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Multi-Criteria Analysis of Investment Choices Following Flood Damage: The Case Study of Sustainable Citrus Farming in Sicily

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Abstract: Current climate change is confronting farms with extreme conditions, with severe drought for a good part of the year and flooding rains for a month. The changes taking place on our planet make it necessary for farmers to understand and assess how they can counteract the damage of climate change by adopting sustainable strategies to cope with the future. This makes environmental, economic and social sustainability more relevant than ever in the production sector. The research, in relation to the spread of exceptional conditions, which cause damage and extraordinary changes in the production system of farmers, aims to define a sustainable assessment model by evaluating the three pillars of sustainability. The proposed methodology, which is based on participatory planning of investment choice, starts from the assumption that the application of methodologies regarding the choice of investment projects must be placed in a broader context than just economic evaluation, including all dimensions of sustainability. Through the involvement of industry stakeholders, it emerged that the implementation of drastic measures is the long-term optimal choice.

Keywords: citrus; innovation; sustainability; economy; environment

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1. Introduction

The definition of an investment programme to be implemented on a farm following flood damage involves the selection of a group of project alternatives [1], not understood as any technical–economic proposal schematised by an investment flow. It is intended to modify the environment and the socio-economic context in which it will be implemented, in accordance with the needs and constraints of the system, capable of pursuing the objectives of the farm's entrepreneurial project [2]. Projects are chosen either by public intervention measures or by the farm's decision [1]. The structural peculiarity of the objectives in the two scenarios will certainly lead to the project initiatives being considered from different perspectives [3]. Different effects are generated on the spatial and temporal horizon of the analyses, on the criteria to be adopted for the identification and measurement of results, on the parameters and assumptions to be used as a basis for evaluations [4]. Reference can be made to economic–financial evaluations, if the impact of the interventions can be translated into financial terms, or to multi-criteria analyses, when it seems far-sighted not to apply the monetary criterion alone, as the objectives are multiple, heterogeneous, and conflicting [5].

The two types of evaluation must be implemented in succession, as is the case when the results of economic and financial analysis are insufficient for project examination and multicriteria analysis is also necessary. In order to avoid this approach, the research, from a methodological point of view, acts exactly the opposite, favouring multi-criteria analysis that, through participatory planning, evaluates the optimal choices to be made, through the active involvement of the sector's stakeholders. In this way, the final evaluation that the company implements assumes a significance as a strategy to be implemented by companies in the sector affected by events of this kind. Multidimensional evaluations transform the heterogeneous aspects of different solutions and implementation strategies based on logical schemes that highlight their advantages and disadvantages in relation to predetermined objectives [6]. An evaluation criterion is identified for each objective, resulting in a multiplicity of criteria. Overall, the result of the multicriteria analysis is a qualitative-quantitative profile [7]. In essence, the basic assumption of future evaluation methodologies and techniques is that the analysis and selection of investment projects must be placed in a broader context than just economic evaluation. Given the prominent role that sustainability, in its economic, environmental, and social dimensions, plays in the production process, the restoration of phytosanitary damage resulting from climate change is an issue that should be addressed with this approach. If this aspect is not taken into account, the analysis cannot be conducted satisfactorily, because the sustainability-based selection criteria, which are a function of the farm's objectives and medium- and long-term strategy, are missing.

The objective of this paper is to show how the supporting method with multicriteria analysis (MCA) [7] can be effectively applied to the agricultural sector in order to determine optimal sustainable planning strategies for farms, combined with economic evaluation. Understanding this is of paramount importance in the current climate change context to make the sector resilient to the damage it causes. The method represents a novelty in the field of multi-objective optimisation, as it follows completely different schemes from those used in classical multi-objective methods [8]. The Decision Maker (DM), through a simple and transparent interaction process with the analyst based on decision rules, selects the solution that expresses his preferences. Moreover, with this approach, the environmental aspects of sustainable planning can be automatically introduced into farm management [9]. In farm governance, it is essential to consider multiple objectives to achieve optimal planning and management results. These objectives must consider not only the economic aspects of the farmer's profitability, but also protection, environmental sustainability, plant longevity and plant health status [10]. Indeed, sustainability is one of the most important concerns of the European Union [11,12], and in the context of EU agricultural policy, farmers must comply with important requirements related to environmental conservation [13] and pollution control (e.g., environmental cross-compliance standards, EU Reg. 2009 No. 73). For this reason, the decisions a farmer must make to manage their farm are becoming increasingly complex [14].

The general framework of multicriteria analysis may be quite suitable for application in the field of business management, due to its characteristics of simplicity and transparency, compared to classical optimisation methods [15,16]. In the context of Italian scientific research, several applications of classical multi-objective optimisation have been made in the agricultural sector since the early 1990s, after a long previous period in which business planning was essentially based on maximising the economic income of the farm as the only goal to be achieved. Some examples of this type of application, aimed at representing the complex structure of farms and thus considering multiple goals of the farmer, can be found in Weighted Goal Programming (WGP) [17,18]. Some researchers have used the WGP method, in which there is a single function, composed of multiple objectives, which in that case concerned: the minimisation of costs, soil pollution by fertilisers and pesticides, environmental impact; the rationalisation of irrigation water and reduction of risk of manual labor, tending to the model proposed in this work. To validate the evaluation model, MCA analysis was applied to a case study of an agricultural investment following flood damage in Sicily, with the ultimate goal of determining an optimal planning strategy, reconciling economic, socio-environmental, and phytosanitary objectives, as well as economic evaluation through partial financial statements.

2. Materials and Methods

2.1. Overview of Citrus Farming and the Main Investment needs Resulting from Structural Damage

Citrus farming area and production in the last 20 years have tended to grow every year, with a volume of citrus fruits produced globally in the 4-year period 2017/2020 of 133 million tonnes [19], an increase of 19% in the last decade (Figure 1). In this context, Italian citrus farming, with almost 2.8 million tonnes of production (2017/2020) and a steadily decreasing invested area of 132,000 hectares [20], reveals a dichotomous situation: on the one hand, citrus farming that is not economically viable, and on the other, efficient citrus farming with production models that tend towards quality (PGI/PDO) and sustainability (organic farming) [12,21].

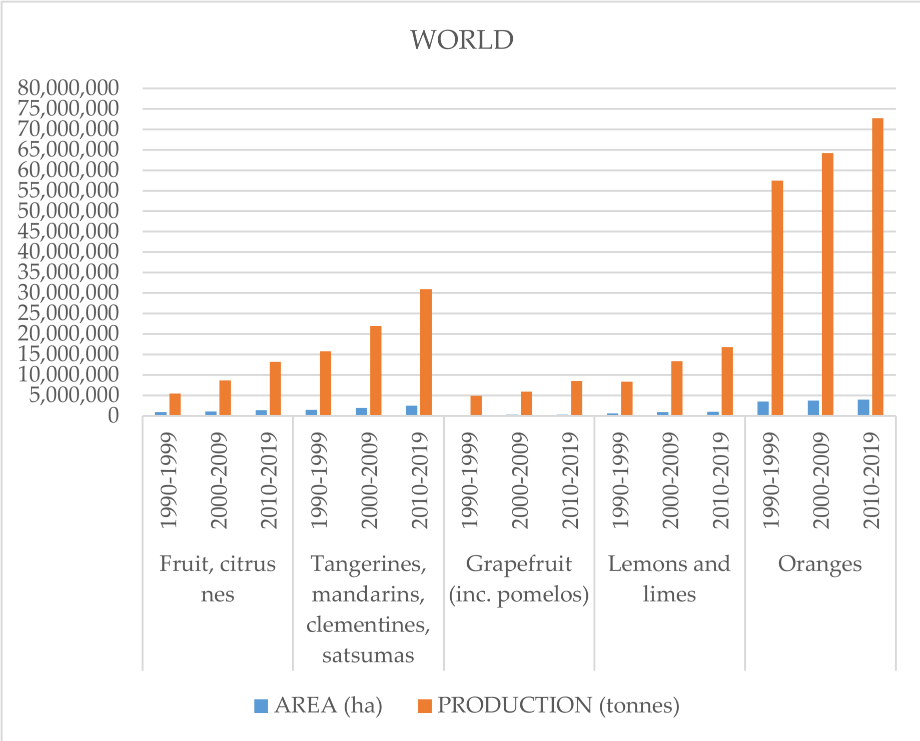

Figure 1. World citrus production per species (*). (*) our elaboration on FAO data.

Investments in Italian citrus farming have decreased from about 182,000 hectares in 1990 to about 132,000 hectares, a drop of over 27% [22]. The evolution of socio-economic systems, climate change, the globalisation of markets, and significant asymmetries in supply chain costs between countries at different stages of development have all contributed to a review of the balance along the supply chain [22–24].

The market situation is exacerbated by the spread of pathological phenomena such as the 'Tristeza virus' and the increasingly widespread presence of diseases resulting from unusual weather patterns that generate hot summers, flooding rains, hail, and a change in the climate of citrus production areas [12,25].

Extreme climatic events, such as flooding rains, have been identified together with summer drought as the main threats to Italian citrus cultivation. This requires the constant intervention of the public institution, which must increasingly intervene to support the damaged farms, to structurally restore the plants as well as to define a course of action for the citrus sector.

Climate change is generating natural disasters that must be considered in an overall management plan for an investment, specifically a citrus grove. From this starting point, the research tends to evaluate different investment hypotheses for sustainability considering the economic, environmental and social scenario that will increasingly characterise agri-food production in the future [26]. The model was applied to a real-life case study of a farm that suffered surface water flooding as a result of the 2018 flood rains in the province of Syracuse (Italy), with differential manifestations of diseases that partially compromised productivity.

2.2. Climate Change and Agricultural Production

Climate change is shaping our productive reality and will only intensify in the future [27]. The frequency of periods of heavy rainfall and flooding will increase further and we will adapt to warmer winters and dry summers [28]. This early evidence of climate change is unevenly recognised at the political level in different parts of the world. It is committed to limiting the global temperature increase below 2 °C compared to pre-industrial levels in order to contain climate change at a manageable level and reduce the likelihood of irreversible ecosystem disruptions [29] (Figure 2).

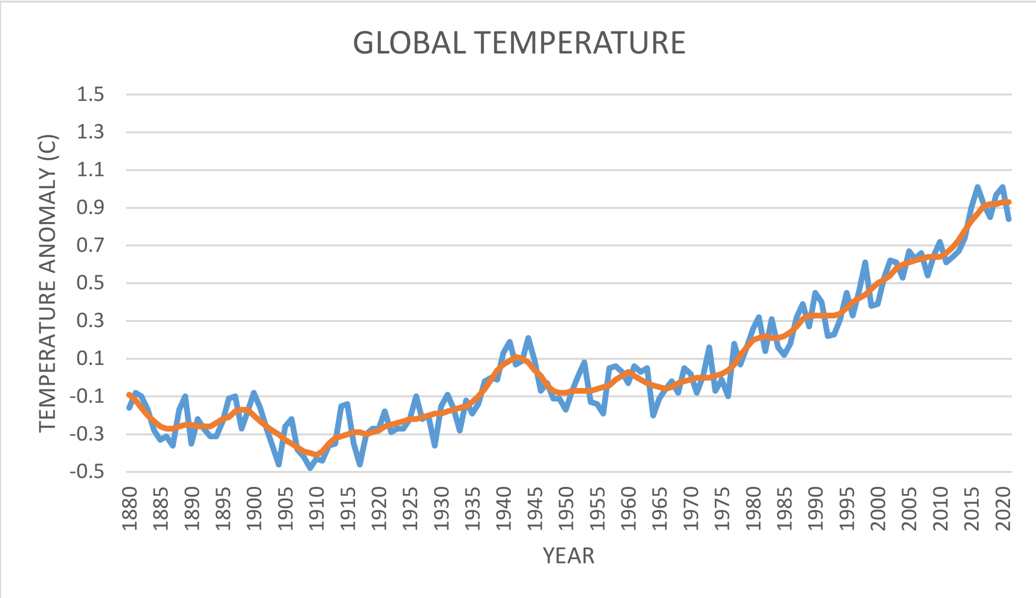

Figure 2. Average global surface temperature (1880–2020); Source: our elaboration on climate nasa gov. data.

However, mitigation cannot be the only answer to climate change and we will have to learn to live with a changed climate. At European level, the need to address adaptation to climate change has recently been recognised and this has led to the European Commission's work on this topic in the "European Green Deal" [30].

This NASA climate centre graph shows the global average surface temperature over the period 1880–2018. After 1940, there was a sharp increase in temperature for a duration of 2 years, and then a continuous increase in temperature after 1980–2016. Researchers believe that the global temperature will continue to rise in the coming decades, mainly due to man-made greenhouse gases. The IPCC (Intergovernmental Panel on Climate Change) predicts an increase of 2.5–9.7 °F over the next century [31], with the future scenario illustrated in Figure 3 where we anticipate what we are beginning to detect: high droughts contrasted with monsoon rains in short periods that our production models are not prepared to withstand.

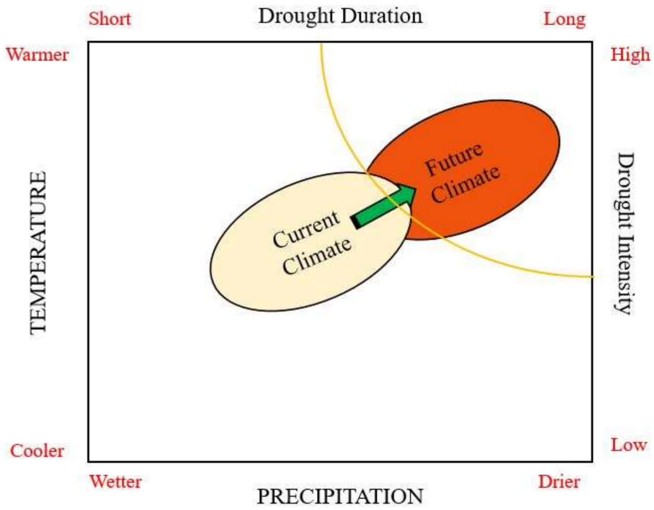

Figure 3. Climate variables, temperature and precipitation in future scenarios; Source: our elaboration on IPCC data.

In relation to what we are witnessing, it is necessary to define appropriate adaptation strategies by quantifying their costs and benefits. Costs are given by the monetary value of works, initiatives and policies that produce adaptation to climate change [28]. Benefits are defined by the amount of climate change damage that could be avoided through adaptation. In order to assess the benefits of an adaptation strategy, it is therefore necessary to know the value of the total damage caused by climate change, also known as the cost of inaction, and how much of this damage can be avoided through the adaptation strategy [32,33].

2.3. Methodology

Methodologically, in assessing the various economic, social, and phytosanitary parameters, a multi-criteria analysis was carried out, submitting the case study to various stakeholders in the sector. For the multi-criteria analysis, the NAIADE method was used [34], in which the three hypotheses of the project strategy were derived as a response to citrus grove damage from the flood rains. For the multi-criteria analysis, both quantitative and qualitative data provided by stakeholders, expressed during the evaluation phase of alternative planning development scenarios, were used.

The proposed model is based on: definition of the assessment context, i.e., the decision criteria; assessment of the impact of alternative scenarios in relation to these criteria; and the final creation of the impact matrix.

The methodology proposed for the analysis of the case study has never been applied to evaluations concerning specific investments, but it was chosen to apply it because it does not only refer to economic parameters and represents an evaluation and operational indication by the stakeholders of the sector in the event of damage resulting from ongoing climate change. From a methodological point of view, a multi-criteria analysis was carried out to assess the various economic, social and phytosanitary parameters, submitting the case study to various stakeholders in the sector. For the multi-criteria analysis, the NAIADE method [34] was used, in which the three project strategy hypotheses were derived as a response to the damage suffered by citrus groves as a result of the flood rains. For the multi-criteria analysis, the quantitative and qualitative data provided by stakeholders, expressed during the evaluation phase of the alternative planning development scenarios, were used.

The proposed model is based on:

Definition of the assessment context, i.e., the decision-making criteria, assessment of the impact of the alternative scenarios in relation to these criteria, and final creation of the impact matrix;

The use of focus groups as a social research methodology, aimed at acquiring information on stakeholder opinions with respect to a set of scenarios to be implemented for farm damage restoration. This is used to provide the evaluation phase of the planning activity with information on different interests with the creation of the equity matrix.

The impact and equity matrices are the basis for the use of the discrete multi-criteria evaluation model, which is able to handle qualitative and quantitative data to evaluate intervention measures. This tool supports: the ranking of the proposed alternative scenarios according to certain decision criteria and the consideration of possible "alliances" and "conflicts" between stakeholder groups regarding the proposed scenarios by measuring their acceptability.

The entire process was divided into three phases, referring in the specific case to citrus fruits with damage resulting from phenomena generated by climate change and specifically by flood rains:

Phase 1 involves the 'planning' of the meetings. During this phase, the following were established the number of sessions and the time devoted to each of them (8, as an expression of the individual categories considered, varying from 4 to 8 h); the selection of participants (stratified selection); the creation of an interview guide to lead the discussion (scientific and popular material on climate change issues, related damages, and flood events).

Phase 2 involves conducting the entire activity, based on the pre-determined interview guide. It starts with the presentation of the action strategy for the management of surface flood damage, using supporting material (documents, results, photographs), specially prepared to introduce the topic under consideration and stimulate discussion and interaction between the participants. During this phase, a variety of ideas and opinions were acquired, representing the feedback from the participants.

Phase 3 involves the processing of the 'qualitative results' and the production of the final report. In this context, various qualitative analysis tools, based on intentionally prepared input and specific rules, proved useful. Overall, focus groups can be considered as social experiments, capable of producing collective opinions, revealing communication barriers, studying conflictual behaviour, acquiring local information, creating acceptable options, synthesising information, etc. [35].

The advantage of the focus group in defining intervention strategies lies in the profound interaction between participants, which highlights its role as a fundamental tool to support a "mutual learning process" [36]. This allows new dimensions of the topic under investigation to emerge, thereby emphasising the participants' ability to produce results. In particular, the analysis aims to rank alternative scenarios on the basis of their performance against certain decision criteria.

The basic input of the NAIADE method is the impact matrix (criteria/alternative matrix), composed of scores that can take the following forms: crunch numbers, stochastic elements, fuzzy elements, and linguistic elements (such as 'good', 'average', etc.) [37]. To compare alternative scenarios, the concept of distance is introduced. In the presence of crisp numbers, the distance between two alternative scenarios with respect to a given evaluation criterion is calculated by subtracting the respective crisp numbers. In any other case, the concept of semantic distance was used, measuring the distance between two functions by which the scores of the alternative scenarios are expressed [37].

The ranking of alternative scenarios was based on data from the impact matrix, which was used for:

Comparison of each individual pair of alternatives for all evaluation criteria considered;

Determination of a credibility index for each of the above comparisons, which measures the credibility of a preference relation " … alternative scenario a is better/worse, etc. than alternative scenario b ";

Aggregation of the credibility indices produced during the previous stage resulting in an intensity index of the preference $\mu^*(a,b)$ of an alternative "a" over another "b" for all evaluation criteria, associated with the concept of entropy $H^*(a,b)$, as an indication of the variation of the credibility indices;

Classification of alternative scenarios on the basis of the above information.

The intensity index μ*(a,b) of preference * (where * stands for >>,>,≅,=,<< and <) of alternative a versus b is defined by the equation [34,38]:

$$\mu*(\mathrm{a,b}) = \frac{\sum_{m=1}^{M} \max(\mu*(\mathrm{a,b})_m - \alpha, 0)}{\sum_{m=1}^{M} \max \mid \mu*(\mathrm{a,b})_m - \alpha \mid} \quad (1)$$

The intensity index μ*(a,b) has the following characteristics:

≤ μ*(a,b) ≤1;

μ*(a,b) = 0 if none of the μ*(a,b)_m are more than α;

μ*(a,b) = 1 if μ*(a,b)_m ≥ α ∀ m and μ*(a,b)_m > α for at least one criterion.

The information provided by the preference intensity index μ*(a,b) and by the corresponding entropies H*(a,b) can be used to construct the degrees of truth (F) of the following statements:

a is better than b;

a and b are the same;

a is worse than b.

The final classification of alternatives was the result (intersection) of two different classifications: the Φ+(a) classification based on the preference relations "better" and "significantly better"; and the Φ-(a) classification based on the preference relations "worse" and "significantly worse".

According to Munda [34,38], the first Φ+(a) is based on the better and much better preference relations, and a value from 0 to 1 indicates how a is "better" than all other alternatives. The second Φ-(a) is based on the worse and much worse preference relations, its value going from 0 to 1, which indicates how a is "worse" than all other alternatives.

Φ+(a) and Φ-(a) are expressed by the following equations:

$$\Phi + (\mathrm{a}) = \frac{\sum_{n=1}^{N-1}\left(\mu_{\gg}(a,n)\,\hat{}\,C_{\gg}(a,n) + \mu_{>}(a,n)\hat{}C_{>}(a,n)\right)}{\sum_{n=1}^{N-1} C_{\gg}(a,n) + \sum_{n=1}^{N-1} C_{>}(a,n))} \quad (2)$$

$$\Phi - (\mathrm{a}) = \frac{\sum_{n=1}^{N-1}\left(\mu_{\ll}(b,n)\,\hat{}\,C_{\ll}(b,n) + \mu_{<}(b,n)\hat{}C_{<}(b,n)\right)}{\sum_{n=1}^{N-1} C_{\ll}(b,n) + \sum_{n=1}^{N-1} C_{<}(b,n))} \quad (3)$$

where N is the number of alternatives (n) and the ˆ operator can again be chosen between the minimum operator, which gives no compensation, and the Zimmermann–Zysno operator, which allows for varying degrees of compensation (from 0 minimum compensation to 1 maximum compensation).

In relation to the objective of this study, the principal priority analysis was applied to define the optimal management model for flood damage resulting from climate change in our context. The stakeholders involved in the focus group were in quantitative terms: producers (4), cooperatives (2), commercial operators (2), processing industries (2), trade unions (2), institutions (2), scientific groups (1), and service sector operators (2). For each of the groups mentioned, seven actors were identified, according to the NAIADE methodology.

Having defined the methodological framework, the next step was the economic assessment of the strategies to be implemented to restore the damage resulting from the flooding. The application area was the municipality of Lentini, in the province of Siracusa (Italy), identified for its high citrus growing vocation and for the frequent damage caused by flooding of the land following the overflowing of the rivers in the area.

Specifically, the case study is characterised by the possible implementation of three action hypotheses, as assessed in the multi-criteria analysis:

Total grubbing-up of the entire plot and its replanting;

Partial grubbing-up of 40% of the area with retention of plants with good vegetative and productive vigour;

Maintenance of the citrus grove in its post-flood state.

From a methodological perspective, in hypothesis "a" a total eradication would be carried out, with hydraulic-agricultural systems including the creation of raised ground bed where the plant would be placed in order to avoid damage from waterlogging due to future flooding, drip irrigation systems in order to optimise water availability and reduce waste, the application of innovative techniques deriving from the "agriculture 4.0" strategy (digitalisation of the process control). In the second hypothesis, it is foreseen to uproot and replant the plants with current and evident phytopathological phenomena deriving from the flooding, estimated at about 40% of the total. It should be noted that plants with obvious symptoms are either scattered or concentrated in parts of the individual plots concerned. Aware that the rest of the plants have a non-normal, albeit satisfactory, vegetative habitus, a curative prophylaxis will be applied to restore the normal, pre-damage productive status. In this second hypothesis, even if 40% of the plants are uprooted, there will be no change in the hydraulic-agricultural systems (raise ground bed), nor in the irrigation system and the management of the plot due to the presence of structural elements that do not allow the diffusion of agriculture 4.0. The third hypothesis is the maintenance of post-flood plants by implementing strategies aimed at restoring the productive vegetation habitus to try to re-establish the normal productive status before the damage.

Reference is made to Serpieri's agrarian economic assessment [39] for the analysis of the economic methodology used, using the Partial Balance Sheets' for each year [15]. The evaluation period considered was 10 years, to have a proper evaluation of the three hypotheses [40–43].

The methodology was applied using both data provided by the farm and data in our possession from other case studies of citrus groves in the same production area. In relation to the above economic data, it was therefore decided to use Gross Income (GI) as an indicator, obtained from the difference between Gross Saleable Production (GSP) and variable costs. The choice of calculating only variable costs and not fixed costs stems from the fact that it avoids partial allocations, which are difficult to apply in the farm's total budget, as it has additional surface areas. The following economic indicators were assessed and estimated: pre-damage GSP, post-damage GSP, post-investment GSP, variable operating costs (VC), and costs necessary for restoration and replanting, from which Gross Income (GI) is determined [44–46].

3. Results

The multicriteria analysis was conducted based on a specific question:

What is the sustainable investment to be implemented in the event of flood damage in a citrus grove, in relation to current climate change, taking into account economic, environmental, and phytosanitary aspects?

Three scenarios are considered:

Hypothesis 1: *eradication and replanting of the full area.*

Hypothesis 2: *partial eradication with partial replanting.*

Hypothesis 3: *maintenance of the citrus grove.*

To evaluate the above three hypotheses, evaluation criteria were defined, which represent " . . . a measurable aspect of the evaluation that can characterise one dimension of the different options considered" [7]. In total, 16 evaluation criteria defined in the methodology were used in this study. These were defined based on the evaluation goals and objectives of the context analysed, which can be considered representative of the Sicilian citrus sector.

The objectives of the evaluation activity are economic, socio-environmental, and phytosanitary.

Specifically, the relative evaluation criteria considered for each objective are reported:

(a) Economic goal: Production, Prices, Gross Saleable Production (GSP), Variable Production Costs, Production Costs, Gross Income, Net Income, Productivity in the presence of damage, Cost of the action strategy to support the affected citrus groves;
(b) Socio-environmental goal: Number of employees, Labour risk, Degrees of activity;
(c) Phytosanitary goal: disease detection, definition of the citrus orchard's useful life, disease management.

During the focus group discussion, individual members were asked to rate the three scenarios under the different evaluation criteria.

Based on the above indicators, the results of the impact matrix leads to the following findings (Table 1):

Table 1. Results evaluation from the impact matrix of the different alternatives (*).

Evaluation Criteria	Hypothesis 1	Hypothesis 2	Hypothesis 3
Economic	Excellent	Good	Poor
Social	Good	Very good	Very good
Phytosanitary	Excellent	Good	Poor

(*) our elaboration.

Hypothesis 1, as an option to be shared, (emphasis on economic and phytosanitary results), was followed by Hypothesis 2 (emphasis on economic and social stability) and lastly Hypothesis 3 (negative evaluation in general except for high employment generating interventions, at the same time not economically viable). Next, the equity matrix was created, expressing the views of the stakeholders, divided into groups on the three proposed hypotheses. The selection of stakeholders was based on their potential to influence the aims and objectives pursued and their role in different segments of the citrus supply chain relating to both the private and public sectors. In particular, eight types of stakeholders were involved: producers, cooperatives, traders, processors, trade unions, institutions, scientific groups, and companies in the tertiary sector (Table 2). It should be emphasised that stakeholder opinions in the multi-criteria model can only be of a qualitative nature (linguistic expressions ranging from less than poor, to poor, medium, good, very good, excellent).

Table 2. Evaluation of impact matrix results of different alternatives (*).

Stakeholder Groups/Scenarios	Hypothesis 1	Hypothesis 2	Hypothesis 3
Producers	Excellent	Good	Good
Cooperatives	Excellent	Good	Poor
Traders	Excellent	Poor	Poor
Processing industries	Good	Very good	Excellent
Trade Unions	Very good	Very good	Good
Istitutions	Very good	Medium	Good
Scientific groups	Excellent	Poor	Poor
Tertiary companies	Excellent	Medium	Good

(*) our elaboration.

The results expressed in Table 3 present the values for the ranking of scenarios at the highest level of consensus. These results show that a considerable group of stakeholders, in addition to agreeing on the ranking of the different application hypotheses, converge for Hypothesis 1.

Table 3. Stakeholder classification of the three hypotheses, impact matrix of different alternatives (*).

Evaluation Criteria	Hypothesis 1	Hypothesis 2	Hypothesis 3
Economic	***0.79***	***0.67***	***0.56***
Production	0.91	0.72	0.54
Prices	0.84	0.52	0.45
GSP	0.87	0.62	0.49
Variable production costs (VC)	0.87	0.74	0.61
Total production costs	0.82	0.69	0.57
Gross income	0.92	0.79	0.51
Net income	0.81	0.77	0.63
Project costs	0.31	0.57	0.75
Social	***0.64***	***0.53***	***0.50***
Employees	0.71	0.51	0.52
Work specialisation	0.87	0.52	0.39
Activity levels	0.34	0.58	0.61
Sustainable use of irrigation	0.93	0.56	0.47
Phytosanitary	***0.90***	***0.48***	***0.36***
Absence of root diseases	0.94	0.39	0.35
Fewer plant protection measures	0.87	0.69	0.38
Useful life of the citrus grove in relation to diseases	0.91	0.38	0.34
Quality of production	0.89	0.47	0.38

Notes: Evaluation grid—1 = maximum, 0 = minimum; (*) our elaboration.

Analysing the data per evaluation criterion, values from 0 (minimum) to 1 (maximum) are reported in relation to the answers obtained from the various interviewees. Overall, there are more positive values for Hypothesis 1, while Hypotheses 2 and 3 show differing results depending on the criteria assessed, with different values in relation to the parameters considered. The above values represent the average of the evaluations expressed by the individual focus group members. As far as the economic aspects are concerned, it is clear that majority of stakeholders assess positively the production, prices and GSP of hypothesis 1, in relation to the potential production of the new plants, the higher prices, and therefore the potential GSP that the plants may have. As far as costs are concerned, Hypothesis 1 is also preferred, in relation to the optimisation of production processes that can be achieved with the new plants. Looking at the incomes of the three proposed scenarios, Hypothesis 1 definitely prevails, more so for the gross incomes, and less for the net incomes due to the depreciation that the farm will have to bear. A negative assessment is given in relation to the costs of the project as it is known that in the absence of compensatory public intervention the cost of replanting appears to be a limit for Hypothesis 1, taking a positive value in the case of Hypothesis 3 of maintenance, despite the phytosanitary costs and the uncertainty of the result. Analysing the items relating to social aspects, it can be seen that, overall, Hypothesis 1 prevails, although there is little difference with the other two hypotheses.

Regarding the analysis of economic data from the preparation of partial budgets according to the Serpieri method [47], in order to analyse only the variable costs arising from the plot under analysis, for each reference year, it was decided not to actualise the results in order to make a comparison on the basis of the nominal value of the three hypotheses, since these are forecast budgets [48]. For the analysis of the first hypothesis, the data obtained from a case study under observation, concerning a 12-year-old citrus orchard, were applied, considering the economic data from planting to the 10th year of ripening, the average prices of quality productions in the area, and the average variable costs obtained from the case study. With regard to the latter, since these are partial budgets, it was decided to apply variable costs and not total costs, as the implications of other farm operating costs would be misleading; moreover, gross incomes in this specific case are explanatory of the economic results for the individual plot. For restoration, grubbing and replanting costs, standard citrus planting costs were applied, with a linear annual breakdown over the 10 years of evaluation. The results are negative for the first few years, related to the lack of production, and decrease over time until a positive result is reached from the 5th year of young plants. Overall, the economic results, compared to the other two hypotheses "b" and "c," have positive margins of evaluation, both from an economic point of view, in relation to the gross income obtained in the 10th year, and because of the greater sustainability in terms of production costs, water savings, and increased competitiveness in the relevant economic system (Table 4).

Table 4. Scenarios "a" total grubbing up (*).

Year	1	2	3	4	5	6	7	8	9	10
Production	0	0	1000	4000	20,000	30,000	40,000	40,000	40,000	40,000
Prices	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
GSP	0	0	500	2000	10,000	15,000	20,000	20,000	20,000	20,000
Variable costs	3175	3493	3810	4128	4445	4763	4763	4763	4763	4763
Gross income without reinstatement costs	−3175	−3493	−3310	−2128	5554	10,236	15,236	15,236	15,236	15,236
Standard plant costs over 10 years	1215	1215	1215	1215	1215	1215	1215	1215	1215	1215
Gross income	−4391	−4708	−4526	−3343	4338	9021	14,021	14021	14,021	14,021

(*) our elaboration.

The analysis of the economic results for hypothesis "b" (Table 5) with the partial grubbing up, maintaining about 60% of the plants, shows an advantage in terms of economic stability over time that leads, even from the first few years, to a positive gross income able to sustain the farm. In this case, the historical economic data of the farm were applied, estimating the growth over the years in relation to the plants replaced and the quality improvement of the fruit obtained from the young plants, in terms of potential selling price. In this case too, the restoration costs were distributed linearly over the 10 years of evaluation, while the costs were assessed as the sum of ordinary management costs and extraordinary management costs in relation to the phytosanitary (root damage) and structural (training pruning) interventions to be carried out on the plants retained in the plantation. The assessment at the end of the 10th year shows unsatisfactory economic results, since although it is sustainable in the short term from an economic point of view, in the long term it is not, due to both lower income and higher management costs, which would lead to a uneven-aged citrus grove with different water, nutrient, and plant health requirements, even though it is part of the same plot of land, as well as a different final useful life due to the different planting period, with economic results that are more than 50% lower than the first hypothesis.

Table 5. Scenarios "b" partial grubbing-up (40%) (*).

Year	1	2	3	4	5	6	7	8	9	10
Production	18,451	18,451	19,000	20,500	23,500	26,000	28,500	28,500	28,500	28,500
Prices	0.35	0.35	0.35	0.35	0.4	0.4	0.45	0.45	0.45	0.45
GSP	6457	6457	6650	7175	9400	10,400	12,825	12,825	12,825	12,825
Variable costs	6258	5006	5131	5319	5444	5507	5569	5632	5694	5757
Gross income without reinstatement costs	199	1451	1518	1855	3955	4892	7255	7192	7130	7067
Standard plant costs over 10 years	634	634	634	634	634	634	634	634	634	634
Gross income	−434	817.24	884	1221	3321	4258	6621	6558	6496	6433

(*) our elaboration.

As for the third hypothesis "c" (Table 6), maintenance of the damaged plant with evident plant pathological symptoms, there is a limited current and long-term economic sustainability, to be discarded as the plants, although green, are not in a normal productive condition. This situation would lead over the years to higher production costs compared to a similar citrus grove, for the necessary phytosanitary operations, with a relative production potential reduced by at least 30% due to the damage present both to the root system and to the epigeal apparatus. This situation is evident from the negative or slightly positive provisional balance sheet results. It should be noted that these results refer to gross incomes (GSP-VC), not taking into account all the rest of the farm's production costs, which would certainly lead to negative net incomes in Hypothesis 3, and perhaps just positive ones in Hypothesis 2.

Table 6. Scenarios "c" plant maintenance with damage (*).

Year	1	2	3	4	5	6	7	8	9	10
Production	18,451	18,451	18,651	18,851	20,451	21,451	22,451	22,451	22,451	22,451
Prices	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
GSP	6457	6457	6527	6597	7157	7507	7857	7857	7857	7857
Variable costs	6258	6258	6258	6258	6258	6258	6258	6258	6258	6258
Gross income without reinstatement costs	199	199	269	339	899	1249	1599	1599	1599	1599
Standard plant costs over 10 years	311	311	311	311	311	311	311	311	311	311
Gross income	−111	−111	−41	28	588	938	1288	1288	1288	1288

(*) our elaboration.

4. Discussion

These results show that a considerable number of the groups surveyed agree in the assessment of the three hypotheses. Specifically, the results of the multi-criteria analysis show that Hypothesis 1 "total uprooting" was the predominant one, followed by Hypothesis 2 (partial uprooting and replanting), while Hypothesis 3 (maintenance) is of marginal significance. It is clear that evaluations among stakeholders in the citrus fruit sector are quite different in relation to the various objectives they have. Specifically, while producers value total grubbing-up more highly (excellent), they also evaluate Hypotheses 2 and 3 positively in relation to its objective of maintaining production with a short-term strategy, without considering the advantages in terms of productivity, phytopathological risks, and reduced sustainability. Cooperatives and commercial operators have a different approach, with a more medium–long-term vision, preferring Hypothesis 1 and negatively evaluating Hypotheses 2 and 3, in relation to the higher-quality potential that could be obtained from the innovative plantings through total grubbing up. A totally opposite view is held by the processing industries, which prefer the production stability of Hypotheses 2 and 3, as well as a lower quality potential, which is essential to maintain their production activity. As for the other stakeholders considered, there is a clear positive assessment of Hypothesis 1 in relation to the potential expressed in terms of sustainability. The results obtained through the equity analysis were used to examine possible alliances and conflicts between stakeholder opinions on the definition of the assumptions to be adopted.

This result translates in a prevailing hypothesis regarding the sustainable use of the irrigation resource, and specialisation of the work appears weak for aspects related to the degrees of activity. Finally, the phytosanitary aspects assessed in the focus group confirm the clear preference for hypothesis 1 (total grubbing-up and replanting). During the comparison, it emerged that the plants almost unanimously showed higher-quality root systems due to the absence of root pathologies in relation to the arrangement with "raised ground bed". Hypothesis 2, for the majority of participants, presents a risk of current and future root pathologies, so even for the plants remaining in the plots affected by the damage, which have an almost normal vegetative vigour, the pathological risk of root death is high. This position results from the fact that individual plants will not be able to be treated differently from those remaining in the plot, generating excessive irrigation and nutrition for small plants and the difficult application of differentiated plant protection measures for the different needs of young and adult plants. The same applies to Hypothesis 3, where for many respondents the phytosanitary intervention will fail to restore the initial production potential. Regarding the useful life of the citrus grove, it is clear that all the participants declared an almost total convergence for Hypothesis 1, equating the valuations of the two remaining hypotheses, which for many are limited to 50% of the normal useful life that a citrus grove pre-damage would have had. Last but not least is the issue of production quality. Among the focus group members, Hypothesis 1 prevails while the maintenance of the plants (Hypotheses 2 and 3) would give rise to lower quality productions that would compromise the farm's future economic results, both for the limited commercial appreciation and for the lower quantity.

The analysis of the results as a whole leads to the assertion that the future of agricultural production in relation to ongoing climate change will be increasingly determined by the choices that the farmer will have to make in the long term, also considering the variables determined by exceptional events. The results made it possible to include multiple views of the valuation problem, increasing the perception of policy makers and individual entrepreneurs of the acceptability of proposed alternatives. This can lead to the improvement of strategic decisions and thus generate innovative ideas and new planning decisions using the possibilities offered by participatory approaches.

The challenge of the future therefore shifts from a sectoral to a holistic view where the evaluation of economic, environmental, and social parameters take equal importance in the choices [49].

The three hypotheses considered are characterised by the high degree of innovation and sustainability of the first hypothesis "a", which, however, presents the limitation of loss of income for the first years. The second hypothesis 'b' is characterised by having the objective of restoring what is most damaged, with the limits described above, since it would result in a citrus grove that is not aged and with differentiated needs, but which would allow part of the production to be maintained. Finally, the third hypothesis 'c' is characterised by the maintenance of the citrus grove in order to implement phytosanitary strategies aimed at regenerating the compromised root system to restore the epigeal apparatus.

The key assumption that emerges from the analysis is that, with hypotheses "b" and "c", citrus plants affected by flood damage continue to live with differentiated productive results, depending on the vigour of the plant, the state of the root and epigean pathologies and the cultivation techniques employed, which are not comparable to those of a normal-productive plant.

The second assumption is that the farmer's main source of income is the profit from his citrus grove, so without the prospect of an income in terms of both time (shorter life span) and money (lower income), he finds himself without a source of livelihood.

The third assumption is one that, even in the presence of ongoing climate change, is of strategic importance: to pursue environmental sustainability, applying where possible all the process and product innovations typical of modern citrus farming, all the more so in areas with a high hydrogeological risk, in order to reduce it and guarantee the entrepreneur's income.

5. Conclusions

Overall, the research has shown that multi-criteria analysis, in the case of damage resulting from climatic emergencies that give rise to phytosanitary problems, is a strategic tool for the economic, socio-environmental, and phytosanitary implications it entails. The specific operational implications evaluated in this work have shown that an 'ex-ante' evaluation allows a sustainable model to be proposed to the system, avoiding intervention strategies that are inadequate and short-sighted for the sector in question. The effectiveness of such an evaluation model lies in the possibility of creating a multi-disciplinary learning platform, which facilitates participation, exchange of information, and mutual understanding on the part of the participants who are guiding towards a spatial development strategy. The evaluation of the results obtained shows that Hypothesis 'a', with total grubbing-up and replanting, presents a higher level of preference, compared to Hypotheses 'b' and 'c', on the part of the stakeholders involved, for almost all the evaluation criteria, results that are also confirmed by the economic estimate, derived from the partial economic budgets.

The evaluation of the case study has highlighted the role of sustainability in the future choices that the entrepreneur will have to make in relation to the challenges dictated by the market (production costs, supply chain costs, consumer, etc.), the climate (flood rains, severe drought, frost, etc.) and the social emergency (world hunger, lack of agricultural labour, etc.) which will play a determining role.

The research therefore opens up an active debate on the future of investments in agriculture, which will have to contemplate the various scenarios in order to be able to fulfil its primary function, which is the production of foodstuffs, otherwise we will arrive at 2050 unable to provide the response that everyone expects. According to what has emerged, the strategy could be to change the productivist approach to a sustainable one with product and process innovations that will have to take into account the changes taking place, reviewing the balance between producer and consumer

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