit prices for the acquisition and reuse of excavated soils and stones.

With regards to point b, the procedures for the management of excavated soils and stones:

- the producer of excavated soils and stones (public or private construction site) should be able to access the Register to identify the specific restoration site where to deliver the materials. This depends on the transport distance and the volumes that can be acquired from the site;
- at the moment of delivery, the producer must pay the prices indicated in the Register, to be established on the basis of the financial criteria set out in Section 7;
- once the re-use has been completed, by means of a computerised procedure, the producer must certify the volumes delivered to the already authorized site. In this way, for the single recovery site, it is possible to update in real time the quantities of excavated soils and stones needed for the completion of the project embankments.

The benefits of such a management system for excavated soils and

**Table 5**  
Investment costs, management costs and revenues.

Specify cost			PHASE 1		PHASE 2		PHASE 3		PHASE 4	
			Quantity	Cost [€/year]	Quantity	Cost [€/year]	Quantity	Cost [€/year]	Quantity	Cost [€/year]
INVESTMENT COSTS	Project drafting	Surveys and preliminary tests	1.00	3500	–	–	–	–	–	–
		Technical expenses	1.00	6300	–	–	–	–	–	–
	Authorization costs	Check submission to VIA	1.00	1200	–	–	–	–	–	–
		VIA procedure	1.00	2500	–	–	–	–	–	–
	Initial obligations	Security documentation	1.00	2800	–	–	–	–	–	–
		Waste management contract	1.00	3200	–	–	–	–	–	–
	Plant engineering - Logistics - Vehicles and equipment	Purchase of operating machines	1.00	45,000	–	–	–	–	–	–
		Truck scale installation	1.00	700	–	–	–	–	–	–
	Site preparation and preliminary work	Quarry area fence	2050.00	16,297	–	–	–	–	–	–
		Vertical signage	1.00	250	–	–	–	–	–	–
		Water well construction	1.00	2500	–	–	–	–	–	–
		User activation	1.00	2000	–	–	–	–	–	–
		Construction of a waste storage area	1.00	2200	–	–	–	–	–	–
MANAGEMENT COSTS	Rental costs	Land rent	1.00	12,000	1.00	12,000	1.00	12,000	1.00	12,000
	Costs of the extraction phase	Rock excavation	–	–	370.50	1580.63	1753	7478.66	18,540	79,095.47
		Expenses for the extraction	–	–	370.50	470.54	1753	2226.31	18,540	23,545.80
	Costs of Environmental recovery	Service roads	2700	35,775	–	–	6625	87,781.25	–	–
		Realization of embankments	87,282.75	576,938.98	76,280.10	504,211.46	77,024.55	509,132.28	80,359.58	531,176.82
		Channels for collecting rainwater	–	–	–	–	522.75	2744.44	–	–
		Rainwater collection tanks	–	–	–	–	750	7440	–	–
		Lay the vegetal soil	–	–	6407.33	6599.55	4321.95	4451.61	8988.65	9258.31
		Sow lawn	–	–	–	–	25,240	25,997.20	22,825	23,509.75
		Supply and installation of native shrubs	–	–	75	671.25	90	805.50	120	1074
		Supply and installation of native trees	–	–	150	2193	150	2193	100	1462
		Irrigation system	–	–	–	–	–	–	1.00	5303.78
		Creation of vegetative pockets on rock walls	–	–	25	253	35	354.20	–	–
	Final fulfillments	Survey of the final state to test the works	–	–	–	–	–	–	1.00	3200
		Dismantling of the construction site	–	–	–	–	–	–	1.00	1200
		Final administrative obligations (Final Report - Test)	–	–	–	–	–	–	1.00	750
	Overheads	10% of total costs	–	35,858.07	–	52,797.94	–	66,260.45	–	69,157.59
<b>TOTAL COSTS [€/year]</b>			<b>753,019.55</b>		<b>580,777.37</b>		<b>728,864.89</b>		<b>760,733.52</b>	

(continued on next page)

Table 5 (continued)

Specify cost		PHASE 1		PHASE 2		PHASE 3		PHASE 4	
		Quantity	Cost [€/year]	Quantity	Cost [€/year]	Quantity	Cost [€/year]	Quantity	Cost [€/year]
Revenues in the extraction phase	Revenue from the sale of dry quarry material	–	–	370.50	2408.25	1753	11,394.50	18,540	120,510
	Revenue from the sale of quarry boulders	–	–	–	–	–	–	–	–
Revenues in the recovery phase	Charges for receiving excavated earth and rocks	87,282.75	261,848.25	76,280.10	228,840.30	77,024.55	231,073.65	80,359.58	241,078.74
	Reuse of excavated earth and rocks	87,282.75	305,489.63	76,280.10	266,980.35	77,024.55	269,585.93	80,359.58	281,258.53
<b>TOTAL REVENUES [€/year]</b>		<b>567,337.88</b>		<b>498,228.90</b>		<b>512,054.08</b>		<b>642,847.27</b>	

Table 6 Financial plan of the investment.

		PHASE 1	PHASE 2	PHASE 3	PHASE 4
Costs [€/year]	Investment	–92,447.50	0.00	0.00	0.00
	Management	–660,572.05	–580,777.37	–728,864.89	–760,733.52
	<b>Total costs</b>	<b>–753,019.55</b>	<b>–580,777.37</b>	<b>–728,864.89</b>	<b>–760,733.52</b>
Revenues [€/year]	Extraction	0,00	2408.25	11,394.50	120,510.00
	Environmental recovery	567,337.88	495,820.65	500,659.58	522,337.27
	<b>Total revenues</b>	<b>567,337.88</b>	<b>498,228.90</b>	<b>512,054.08</b>	<b>642,847.27</b>
Cash Flows [€/year]	CASH FLOWS	–185,681.68	–82,548.47	–216,810.81	–117,886.26
	<b>DISCOUNTED CASH FLOWS</b>	<b>–178,540.07</b>	<b>–76,320.70</b>	<b>–192,744.02</b>	<b>–100,769.67</b>

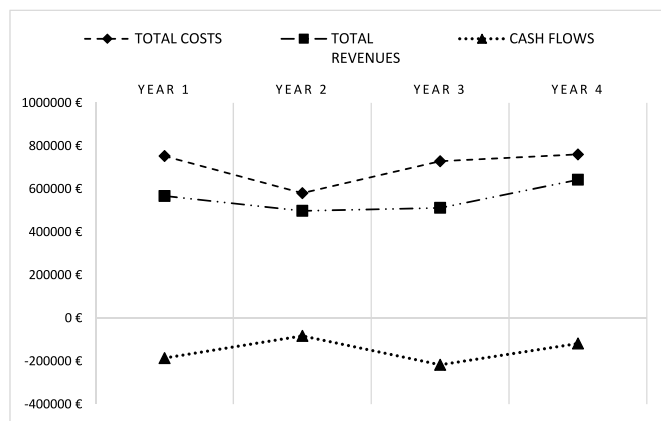


Fig. 4. Cash flows for the case study.

Table 7 Revenues.

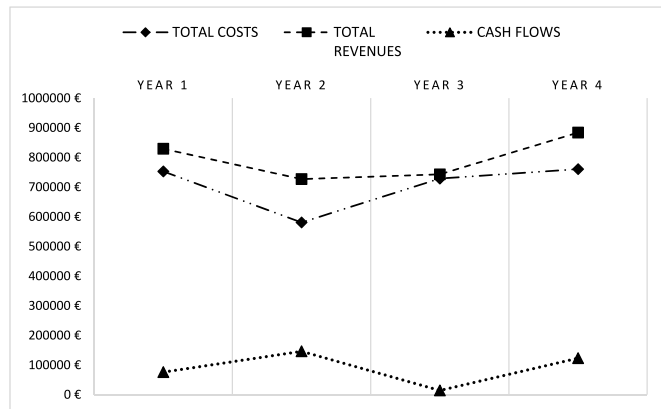
Minimum eligible unit revenue in the management of excavated earth and rocks		
Description	Current average unit revenue [€/m <sup>3</sup> ]	Minimum unit revenue [€/m <sup>3</sup> ]
Charges for receiving excavated earth and rocks produced on external worksites (Fig. 2c)	3.00	4.00
Charges for the processing and arrangement for re-use of such materials (Fig. 2d)	3.50	5.50

stones would be the following:

1. Existence of a concrete incentive for environmental restoration. As evaluated in Section 7, by ensuring acceptable revenues when acquiring and reusing excavated soil and rock, environmental restoration would generate profitability. Thus, mining operators would have an incentive to restore areas;
2. Reduction of the time for performing the restoration projects. It is currently difficult to find the volumes of excavated soils and stones required within the timeframe foreseen by the restoration project. According to the proposed model, all excavated soils and stones produced in a given area would be automatically reused for the restoration. The operators would no longer have to recover somewhere else the materials necessary for the formation of the embankments;
3. Reduction of the illegal disposal of excavated soils and stones. Many operators in the mining sector illegally acquire excavated soils and stones in the quarry areas disadvantaging the sites authorized for restoration. Making it possible the reuse of excavated soils and stones only at a specific authorized restoration site, the opportunities for illegal disposal would be drastically avoided;
4. Definition of an effective system of control and contrast of the illegal activities of extraction of limestone material. The Register allows you to record the residual quantities of excavated soils and stones that a restoration site has yet to acquire for the completion of the project embankments. If for a given site this value is zero, this would indicate the completion of the project embankments. So, if in reality this does not turn out, the reasons could be only two:
  - the volume of excavated soils and stones necessary for the construction of the restoration embankments was underestimated in the design phase;
  - illegal excavations were carried out. In other words, gaps or retreating fronts have been illegally created and need to be investigated.

**Table 8**  
Financial plan of the investment, considering the revenues indicated in Table 7.

		PHASE 1	PHASE 2	PHASE 3	PHASE 4
Costs [€/year]	Investment	-92,447.50	0.00	0.00	0.00
	Management	-660,572.05	-580,777.37	-728,864.89	-760,733.52
	Total costs	-753,019.55	-580,777.37	-728,864.89	-760,733.52
	Discounted total costs	-724,057.26	-536,961.33	-647,958.23	-650,278.20
Revenues [€/year]	Extraction	0,00	2408.25	11,394.50	120,510.00
	Environmental recovery	829,186.13	724,660.95	731,733.23	763,416.01
	Total revenues	829,186.13	727,069.20	743,127.73	883,926.01
	Discounted total revenues	797,294.36	672,216.35	660,637.85	755,583.66
Cash Flows [€/year]	CASH FLOWS	76,166.57	146,291.83	14,262.84	123,192.48
	DISCOUNTED CASH FLOWS	73,237.09	135,255.02	12,679.61	105,305.45



**Fig. 5.** Cost-Revenue Analysis of the environmental restoration work, considering the revenues indicated in Table 7.

An important clarification must be made on the materials to be used in the formation of the restoration embankments. They can take on great importance, both from an environmental point of view and in terms of circular economy (Dal Sasso et al., 2012; Talento et al., 2020; Tan et al., 2019; Cristiano et al., 2021).

This research refers to excavated soils and stones, to be reused for recovery embankments. Currently, for the realization of these interventions are often reused also recycled aggregates, produced by the recycling of construction and demolition waste. This is because their reuse in the construction sector now encounters great difficulties, mainly due to a low demand caused by a lack of confidence on such products (Tsolaki-Fiaka et al., 2018). It therefore happens that recycled aggregates are also disposed of in environmental restoration sites, rather than being available in recycling plants. This may have negative effects both on the recycling chain and on the management process of excavated soils and stones. The reuse of aggregates in environmental restoration prevents their better valorisation according to the principles of the circular economy: for example, for the production of non-structural concrete or for the construction of sub-foundations in mixed limestone (Garbarino et al., 2020; Worlanyo and Jiangfeng, 2021). At the same time, the improper use of recycled aggregates contributes to incentive the illegal management of excavated soils and stones. The latter, in fact, has lower reuse opportunities due the use of recycle aggregate that in this case act as substitutes of soils and stones.

As a result, in the construction of the embankments of environmental restoration only the reuse of soils and stones from excavation should be allowed, limiting any form of reuse of the recycled aggregates, except for the formation of service tracks and/or secondary works.

## 8.2. Regulatory interventions

The regulations produced in Italy over the last 30 years have not a

common intervention strategy as they are mainly based on regional laws. The Regional Plans of Mining Activities (RPMA) are often very different from each other, not to mention that some Regions do not yet have a RPMA.

Therefore, it would appear to be more adequate a national regulatory framework that – in compliance with EU guidelines – provides guidance on strategic urban planning and land use policy in post-mining. This would make much clearer the strategic lines and procedures to be followed in the management of mining and environmental restoration activities. Individual regions would be responsible for local controls on environmental restoration.

## 8.3. Definition of a new marketing system for limestone materials extracted during the environmental restoration phase

A marketing system along the lines of the one proposed in this study for the management of excavated soils and stones could also be adopted for the management of aggregates deriving from restoration operations (re-profiling, scaling, benching, etc.).

Specifically, to incentivise restoration, at least for public and private works with a high financial commitment, it could be useful to incentive operators to purchase a given percentage of aggregates from authorized sites for environmental restoration. In this case, by setting minimum selling prices it would be possible to generate an additional source of revenue for those who perform environmental restoration projects.

This last proposal can be based on operating modalities that are similar to those already suggested for the management of excavated soils and stones. In other words, it is a question of setting up a specific Register, in which to indicate the area of competence for the individual site to be recovered, as well as the residual quantities of marketable aggregates, as per the approved project.

## 8.4. Reuse of recovered areas and incentives for future activities. Creation of additional financial benefits

Currently, once restoration operations are completed, the areas revert to their original land use, usually agricultural. It could be also useful to provide incentives to entrepreneurs who successfully complete environmental restorations. However, these incentives should allow for virtuous entrepreneurs to perform further activities on the restored areas since such activities would be source of additional financial benefits. For example, economic incentives could be given for the following additional activities:

- activities compatible with the territorial context of reference (agricultural production, livestock breeding, further extraction of limestone materials and so on);
- installation on restored areas of renewable energy production plants, tourists and/or recreational facilities, etc.

If the restored areas are not suitable for subsequent exploitation, the

transfer of incentives to other areas and/or in favour of other activities available to the entrepreneur could be envisaged.

#### 8.5. Intensification of controls and higher penalties. Establishment of the register of sector operators

Although it is essential to ensure restoration, clearly not all operators should benefit from the proposed incentives. Those who have carried out illegal extraction and recovery activities must necessarily be excluded from the supporting measures.

The proposed incentive policies should be certainly associated to measures to contrast the illegal activities, more controls and the application of high penalties. It is essential to define a system of penalties proportional to the damage that the illegal activities cause to the territory and to the community. In the Campania Region, for example, controls are often late and ineffective, and the penalties for illegal activities are completely inadequate compared to the damage. The sanctioning system should be outdated being regulated by the Regional Law 54/85, whose scope underestimated the magnitude of the issue of illegal extraction activities.

In this sense, the establishment of a Register of operators in the extractive sector becomes crucial and mandatory. In this way, each entrepreneur in the sector can be placed within a merit list. The scores assigned must depend on the technical and organizational skills of the individual operator as well as on his/her own conduct. Those who carry out illegal activities should be punished according to a specific regulatory system, depending to the extent of the abuses and the landscape characteristics of the involved areas.

Consequently, illegitimate activities can be punished by implementing a progressive loss of points in the ranking, up to the temporary suspension or definitive cancellation from the Register, in case of serious abuse.

In the latter case, to guarantee the completion of the extraction and environmental restoration works, the completion of the cultivation and environmental recovery activities can be entrusted to the subjects who request it, according to the order of merit indicated in the ranking. The successor can complete the works and enjoy the incentives provided for the restoration.

The proposed merit-based system incentivises all entrepreneurs to operate in a more responsible manner. In fact, every entrepreneur has a direct interest in monitoring that the management of activities in the area agrees with the legislation.

## 9. Discussion and conclusions

In this study, our aim was to investigate the issue of environmental restoration of construction limestone extractive sites cultivated illegally or before the introduction of the Regional Law on mining activities. To this purpose we shed light on the characteristics of extraction sites abandoned at the end of the quarrying activities, the key financial and technical regulatory factors that cause their abandonment and the solutions to favour a virtuous process of environmental restoration.

The financial analyses, conducted according to the Cost-Revenue Analysis approach and applied to a case study of environmental restoration in Campania Region (Southern Italy), provide an overall picture of the main factors involved, showing the different types of costs and revenues that contribute to the profitability of the restoration project. It turns out that the abandonment of the former quarry areas and the failure to restore the environment are the effect of an economic and regulatory context that generally does not guarantee adequate financial remuneration to operators and most often occurs in the absence of adequate controls and an effective sanctioning system. More

specifically, although the current regulatory framework requires post-mining environmental restoration, it does not encourage its practical adoption. In addition to this, there is an ineffective system of sanctions against those who carry out the illegal operation: in fact, penalties are minimal for those who do not respect the risk assessment and administrations are not able to impose restoration at the expense of those who cause the damage.

Therefore, the results from our analysis allow us to propose policies and regulatory interventions useful to improve the sustainability of the whole sector and sustainable land re-use after mining, with the aim of promoting the implementation of environmental restoration for the former abandoned quarry areas.

Although there are few studies that investigate the legislative and regulatory aspects related to the environmental restoration of quarries, the results achieved by the study are in line with what has been found in other areas of the world. In this regard, [Yahya et al. \(2018\)](#) point out that to date, there are no specific laws addressing quarry rehabilitation in Malaysia, resulting in an ineffective approach and procedures for its implementation. According to the Authors, another critical issue concerns the lack of sanctions as well as adequate controls for failure to restore the quarry. Finally, there is also a lack of comprehensive planning and implementation of restoration during the life of a quarry, highlighting how there are no measures to rehabilitate the quarry but only mitigation measures that prevent environmental damage. Another example is that of [Monteiro et al. \(2021\)](#), which highlight the shortcomings of Brazilian mining laws. These include: (i) slow adjudication processes; and (ii) defects in the application of certain principles that impact sustainability in the development of the business, in particular regarding environmental and social responsibilities remaining after the closure of the mine.

In conclusion, this study applies an innovative Cost-Revenue Analysis to a generic environmental restoration project of a former limestone mining site demonstrating that restoration activities are currently daunting for entrepreneurs. Future research will allow us to delve deeper into the effects that restoration activities can have on society and the environment, in addition to the financial critical issues. In fact, integrating sustainable development into the mining industry means applying the principles of sustainability simultaneously, making it necessary to define novel evaluation approaches capable of balancing economic, environmental, and social concerns.

### CRedit authorship contribution statement

**Antonio Nesticò:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Gianni D'Ambrosio:** Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Visualization, Writing – original draft, Writing – review & editing. **Patrizia Ghisellini:** Formal analysis, Investigation, Methodology, Resources, Visualization, Writing – review & editing. **Gabriella Maselli:** Formal analysis, Investigation, Methodology, Resources, Visualization, Writing – review & editing. **Sergio Ulgiati:** Conceptualization, Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix

**Table 1**  
New price analysis sheets.

New price analysis sheets 1										
Interception of existing water line										
Processing code	Price list	Description	M.U.	Num units	Length	Width	Height	Quantity	Unit price	Amount
U.05.010.020.a	Campania 2018	Demolition of asphalt pavement	m <sup>3</sup>		1.00	0.40	0.07	0.03	15.79 €	0.44 €
E.01.015.010.a	Campania 2018	Cut-and-cover excavation	m <sup>3</sup>		1.00	0.40	0.60	0.24	4.66 €	1.12 €
C.01.070.010.b	Campania 2018	PE 80 polyethylene pipe for plant lines	m		1.00			1.00	6.65 €	6.65 €
U.04.010.010.a	Campania 2018	Sand backfill	m <sup>3</sup>		1.00	0.40	0.50	0.20	35.90 €	7.18 €
U.04.020.010.b	Campania 2018	Pedestrian connection pit, not diaphragmatic, 30 × 30 × 30 cm	each	0,03			1.00	0.03	36.28 €	0.91 €
U.04.020.010.b	Campania 2018	Manhole cover for pedestrian connection, 40 × 40 cm	each	0,03			1.00	0.03	49.16 €	1.23 €
NP.001.AP	New price	Supply and installation of WATER NETWORK SIGNAGE TAPE	m		1.00			1.00	2.90 €	2.90 €
U.05.020.085.a	Campania 2018	Cement-mix foundation layer	m <sup>3</sup>		1.00	0.40	0.10	0.04	1.90 €	0.08 €
U.05.020.095.a	Campania 2018	Asphalt for the binder course	m <sup>2</sup> /cm		1.00	0.40	4.00	1.60	1.54 €	2.46 €
U.05.020.096.a	Campania 2018	Bituminous conglomerate for wearing course	m <sup>2</sup> /cm		1.00	0.40	3.00	1.20	1.68 €	2.02 €
<b>APPLICATION PRICE</b>										<b>24.98 €/m</b>
NEW PRICE ANALYSIS SHEETS 2										
Open section excavation for earthworks										
MEANS AND EQUIPMENT										
OPERATING MACHINES			M.U.	Quantity			Unit price			Amount
Rental with operator of excavator with breaker			fixed basis	0.0165			55.00 €			0.91 €
Rental with operator of excavator with bucket			fixed basis	0.0165			50.00 €			0.83 €
Rental with operator of dumper			fixed basis	0.0165			65.00 €			1.07 €
<b>TOTAL COST OF MATERIALS</b>							<b>2.81 €</b>			
LABOUR										
LABOUR			M.U.	Quantity			Unit price			Amount
Specialised worker			hours	0			26.35 €			- €
Qualified worker			hours	0.0165			24.53 €			0.40 €
Ordinary worker			hours	0			23.18 €			- €
<b>TOTAL LABOUR COSTS</b>							<b>0.40 €</b>			
<b>SECURITY COSTS</b>							<b>0.50 €</b>			
<b>TOTAL COST NET OF GENERAL COSTS</b>							<b>3.71 €</b>			
<b>GENERAL COSTS (15% of total cost)</b>							<b>0.56 €</b>			
<b>APPLICATION PRICE</b>							<b>4.27 €/m<sup>3</sup></b>			
Incidence of labour							<b>9.49%</b>			
Security impact (inherent in the price)							<b>11.72%</b>			

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