Scientific Research Publishing

**Journal of Geoscience and Environment Protection, 2025, 13(12), 525-537**
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

# An Alternative Reclamation System of Stony Soils: A Case Study

**Pietro Toscano**

CREA-IT, Research Centre for Engineering and Agri-Food Processing, Treviglio, Italy
Email: pietro.toscano@crea.gov.it

**How to cite this paper:** Toscano, P. (2025). An Alternative Reclamation System of Stony Soils: A Case Study. *Journal of Geoscience and Environment Protection, 13,* 525-537.
https://doi.org/10.4236/gep.2025.1312027

**Received:** November 17, 2025
**Accepted:** December 26, 2025
**Published:** December 29, 2025

## Abstract

The "sustainability" concept means a process or state that can be maintained indefinitely in time and space at a defined level. In agricultural management, the concept of sustainability is also associated with the soil quality and productivity, and related to the physical, chemical, and biological fertility of the active layer. Since soil is a non-renewable resource, agriculture "4.0" must therefore avoid its exploitation and degradation in the intensification of cropping systems, according to the principles of marginal productivity in the use of production factors. However, in many agricultural lands, over the fine earth fractions, there are high coarse fractions percentages that hinder the functionality of cultivation machines and increase their wear. In this study, a deep burial reclamation trial was carried out, as alternative to stone removal and on-site crushing, to constitute a cultivation layer with a higher percentage of fine earth, with the aim of improving in long term the soil quality and workability, the efficiency of cultivation machines and the crop yield. The results obtained confirmed the achievement of set goals, avoiding the drawbacks of the other soil destoning systems, making the proposed method viable for a wide range of potential users, both for the implementation of precision farming systems and the recovery of productivity of stony soils.

## Keywords

Stony Soil Reclamation, Soil Quality, 4.0 Precision Agriculture, Agro-Industrial Crops

## 1. Introduction

Conventional, integrated, organic, biodynamic, sustainable, conservative, regenerative...: the evolution of cultivation methods in income farming has led to the definition of various cultivation systems or models, developed according to political, market or social needs and sometimes adopted ignoring or neglecting their long-term effects, or their compatibility with crops characteristics or environmental sustainability of cultivation areas. Thus, the indiscriminate use of synthetic fertilizers and pesticides, while it has allowed crop yields maximization in the short term, it has also led to the destabilization of agroecosystems and the depletion of organic soil fertility. The result has been a general flattening and even decreased soils productivity, with the consequent widespread increase of desertification processes, sometimes compromising also the products wholesomeness. On the other hand, the totally renounce of the use of synthetic agro-chemicals, in the name of questionable quality and genuineness indices, would be difficult to reconcile with the profitability of agro-industrial crops, which is the main, if not the only, reason for committing resources and capital to income agriculture. Whatever the type of agriculture, the primary factor of the cultivation success is the soil management, since soil is the medium where plants are physically located and from which they draw their nutrients. Any soil processing considered useful in the different phases of the crop cycle must be, therefore, rationally planned and correctly executed, both to maximize its effects and to optimize time and operating costs, in order to satisfy the needs of: *i)* the crop, which draws support and nourishment; *ii)* the environment, since soil is a non-renewable resource, easily subject to degradation by anthropogenic pressure; *iii)* the economics, which conditions cultivation plans and operating methods (FAO, 2010).

The concept of sustainable agriculture has been discussed for several decades and has focused on four general aims: sufficient food and fibre production, environmental stewardship, economic viability, and social justice (Kirchmann & Thorvaldsson, 2000). Today, the commonly accepted concept of "sustainability" define a process or a state that can be maintained at a certain level indefinitely in time and space; and the American Society of Agronomy defines the Sustainable Agriculture *"as something that, over the long term, enhances environmental quality and the resource base in which agriculture depends; provides for basic human food and fibre needs; is economically viable; and enhances the quality of life for farmers and the society as a whole"* (ASA, 1989).

More recently, the term "sustainability" has been associated with the concept of *"net zero"*; however, while the perception of the general public is that we should not use more resources and release more pollutants, to far-sighted thinkers the concept of *"net zero"* is not enough, because it does not solve the problem: it should be aiming for *"net positive*" (Brockotter & McCullough, 2022).

Given that agriculture is the most important tool for the future of our planet, the greatest attention should be mainly focused also on the growth of world population to somewhere between 9 and 10 billion by 2050, which would entail a 70% increase in food production, while land consumption advances generating an irreversible loss of environmental resources and ecosystem functions at a global level. This leads to a reduction of biodiversity and productivity and compromises the availability of resources, due both to anthropization (overbuilding), and un-sustainable choices in the use of resources that contribute to soil degradation (e.g., climate change, drought, SOC loss, desertification, desertization).

In this scenario, the rise of the Global Hunger Index (GHI, 2021) is plausible in an increasingly large part of the world's "industrialized" population—also given the increasingly intensity of migration flows—with increasing discrimination between ethnic groups and social classes that will be able to enjoy quality and nutritionally viable food and others, much more people, forced to feed on insects, already touted as *"sustainable food"* or *"food of the future"* or *"perfect candidates for ecological and sustainable food"* from multiple sources (FAO, 2021; Klein, 2019), with the global market for edible insects that is expected to reach approximately USD 8 billion by 2030 (Research and Markets, 2019); as well as rodents, which are already food sources for many cultures in various parts of the world (Gruber, 2016). Currently, it is implausible to increase the agricultural production by the expected 70% only by "improving sustainable production", or even by using the latest genetic technologies; and the near future of human feed seems to be the one provided by the "Super Sprout Factories" (Murakami Farm, 2021).

It is peculiar how such conditions of food scarcity are generally attributed to climate change, wars or epidemics, ignoring or rather almost intentionally, avoiding any mention of overpopulation as the primary cause of hunger in the world.

In these conditions it need recovery of abandoned or not adequately managed agricultural areas, adopting the more usefulness agricultural reclamation systems in the different agricultural lands, for the restoration of physical, chemical and biological fertility; also to allow the implementation of the most modern technologies of 4.0 agriculture in precision farming systems, to maximize production yields, contain production costs and reduce the environmental impact of agro-industrial crops (Bongiovanni & Lowenberg-DeBoer, 2004; Dayioğlu & Türker, 2021; Tey & Brindal, 2012) and contribute to achieve the "Net positive" balance of the future agriculture.

However, the efficiencies of agricultural soil management systems are strongly conditioned by the presence of coarse fractions (skeleton) in the cultivation layer. These fractions can interfere with the cultivation needs, damage the machinery, penalize the seedbed quality, and require more energy in tillage operation; till to making the use of some cultivation machines impractical. In this context, the goal of this project was to evaluate/validate a deep burial reclamation technique of stony soils, alternative to the stone removal or the on-site stone crushing, for the long-term improvement of the structural and textural characteristics of the arable layer, to optimize operative efficiency of PA cultivation machines, and maximize crops profitability in terms of both yield increase and reduction of cultivation costs.

## 2. Soil Skeleton

The rock fragments or coarse fractions of soil by over 2 mm of diameter up to those with a horizontal dimension less than the size of a pedon, constitute the soil skeleton (USDA, 1999). As intensive agriculture is predominantly interested in fine-and the medium-textured active layer of soils, the fractions over 2 mm of diameter (gravel and stones) are usually excluded in determining the soil texture because considered as an inert fraction in crops dynamics. However, the skeleton can play a significant role in soil physical and chemical properties, such as water retention and flow, structure improvement, protection against compaction and erosion, thermal regulation, and bulk density. In some cases, the skeleton also shows chemical properties similar to or higher than those of the fine earth contributing to the dissolution of carbonates, forming secondary minerals, and releasing nutrients. Therefore, coarse fractions play a significant role as a reservoir of nutrients, a source of cation exchange capacity (ECEC) and as adsorber of organic pollutants, also with favorable effects on plant growth (Poesen & Lavee, 1994; Ugolini, Corti, Agnelli, & Piccardi, 1996; Flint & Childs, 1994). On the other hand, an excessive presence of skeleton in the soil's arable layers hinders or is incompatible with the operational requirements of modern machinery and cultivation techniques (e.g., minimal tillage, precision sowing), which require arable layers of fine heart.

## Soil Stoniness Assessment

The coarse fractions of the soil's arable layer have been variously defined in terms of skeleton classes percentage by weight, size, surface coverage, volume (Buchter, Hinz, & Flühler, 1994; Corti, Ugolini, & Agnelli, 1998; Miller & Guthrie, 1984); or through dimensionless indexes such as: Stoniness Degree (Equation (1)), Crushing Degree (Equation (2)), Stoniness Index (Equation (3)):

$$\mathrm{SD} = \mathrm{StM}/\mathrm{SoM} \tag{1}$$

$$\mathrm{CD} = \frac{\sum_{i=0}^{5} n_i \cdot StMi}{SoM} \tag{2}$$

$$\mathrm{SI} = \mathrm{SD}/\mathrm{CD} \tag{3}$$

where StM = Stones Mass; SoM = Soil Mass; $i$ and $n$ index as per **Table 1** (Colzani, Cammilli, & Pirrone, 1989a).

**Table 1.** Stone classes indexes.

| i value | Stone Size (mm) | n value |
|---|---|---|
| 0 | <2 | 1.0 |
| 1 | 2 ÷ 20 | 0.8 |
| 2 | 20 ÷ 50 | 0.6 |
| 3 | 50 ÷ 150 | 0.4 |
| 4 | 150 ÷ 400 | 0.2 |
| 5 | >400 | 0.0 |

While the workability Disturbance Degree (DD) evaluates the stoniness impact on the efficiency and operational capabilities of soil tilling and cultivation machines. The DD relates to the size of the stones, and the distribution of their size classes as per Equation (4) (Colzani, Cammilli, & Pirrone, 1989b):

$$DD = 0 \times X + 10 \times Y^{5} + 10 \times Z^{2} + 10 \times U^{0.9} + 10 \times W^{0.5} \qquad (4)$$

where X, Y, Z, U, W, indicate the proportions, expressed in unit terms, of the different particle size classes, the sum of which must always be equal to 1 (100%).

Of these, the X class, corresponding to the fine earth, always has zero value; Y class (gravel, fine & medium gravel: 2 - 20 mm) does not represent an impediment to soil tillage's; the Z class (gravel, coarse gravel; medium stone: 20 -50 mm), at about 40% - 50% affects the operational capabilities of the PTO moved machines; the U class (cobble, large stones: 50 - 150 mm), sets significant limits for machining already from 15% - 30%; the W class (stones, huge stones: >150 mm), involves severe problems of soil tillage's management already at the 10% of presence.

Based on the different levels of Disturbance Degree, in **Figure 1** are reported the operative limits of some cultivation machines: in the graph, the green zone indicates soils that can be tilled without limitations; the yellow zone, the soils workable with appropriate precautions, to avoid early wear or breakage of the working tools; the red zone, represent soils having stoniness incompatible with an acceptable quality of work and/or the integrity of respective cultivation machines.

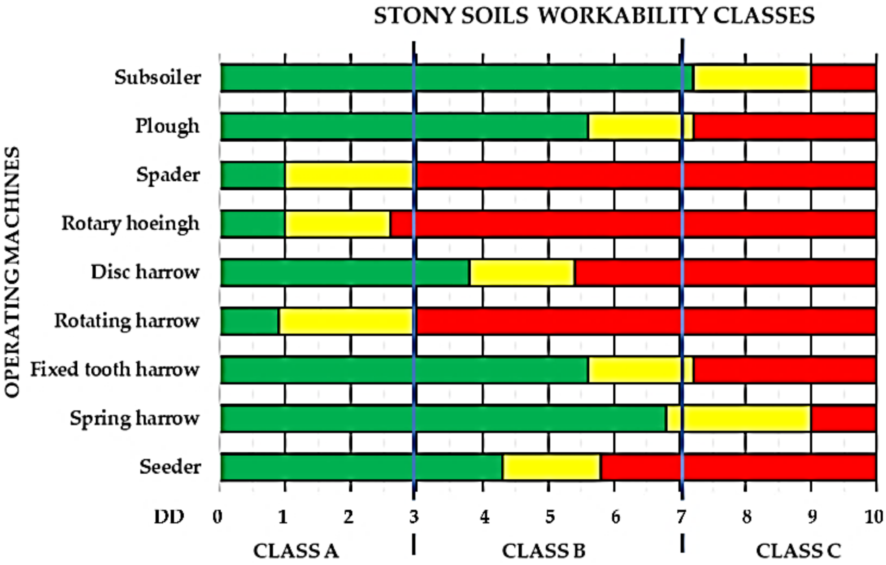


**Figure 1.** Operative limits of some cultivation machines at different DD levels of soils stoniness.

Since stone reclamation is a very expensive process, the choice of best reclamation method depends on environmental and management factors, such as soil structure, percentage, types and size of stones, crop needs, and machinery availability. The most used destoning systems in agricultural lands are basically three: the stones collection and removal from the field, the on-site stones crushing, and the stones burial (Toscano, Brambilla, Cutini, & Bisaglia, 2022a).

## 3. Materials and Methods

This case study was conceived from the assessment of the high stoniness of Treviglio's countryside soils, that lie between the high gravel plain and the river valleys of the Holocene waterways (**Figure 2**).

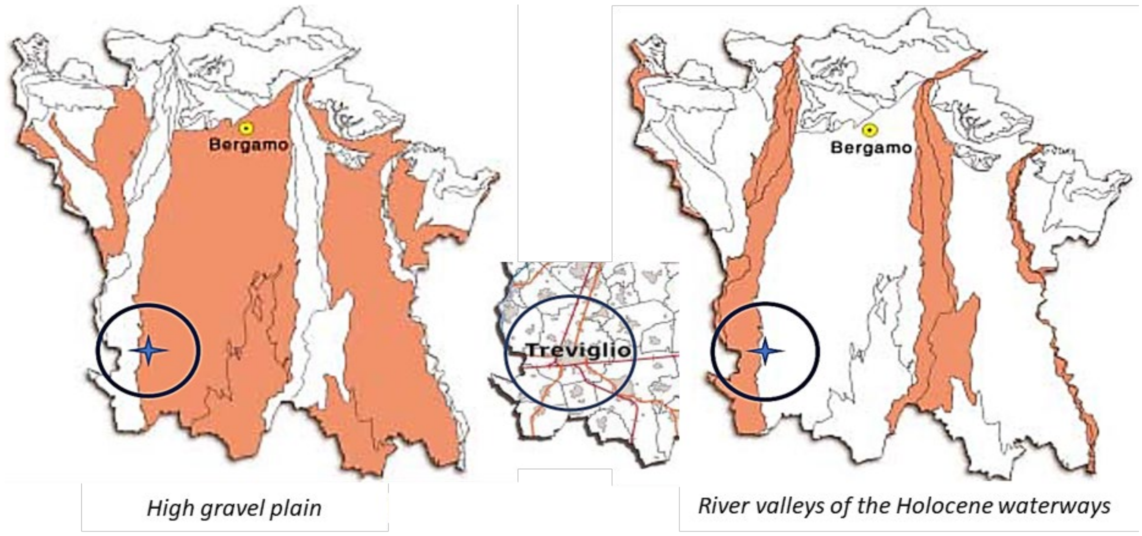


**Figure 2.** Soils of Bergamo's province (Lombardy, Italy).

In the research center facility of CREA-IT on Treviglio (Bergamo's province, Northern Italy, 45˚31'14"N; 9˚35'27"E; +128 m asl), the soils have a stoniness with varying degrees of hardness, from limestone to crystalline shale and quartzites of hardness from 3 to 7 degrees Mohs, with "B" workability class, and Disturbance Degree (DD) between 3.2 and 5. On these soils, some experimental reclamation activities of stone removal and on-site crushing were carried out at the end of the 1990s (Colzani, Cammilli, & Pirrone, 1989c). However, these methods have some drawbacks that limit their effectiveness, such as low operating depth, reduction of topsoil volume, and stones resurfacing after soil tillage's; solving the cultivation problems only partially and in the short-term. In this project, an alternative destoning method was tested of long-term effectiveness, for the constitution of an arable layer more compatible with the operative needs of cultivation machines.

For the planned reclamation activities, in a previously geoelectrical characterized field of high stoniness (**Figure 3**) (Brambilla, Romano, Toscano, Cutini, Biocca, Ferré, Comolli, & Bisaglia, 2021), four contiguous plots of 10 × 20 m (**Figure 4**) were identified as P1, P2, P3, P4. The P1 and P3 plots was reclaimed by using a crawled arm excavator, equipped with a dozer blade, a toothed bucket, a smooth-blade bucket, and a sieving bucket with 40 mm grid holes; while the P2 and P4 contiguous plots have represented the undisturbed control tests, for the planned agro-mechanical comparisons.

In the P1 and P3 plots, the soil was dug up to about 1 m deep; the dug soil was then sieved, time to time discharging in the trenches the stones retained by the grid of sieving bucket. The stone layer formed at the bottom of the trenches was levelled and compacted with repeated passages of the crawled excavator; then the filling of the trenches with the sieved fine earth, including skeletal fractions up to 40 mm (Y and Z classes), was completed (Toscano, Cutini, Cabassi, Pricca, Romano, & Bisaglia, 2022b).

**Figure 3.** Sample of soil profile.

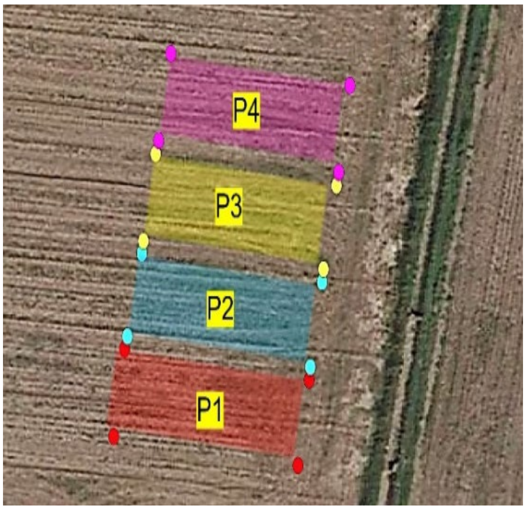


**Figure 4.** Experimental plots: P1, P3 destoned; P2, P4, undisturbed control.

For the validation of this reclamation system some other collateral trials have been carried out to analyse the different responses of reclaimed vs. undisturbed soil, in terms of both mechanical and agronomical soil quality, as described in Results section below.

## 4. Results and Discussion

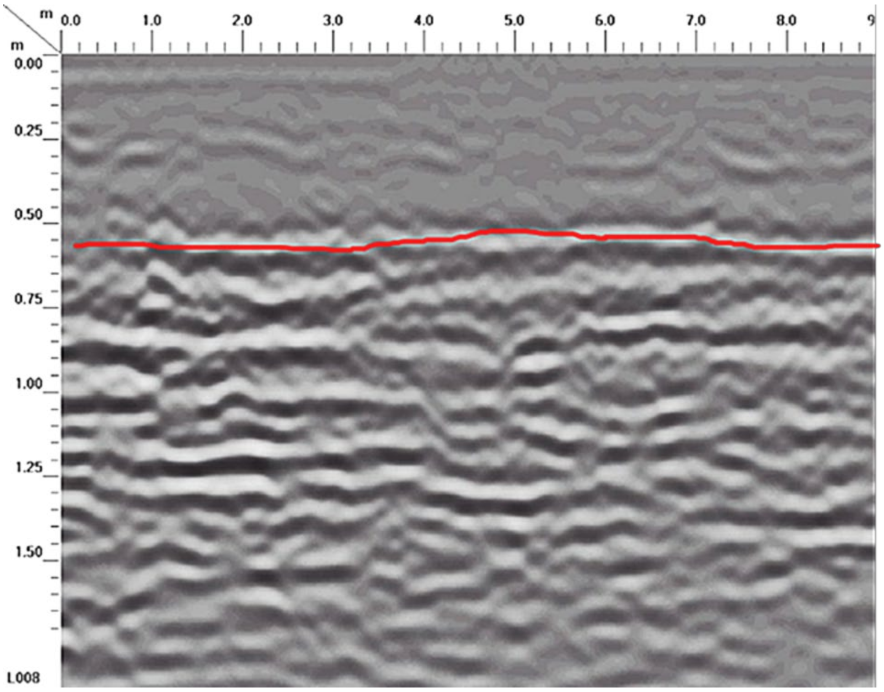
In this section are reported the results obtained on soil quality, sowing efficiency and crop biomasses.

### 4.1. Soil Quality

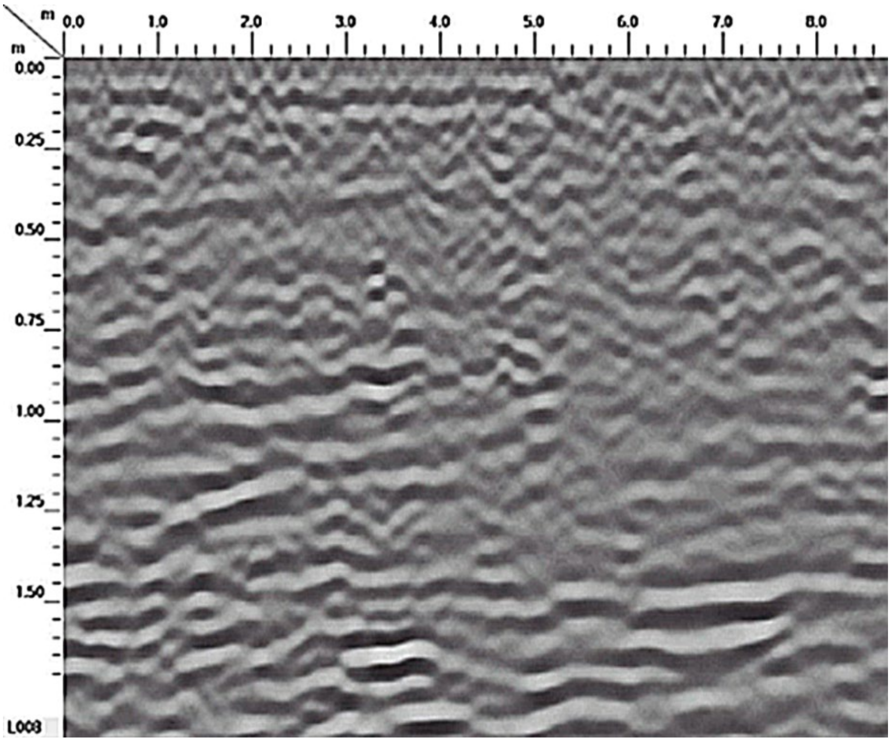
With this deep stone burial reclaiming system, a noticeable improvement of the original soil profile composition in terms of soil disturbance degree (DD) and workability class was obtained: from a class "B" and DD = 4.15 (estimated X = 0.6, Y = 0.1, Z = 0.1, U = 0.15, W = 0.05), to an arable layer of about 600 mm of "A" workability class and DD = 0.1 (estimated X = 0.8, Y = 0.1, Z = 0.1, U = 0, W = 0); with the U and W stone classes that constituting a draining layer of about 400 mm. This result was obtained without lowering the field plan, as occurred in the case of stones removal that, in our trial condition, would amount to 400 mm; nor the chemical characteristics of fine earth in the constituted arable layer, as in case of stones crushing. The very low value of the calculated Disturbance Degree in the reclaimed plots, does not constitute obstacles for the cultivation machines (harrow, seeder), while the presence of Y and Z gravel classes can be useful in the preservation of some soil structural characteristics, contributing to the reduction of physical degradation of fine-textured soils (Magdoff & Van Es, 2021).

The enhancement of soil quality in reclaimed plots has been evidenced also by soil profile traces recorded by Ground Penetrating Radar survey carried out in the experimental plots, using a GSSI UtilityScan RLT3 with 350 MHz HyperStacking antenna (Codevintec, 2004).

The difference between A (P1 and P3: reclaimed) and B (P2 and P4: undisturbed) plots is evident in the 0 - 600 mm depth, corresponding to the "fine earth" layer obtained by sieved soil: the low backscatter of the signal is due to the lack of agglomerations and stones in the reclaimed areas (A) (**Figure 5(a)**); meanwhile, in undisturbed areas (B), the signal has greater backscatter and attenuation along



(a)



(b)

**Figure 5.** (a) Soil A (reclaimed) GPR profile. The red line shows the bottom layer of reclaimed soil; (b) Soil B (undisturbed) GPR profile with more scattered layer compared to the soil A profile.

the depth axis (**Figure 5(b)**) (Toscano, Cutini, Filisetti, Premoli, Porcu, Catalano, Bisaglia, & Brambilla, 2022c).

### 4.2. Sowing Efficiency

Various authors have evaluated the performances of different seeders in different areas and for different crops; however, neither bibliographic references nor technical documentation report correlations between machinery performances and soil condition, assuming that the soil is optimal for the performances of the described machines. On the contrary, the type and structural conditions of the soil on which sowing occurs heavily affect the operational efficiency of seeders in terms of waving, humidity, seedbed preparation and presence of skeleton in the cultivation layer.

In particular, soil stoniness can severely compromise the efficiency of seeders, in terms of both sowing effectiveness and structural integrity, even for those equipped with the most advanced vibration-damping and downforce control systems of sowing elements, limiting their operating speed up to a third of the operative potentiality.

Being seeders a key tool for optimizing crop results, a sowing trial was carried out on four soil plots to verify whether the vibration and noise arising during this operation significantly change with varying the stoniness disturbance degree on soil workability (Toscano, Cutini, Filisetti, Premoli, Porcu, Catalano, Bisaglia, & Brambilla, 2022c).

On the pneumatic seeder used, 5 triaxial accelerometers and 1 microphone were applied for vibrations and sound pressure level collection. As a result, the highest accelerations were found at the roller and ranged from 0.3 g in the destoned soil to 0.59 g in the undisturbed plots, with significant differences in all the five accelerometers. For the phonometric survey too, significant differences (6 dBA and dBC) in the noise value between the different plots were found. Both parameters could therefore be used in TIM (Tractor Implement Management) systems to optimize the operational efficiency of precision seeders, automatically adjusting the forward speed according to the acceleration or noise levels induced in real time by the soil characteristics on which the machine operates, thus reducing the risk of wear or breakage, and the related costs due to downtime and repairs.

### 4.3. Biomass Yields

For the final validation of this deep burial reclamation system, in the three-year period 2022-2024 the biomass yields were detected among the reclaimed vs. control plots of different crops usually grown in the geographical area of investigation.

As shown in **Table 2**, in destoned plots higher biomass yield (Δ%) were recorded in all years, respectively:

*i)* in 2021 winter Triticale, sown at a density of 180 kg/ha and 125 mm row spacing, by 20.7%;

*ii)* in 2022 spring mowing Sorghum, sown at 30 kg/ha and 375 mm row spacing, by 23.1%;

*iii)* in 2022 winter barley, sown at 80 kg/ha and 125 mm row spacing, by 23.6%;

*iv)* in 2024 spring dual-purpose hybrid sorghum, sown at 34 seeds/sqm and 700 mm row spacing, by 22.8%.

**Table 2.** Crop biomasses at harvest (Avgs. equivalent t/ha).

| | Winter Triticale (31/05/2022) | Spring Mowing Sorghum (05/10/2022) | Winter Barley (17/05/2023) | Dual-purpose hybrid spring Sorghum (20/09/2024) |
|---|---|---|---|---|
| Avg. Recl. | 21.6 | 16.0 | 22.5 | 43.0 |
| Avg. Ctrl | 17.9 | 13.0 | 18.2 | 35.0 |
| Δ% | 20.7 | 23.1 | 23,6 | 22.8 |

## 5. Conclusion

Suitable soil management is a key factor for successful farming process in any cropping system and, more significantly, in modern site-specific agricultural systems. In the current state of soil consumption, degradation, and desertification processes, it needs to maximize the efficiency of agricultural management for the optimization of the physical, chemical, and biological fertility of soil's active layers, reducing the production costs, and enhancing the environmental sustainability of agro-industrial crops; at the same time avoiding the overexploitation and degradative phenomena of the non-renewable resource "soil". Among the factors that most influence cultivation managements, the soil skeleton negatively affects the tillage quality, the performance and integrity of cultivation machines and the crop yields. Although the stones reclamation of agricultural land is an expensive process, given the operational needs of agro-industrial crops and the diffusion of precision farming techniques, it needs to operate—as far as possible—on fine earth arable layers, or with a stoniness compatible with cultivation machines (i.e., precision seeders). If the skeletal amount exceeds the workability Disturbance Degree (DD) acceptable by machinery, it becomes necessary to proceed with destoning, for which can be adopted various technologies and machinery designed for different environmental and stoniness conditions. The choice of the best method involves various factors, such as nature and distribution of coarse fractions, crop needs and machinery availability; also considering the possible negative effects of the destoning methods, such as the lowering of the field plan, in the case of the stone's removal, or the modification of the chemical-physical characteristics of the soil, in the case of on-site crushing. The deep stone burial reclamation system tested in this case study has instead proven to be more effective in the long term, both in terms of soil quality and workability, and improvement in crop yield, as achieved in our experimental conditions, without the drawbacks of the two other systems mentioned. Although the remediation process used in this case study is not feasible on a large scale, the specific long-term cost/benefit analyses, in the different agropedological conditions of interest, could encourage the development of specific machines for the execution in same time of the reclamation steps (excavation, sieving, stratification, filling), and significantly reducing the reclamation costs. This would make the proposed method viable for a wide range of potential users, encouraging the implementation of PA techniques, and recovering productivity and profitability even from stony soils, according to the principles of Marginal Productivity of the production factors in agro-industrial crops.

## Fund

This study was carried out in a PhD project: "Implementation of Reclamation Techniques in Agricultural Stony Soils for the Optimization of Precision Farming Systems". On 35° PhD course: Engineering for Energy and Environment. Dept. DEIM-DAFNE, University of Tuscia, Viterbo (Italy), and funded by the Italian Ministry of Agriculture (MIPAAF) under the AgriDigit program, DDL n. 2111-B/2015.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

## References

American Society of Agronomy (ASA) (1989). *Decision Reached on Sustainable Agricul-*

*ture*. Agronomy News, January, 15, ASA.

Bongiovanni, R., & Lowenberg-Deboer, J. (2004). Precision Agriculture and Sustainability. *Precision Agriculture, 5,* 359-387. https://doi.org/10.1023/b:prag.0000040806.39604.aa

Brambilla, M., Romano, E., Toscano, P., Cutini, M., Biocca, M., Ferré, C. et al. (2021). From Conventional to Precision Fertilization: A Case Study on the Transition for a Small-Medium Farm. *AgriEngineering, 3,* 438-446. https://doi.org/10.3390/agriengineering3020029

Brockotter, F., & McCullough, C. (2022). *Net Zero Doesn't Cut It. All about Feed.* https://www.allaboutfeed.net/market/market-trends/net-zero-doesnt-cut-it-2/

Buchter, B., Hinz, C., & Flühler, H. (1994). Sample Size for Determination of Coarse Fragment Content in a Stony Soil. *Geoderma, 63,* 265-275. https://doi.org/10.1016/0016-7061(94)90068-x

Codevintec (2004). https://www.codevintec.it/media/strumentiPdf/gs-2004-utilityscan-eng-lo_KILux_it.pdf

Colzani, G., Cammilli, A., & Pirrone, S. (1989a) Stato di Pietrosità dei Terreni e Lavorazioni Agricole. *L'Informatore Agrario, 42,* 61-64.

Colzani, G., Cammilli, A., & Pirrone, S. (1989b). Spietramento dei terreni Agricoli. Seconda Parte. Grado di Disturbo alla Lavorabilità dei Terreni Pietrosi. *L'Informatore Agrario, 44,* 39-43.

Colzani, G., Cammilli, A., & Pirrone, S. (1989c). Spietramento Dei Terreni Agricoli: Prestazioni di Cinque Macchine Spietratrici. *L'Informatore Agrario, 50,* 33-37.

Corti, G., Ugolini, F. C., & Agnelli, A. (1998). Classing the Soil Skeleton (Greater than Two Millimeters): Proposed Approach and Procedure. *Soil Science Society of America Journal, 62,* 1620-1629. https://doi.org/10.2136/sssaj1998.03615995006200060020x

Dayioğlu, M. A., & Turker, U. (2021). Digital Transformation for Sustainable Future—Agriculture 4.0: A Review. *Journal of Agricultural Sciences, 27,* 373-399. https://doi.org/10.15832/ankutbd.986431

FAO (2010). *Conservation Agriculture: Conserving Resources above and below the Ground.* Food and Agriculture Organization (FAO) of the United Nations. http://www.un.org/esa/sustdev/csd/csd16/documents/fao_factsheet/conservation.pdf

FAO (2021). *Looking at Edible Insects from a Food Safety Perspective. Challenges and Opportunities for the Sector.* Rome. https://doi.org/10.4060/cb4094en

Flint, A. L., & Childs, S. (1994). Ch. 10. Physical Properties of Rock Fragments and Their Effect on Available Water in Skeletal Soils. In J. D. Nichols, P. L. Brown, & W. J. Grant (Eds.), *Erosion and Productivity of Soils Containing Rock Fragments* (Vol. 13, pp. 91-103). John Wiley & Sons.

Global Hunger Index (2021). https://www.globalhungerindex.org/pdf/it/2021.pdf

Gruber, K. (2016). Rodent Meat—A Sustainable Way to Feed the World? Using Rodents as Food Has a Long Tradition in Many Parts of the World. *EMBO Reports, 17,* 630-633. https://doi.org/10.15252/embr.201642306

Kirchmann, H., & Thorvaldsson, G. (2000). Challenging Targets for Future Agriculture. *European Journal of Agronomy, 12,* 145-161. https://doi.org/10.1016/s1161-0301(99)00053-2

Klein, A. (2019). Would You Eat Insects to Help Save the Planet? These Companies Are Betting Yes. *The Washington Post.* https://www.washingtonpost.com/lifestyle/2019/01/09/would-you-toss-roasted-insectsinto-yourmeal-this-health-app-is-betting-yes/

Magdoff, F., & Van Es, H. (2021). *Building Soils for Better Crops. Sustainable Soil Management*. IV Ed, Sustainable Agriculture Research and Education (SARE) Program, National Institute of Food and Agriculture. https://www.sare.org/wp-content/uploads/Building-Soils-for-Better-Crops.pdf

Miller, F. T., & Guthrie, R. L. (1984). Classification and Distribution of Soils Containing Rock Fragments in the United States. In J. D. Nichols, P. L. Brown, & W. J. Grant (Eds.), *Erosion and Productivity of Soils Containing Rock Fragments* (pp. 1-6). Soil Science Society of America, Special Publication No. 13.

Murakami Farm (2021). *Super Sprout Factory*. https://www.designboom.com/technology/super-sprout-factory-murakami-farm-japan-02-23-2021/

Poesen, J., & Lavee, H. (1994). Rock Fragments in Top Soils: Significance and Processes. *Catena, 23,* 1-28. https://doi.org/10.1016/0341-8162(94)90050-7

Research and Markets (2019). *Globe Newswire: $7.95 Billion Edible Insects Market: Global Forecast to 2030*. https://www.globenewswire.com/news-release/2019/04/01/1790970/0/en/7-95-Billion-Edible-Insects-Market-Global-Forecast-to-2030.html

Tey, Y. S., & Brindal, M. (2012). Factors Influencing the Adoption of Precision Agricultural Technologies: A Review for Policy Implications. *Precision Agriculture, 13,* 713-730. https://doi.org/10.1007/s11119-012-9273-6

Toscano, P., Brambilla, M., Cutini, M., & Bisaglia, C. (2022a). The Stony Soils Reclamation Systems in Agricultural Lands: A Review. *Agricultural Sciences, 13,* 500-519. https://doi.org/10.4236/as.2022.134034

Toscano, P., Cutini, M., Cabassi, G., Pricca, N., Romano, E., & Bisaglia, C. (2022b). Assessment of a Deep Burial Destoning System of Agrarian Soils Alternative to the Stone Removal and On-Site Crushing. *AgriEngineering, 4,* 156-170. https://doi.org/10.3390/agriengineering4010011

Toscano, P., Cutini, M., Filisetti, A., Premoli, E., Porcu, M., Catalano, N. et al. (2022c). Workability Assessment of Different Stony Soils by Soil-Planter Interface Noise and Acceleration Measurement. *AgriEngineering, 4,* 1139-1152. https://doi.org/10.3390/agriengineering4040070

Ugolini, F. C., Corti, G., Agnelli, A., & Piccardi, F. (1996). Mineralogical, Physical, and Chemical Properties of Rock Fragments in Soil. *Soil Science, 161,* 521-542. https://doi.org/10.1097/00010694-199608000-00007

USDA (1999). *Soil Survey Staff, Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys* (2nd ed.). Agriculture Handbook, No. 436. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051232.pdf