Sandro Sacchelli,
Veronica Alampi Sottini

GESAAF – Department of Agricultural, Food and Forest Systems Management, University of Florence

E-mail: *sandro.sacchelli@unifi.it*
veronica.alampi@unifi.it

Keywords: *climate change, policy scenario, Fuzzy Cognitive Maps, evolutionary algorithm, nonlinear programming, wine chain, Tuscany region*

Mitigation of socio-economic damage due to climate change: a fuzzy cognitive map optimisation for the tuscan viticulture sector

Climate change is considered one of the main potential causes for socio-economic damages in viticulture in the future. The analysis of such systems has to be carried out adopting a methodology able to link different spatial and temporal variables, as well as evaluating the uncertainty related to climatic scenario. Thus, the Fuzzy Cognitive Map (FCM) approach was adopted to analyse potential viticulture trends under climate alteration in the Tuscany region (Italy). Best allocation of policy resources and incentives for mitigation of socio-economic impacts were tested through the application of nonlinear programming (NLP). Best policy scenario were depicted applying a multicriteria approach. Results highlighted the importance of regulation measures and the maintenance of quality brand.

Introduction

The concept of socio-economic damage related to climate change is mainly based on the evaluation of vulnerability, for which the damage is directly linked with climate change, and on the resilience that considers the expenses related to the mitigation of climate change effects (IPCC, 2007).

The influence of climate variability and the impact of climate change on the wine sector have been examined by different authors in several regions. The studies mainly focused on the modelling of vine productivity variation (Bindi et al., 1996; Holland and Smit, 2010; Schultz and Jones, 2010), on the impact on phenological activity (Schultz, 2000; Webb et al., 2007) and on the potential spread of pests and plant diseases (Jones et al., 2005; Stock et al., 2005; Caffarra et al., 2012). The results of the above mentioned studies are rather variable and appear to be region-specific. Other studies focused on the modification of distribution for a particular cultivar or on the maintenance of land suitability for viticulture under climate change (Schultz, 2000; Schultz and Jones, 2010; Fraga et al., 2012; Ruml et al., 2012). In this analysis, the results were more homogeneous, showing solutions like a shifting of the current adopted cultivar to cooler area and the potential introduction of vine varieties more resistant to drought. Modification in the structure of the wine chain and of the wine industry were examined in Hadarits et al. (2010) and Keller (2010). The perception of local stakeholders on the impact of climate change was verified in Battaglini et al. (2009), Hadarits et al. (2010) and

Alonso and O'Neill (2011). Bernetti et al. (2012) and De Salvo et al. (2013) focused on the economic damage due to climate change. In the last two researches, net revenues of the viticulture process appear to be negatively influenced by climate change unless irrigation systems are introduced (De Salvo et al., 2013).

The high spatial variability of the examined territories and the high specificity linked to each cultivar show that the evaluations of possible interventions to assist the sector under climate change conditions are highly site-specific. Furthermore, the analysis of the above aspects points out how the majority of researches focuses just on precise levels of the wine chain. A detailed and holistic evaluation of climate change consequences on the viticulture system is in fact a difficult task to accomplish (Schultz, 2010). An attempt to investigate at the same moment a wider range of features is developed by Lereboullet et al. (2013): they adopted a Mixed-methods analysis based on socio-ecologic and socio-economic parameters, which is able to support adaptation strategies for Mediterranean viticulture in general. However, the additional emerging need for the analysis of the viticulture system is a unique methodology able to relate different variables and opinions. This methodological approach should lead to the definition, and quite easy interpretation, of potential scenarios and facilitate the identification of specific management policies aiming at mitigating the damages.

A possible methodology suitable for the above mentioned purpose might be identified in the Fuzzy Cognitive Maps (FCMs) technique. The FCMs have been used in several fields, such as (Ackermann et al., 2004): i) problem solving processes within areas characterized by poor or complex data and by a high degree of uncertainty, ii) facilitation of communication and of data interpretation through the objectification and schematization of interview topics and iii) management of qualitative information.

At the national level, the FCMs were used for providing management scenarios of water resources in Southern Italy (Khadra et al., 2009) and for the assessment of the perception among the local residents on the construction of biomass plants (Lopolito et al., 2011). A few studies applied FCMs for the evaluation of climate change impact. For instance, the expected impacts of extreme events on different social groups in India was examined in Reckien et al. (2013) and perceived environmental change analysed through FCMs was used to support environmental policy makers by Kontogianni et al. (2012). Currently, according to authors' knowledge, FCMs have never been applied for the mitigation of potential socio-economic damage in the viticulture sector under climate change conditions. Therefore, the main goals of the paper are: i) to develop a FCM able to identify potential trends in the viticulture system in the case of a climate variation and ii) to analyse policy scenario able to mitigate potential socio-economic damage due to climate change.

A FCM was carried out through a deep literature analysis and a validation through focus groups. A nonlinear programming (NLP) model was also applied in order to optimize resource allocation in policy scenarios. Lastly, different scenarios were compared with each other and NLP efficiency was verified applying the multicriteria analysis (compromise programming).

Methodological Approach

Fuzzy Cognitive Maps: general characteristics and analysis

The FCMs are defined as a graph structure representing causal relationships among the variables. These relationships can be uni- or bidirectional and involve iterative processes (Kosko, 1986). The quantification of the relations is generally done adopting fuzzy logic (Chen and Hwang, 1992) and for this reason FCMs are defined as a semi-quantitative technique. The FCMs can be obtained through a variety of methods, included into two main categories: direct interviews (e.g. focus groups) or extraction of information from bibliographic data that show a causal relationship (Özesmi and Özesmi, 2004). According to the theoretical application presented in Kok (2009), the elements of a FCM can be summarized in *concepts* (or factors), which are the components of the system, and *links,* that represent the causal relationships among concepts and are characterized by a direction as well as a weight.

The major indexes describing FCM can be identified as follows (see Özesmi and Özesmi, 2004 for more details):

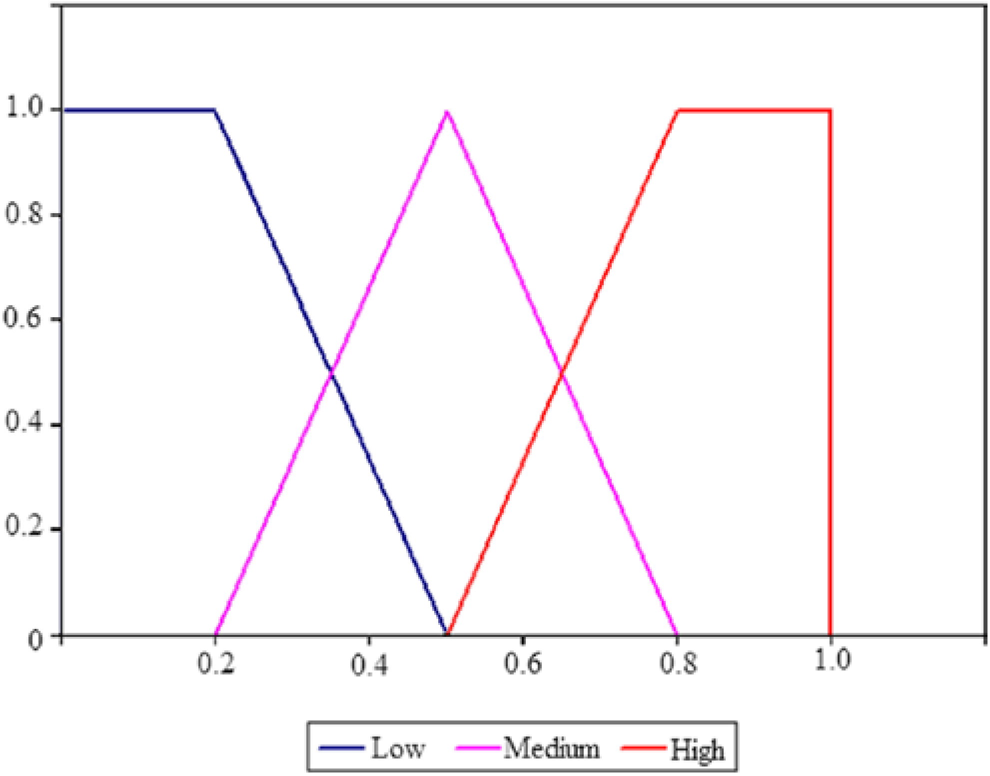
- Density (D): it evaluates the index of connections among the variables of the map; it depends on the number of variables and on the number of connections.
- Type of variable: it depends on the interaction of the variable with the other variables. Each criterion can be classified as: i) transmitter (characterized by output and no input links), receiver (characterized by input and no output links) and ordinary (with input and output links).
- Centrality: shows the strength of connection of a variable with the others, in relation with the weight of the interactions. In other words, it indicates the contribution of a criterion within the FCM.
- Hierarchical index: it is a value included in the range 0-1. It evaluates a fully hierarchical map if it is equal to 1 and a completely democratic one if equal to 0.

In the present paper, a FCM was implemented as follows. Firstly, through a literature analysis, the potential climate change impacts on the wine sector at the regional level were pointed out and FCM was designed; then FCM was integrated and validated by interviews (within focus groups) for the definition of experts' opinions (Ackerman, 2004). The value of the links among the criteria was quantified through a fuzzification of the qualitative verbal assessment related to scale 2 by Chen and Hwang (1992) (Figure 1), for both positive and negative correlations.

Nonlinear Programming Model and comparison of the scenarios

Once a FCM is implemented, the system can be run as an iterative process according to the following formula (Papageorgiou et al., 2011):

Figure 1. Scale 2 by Chen and Wang (1992).



$$C_{i,k} = \sum_i C_{i,k-1} \cdot w_{j,i}$$
$$A_k = \{C_{i,k}\} \qquad [1]$$

where $C_{i,k}$ is the value of concept i at iteration k, $w_{j,i}$ is the value of the link between concept j and receiver concept i and A_k is the state vector at iteration k.

The result of a FCM can be represented by its vector at steady state A_{ss} (Kok, 2009). Four possible situations can result for the steady state: i) "implosion" of the concepts to zero, ii) "explosion" of the concepts that can increase/decrease continuously, iii) cyclic stabilization of the concepts and iv) stabilization at a constant value. Due to dynamic behaviour of concepts, the steady state represents the reference value for the analysis of FCMs.

Scenario analysis can be developed activating a particular driver concept (e.g. policy) to other ordinary/receiver concepts. In this case, a fuzzified value of the link j,i was assigned to design the influence of a driver concept to the related variable(s). In order to identify the best allocation of resources from the drivers to the ordinary/receiver variables, the optimization procedure of the FCM has to be introduced. FCMs are a typical nonlinear system (Ferrarini, 2011) and, as a consequence of this, optimization strategies may be attained with nonlinear programming (NLP) approaches. Some attempts of FCM optimization have already been introduced in literature, mainly based on the Differential Evolution (DE) algorithm (Storn and Price, 1997). Among the different examined researches, Papageorgiou and Groumpos (2005) show an hybrid method for training FCM, which is based on the DE algorithm and on the nonlinear Hebbian rule. More recently, an optimal FCM weight matrix was achieved applying the DE and the Sequential Quadratic Programming (DE-SQP) algorithms (Shou et al., 2012). According to the validated results, one of the most solid and efficient algorithm seems to be the DEPS, an hybridation of the Particle Swarm optimization and the DE (Parsopoulos et al., 2004). DEPS evolutionary algorithm was therefore applied in this paper for FCM optimization together with NLP, as follows.

Let $A_{ss}\left\{C_{i,ss,p},C_{i,ss,n}\right\}$ with $C_{i,ss,p}$ being the value of the concepts at steady state that positively influence the system (e.g. efficiency of the production process) and $C_{i,ss,n}$ the value of the concepts at steady state that negatively influence the system (e.g. phytopathology). Therefore, the objective function of the model will be:

$$
\begin{aligned}
&MAX\left(\sum C_{i,ss,p} - \sum C_{i,ss,n}\right)\\
&s.t.\\
&w_{pol,x,p}\left[0,1\right]\\
&w_{pol,x,n}\left[-1,0\right]\\
&\sum w_{pol,x,p} + \left|\sum w_{pol,x,n}\right| = 1
\end{aligned}
\qquad [2]
$$

where $w_{pol,x,p}$ is the influence (weight) of policy variable on a specific positive concept referred to scenario x and $w_{pol,x,p}$ is the influence (weight) of policy variable on a specific negative concept referred to scenario x.

The efficiency of the NLP model is verified applying multicriteria analysis. In particular, compromise programming approach (Malczewski, 1999) is applied and the distance from the ideal point of every scenario is computed through the following procedure. First of all, every concept of the FCM is normalized in the range [0,1]:

$$C_{i,ss} = f(C_{i,ss-1}) + \sum_i C_{i,ss-1} \cdot w_{j,i} \qquad [3]$$

where f is (generally) an exponential equation able to both compel the results in the range [0,1] and facilitate the qualitative interpretation of FCM. The used f form is:

$$f(C_{i,ss-1}) = \frac{1}{1+e^{-\lambda \cdot C_{i,ss-1}}} \quad [4]$$

where λ is a positive number set at 1, because of good results showed in literature (Papageorgiou et al., 2011).

Then, the distance from ideal point $d_{i,ss}$ of each concept was computed as follows:

$$d_{i,ss} = \frac{id_i - C_{i,ss}}{id_i - nid_i} \quad [5]$$

where id_i is the ideal value of the concept (1 for positive variables and 0 for negative ones) and nid_i is the non-ideal value of the concept (0 for positive variables and 1 for negative ones).

Eventually, the distance of scenario D_x from ideal point was computed as:

$$D_x = \sqrt[m]{\sum (d_{i,ss})^m} \quad [6]$$

where m is the metric of the system. Three examples of metrics were used: m=1 for a totally compensatory approach (all concepts have the same influence on D_x), m=2 for a partially compensatory approach and m=∞ for a totally no-compensatory approach (the worst distance from the ideal point that influences the system).

Implementation of FCMs and the scenario for Tuscany region

The paper focuses on the wine chain of Tuscany, a region located in central Italy. The study area is to be considered of high interest at national level for its specific *terroir*, for its several premium quality wines and for the high percentage of Controlled Designation of Origin (DOC) and Controlled and Guaranteed Designation of Origin (DOCG) areas. In addition, for Tuscany wine sector, the quantification of the potential economic damage due to climate change and potential adaptation strategies at farm level have already been developed in some researches (Moriondo et al. 2011; Bernetti et al., 2012). For this reason it is seems of high interest to go further with the assessment of possible policy measures to mitigate socio-economic damage due to climate change.

Climate change trends are based on IPCC scenario. The IPCC (2007) estimates the emissions of greenhouse gases in response to different regimes of global development, through general circulation models (GCM). The GCM are, however, unsuitable for their application at the local level because of their low resolution. Thus, GCM were applied to regional areas by means of downscaling procedure as applied in Moriondo and Bindi (2009). In particular, this procedure concerned two different GCM (HadCM3 and CGGM) and two different scenarios (A2 and B2 characterized by regionally oriented economic development and local environmental sustainability, respectively). The current research will mainly refer to the results of the HadCM3 model and the A2 scenario, since it is considered the most plausible to the local situation (Moriondo et al., 2010).

Moriondo and Bindi (2009) assessed the potential impacts of global change on some key aspects of the grape cultivar, in particular: i) cultivation distribution (phenology, yield, bio-climatic indices) and ii) adversity (plant diseases, pests, frost risks during germination and heat waves during veraison, that is when the berry is turning its colour and it is ripening).

The main results show that the suitable arable land for viticulture tends to increase. On the one hand, this aspect might potentially favour a growth of the vine area, but on the other, variations of bio-climate characteristics could lead to: i) the possibility of moving specific vineyards from a territory to other ones and ii) the adoption of different cultivars suitable for those areas characterized by increased aridity conditions. Both consequences are potentially leading to a failure to comply with the product specifications. These specifications are generally seeking for: i) the distinction in the quality of the wines, ii) the maintenance of the traditions, iii) the increase of transparency in the market, iv) the differentiation of wine producer of a specific area and v) an easy identification of producers by the consumers.

The expected temperature increase should cause an anticipation of the germination and ripening periods and a reduction of the vegetative cycle of the vine. The negative effect on the accumulation of biomass could be partially offset by the increase in atmospheric CO_2. However, for the A2 scenario a general loss of productivity (per hectare) throughout the region could be reported, partly due to a medium-high risk of frost in the germination period and heat waves during the ripening process. As for the impact due to phytopathology (plant diseases and pests - in this case cycles of powdery mildew and moth have been analysed), future climate change scenarios seem not to have such a negative impact on the vines as confirmed by Caffarra et al. (2012); however, different perceptions on pest risk was highlighted among several stakeholders for the case of Italy (Battaglini et al., 2009).

An important element that could be modified by climate change is the introduction of irrigation (Grifoni et al., 2006) both in terms of complementary/supplemental and systematic irrigation.

The current regional legislation, in the particular case of Tuscany, does not allow for a systematic irrigation for those wines belonging to a Designation of Origin. The only permitted irrigation typology is the complementary/supplemental one, within the first three years from plantation and/or in particular dry years. The possibility of irrigation depends on the availability and distance from artificial lakes and streams from which the water can be drawn from pumping systems and from the presence of other irrigated crops.

A modification of the vegetative cycle implies a modification in the production practices (Holland and Smit, 2010; Keller, 2010). As a matter of fact, as stated by Alonso and O'Neill (2011) for three areas of Spain, some strategies indicated by grapevine growers to reduce impacts are: an earlier harvesting of the grapes, a change in the vine growing typologies and the experimentation of other varietals that are more resistant to heat and drought. All these solutions may potentially cause a short and medium-term increase in the production costs (Lereboullet et al., 2013). Production costs might be also influenced by mitigation strategies or losses due to an increase of extreme events (Mechler et al., 2010). On the other side, revenues are obviously depending on the product quantity and on the selling price of the main product and of any contingent by-product. Simplifying the market for wine, it is possible to state that often the selling price of wine is related to intrinsic attributes, such as qualitative characteristics related to alcohol degree, acidity, colour and grape variety (Tomasi et al., 2010), and extrinsic ones, such as country of origin (Veale and Quester, 2008), brand, international market trends and presence of funding and policy incentives. Climate change can mainly affect qualitative parameters of grape and wine (Mira de Orduña, 2010). A literature review developed by Holland and Smit (2010) highlighted that the impact of climate change is likely to be region-specific. A conclusion, relevant for Tuscany region, is that "*regions with warmer growing seasons may become too warm for the varieties currently grown there. Furthermore, hot regions may become too hot to produce high-quality wines of any type*". From the relation between quality and selling price, the authors highlight also the results of Jones and Storchmann (2001) that explain how the sensitivity to climate by the different vine cultivars, and thus the quality of the final product and its selling price, is strictly specific and single vine related, showing positive and negative responses which do not allow for a generalization of the results. Territorial marketing operations and cultural heritage induce in the final consumer a quality perception linked to the country of origin especially in terms of the typical landscape of the production area (Veale and Quester, 2008; Tomasi et al., 2010). In this case, climate variability could turn into a loss of landscape scenic beauty and perceived quality of the product due to a change in the cultivated crops. Under a climate change condition, some areas could face the need of shifting towards different agricultural cultivations, directly, because of the unsuitability of vine growing, and indirectly, for abandonment of uneconomic vineyards.

Additional economic variables are strictly related to farm and farmer characteristics. Adaptation strategies to climate change at farm level depend on the relationship between socio-economic variables and adaptation behaviours of farmers (Below et al., 2012). The main variables that seem to be influencing the implementation of adaptation actions depends on professional, training and education of farmers, on their specialization and on their capabilities of promptly reacting to new and unexpected situations (Bernetti et al., 2012).

According to the above analysis, scenarios related to mitigation policy were defined as follows:

- base scenario: baseline scenario with no policy activation.

- Scenario A: implementation of policies that favour irrigation practices (e.g. creation of artificial lakes and irrigation systems or economic incentives for irrigation).
- Scenario B: changes on specific regulations. In this sense, particular denominations and their related product specifications (DOC, DOCG, etc.) could be modified in terms of allowing for new cultivars, extended/relocated production areas, agronomic practices, etc. in order to overcome the limitations due to climate change.
- Scenario C: implementation of policies to encourage the training/education of the farmers (e.g. business knowledge, information on innovative agronomic practices, etc.) and to increase the value added of the farms (funding for the purchase of new technologies, etc.).
- Scenario D: researches for genetic improvement of the cultivars in order to plant more resilient typologies and to improve the efficiency of the production process.
- Optimized scenario: policy resources are distributed among specific concepts (see Figure 2) through the application of the NLP model.

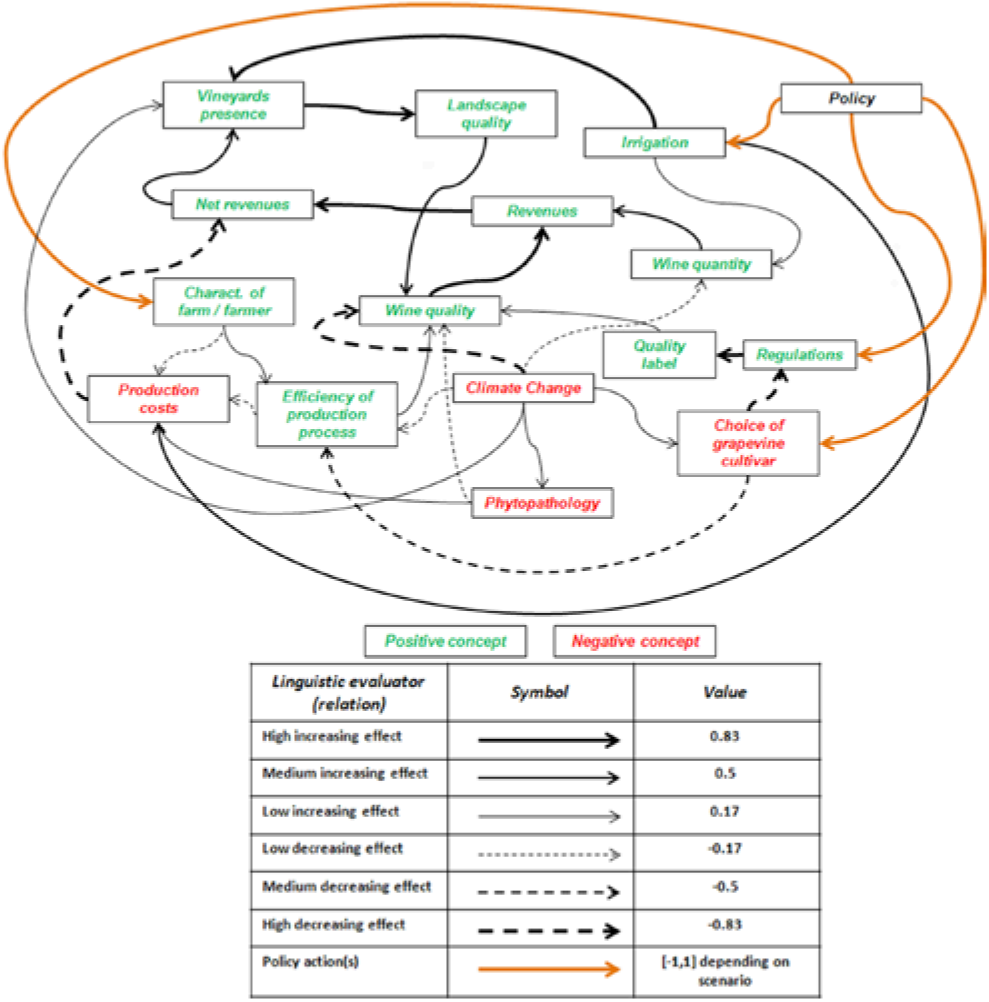
Results and discussion

The elaboration of FCM is showed in Figure 2. The map points out 11 positive concepts and 4 negative concepts, with the policy driver able to influence irrigation (scenario A), regulations (scenario B), the characteristics of farm/farmer (scenario C), the choice of grapevine cultivar (scenario D), or all previous concepts simultaneously (optimized scenario).

The analysis of FCM (Table 1) highlights a total of 2 transmitters and 14 ordinary variables, but no receivers. Density is 0.12 and the hierarchy index reaches the value of 0.02. These values imply that the relations among the variables are not very strong, even though the map seems to be highly "democratic", as it is demonstrated by the low value of standard deviation for centrality (0.72). Centrality can be synthesized in the importance of a variable in the system. In accordance with the existing literature, phytopathology does not seem to be a central parameter of the FCM. On the other hand, wine quality reaches the greater importance among the variables. This result is consistent with the characteristics of Tuscan viticulture, which is highly focused on the importance of its wine brand and on the perception of final product in the national and international markets. Other relevant parameters are the efficiency of the production process and the economic variables.

Components are analysed according to their steady state by a multicriteria approach. The computation of the distance from the ideal point for each component leads to the results showed in figure 3. Best parameters in terms of distance from ideal point seem to be revenues and landscape quality in every scenario. Regulations, efficiency of the production process and the production costs reach the worst value in most of the hypotheses. The introduction of policy measures influences mainly receiver concepts (see e.g. irrigation, characteristics of farm and farmer, regulations and choice of grapevine cultivar in the specific scenario).

Figure 2. Fuzzy Cognitive Map.



An in-depth analysis of the scenarios highlights how, with the application of metric m=1 and m=2, scenario C is the optimal one (Figure 4); the use of $m=\infty$ depicts the best choice for scenario B.

Performances of optimized scenario are then introduced. Optimized scenario is based on NLP approach and DEPS algorithm. This algorithm includes a series of variables that has to be parameterized in order to achieve the best result. The sensitivity analysis here carried out defines the ranking of the optimized scenario in respect to base, A, B, C and D, according to the variation of "swarm" parameter (Figure 5). In DEPS algorithm "swarm" defines the number of hypothetical individuals to participate in the learning process. In the simulation process, each individual finds his/her own solutions and contributes to the overall knowledge.

Table 1. Analysis of FCM.

Concept	Centrality	Transmitter	Receiver	Ordinary
Vineyards presence	1.50	no	no	yes
Landscape quality	1.33	no	no	yes
Irrigation	0.67	no	no	yes
Wine quality	3.33	no	no	yes
Wine quantity	0.84	no	no	yes
Characteristics of farm and farmer	0.83	no	no	yes
Efficiency of the production process	2.17	no	no	yes
Quality label	1.33	no	no	yes
Regulations	2.00	no	no	yes
Net revenues	2.16	no	no	yes
Revenues	2.16	no	no	yes
Production costs	2.17	no	no	yes
Phytopathology	0.51	no	no	yes
Choice of grapevine cultivar	2.00	no	no	yes
Climate change	1.68	yes	no	no
Policy	1.00	yes	no	no
N° of variables	16			
N° of transmitter variables	2			
N° of receiver variables	0			
N° of ordinary variables	14			
N° of connections	29			
Connections/variables	1.81			
Density	0.12			
Hierarchy index, h	0.02			

Figure 5 shows how the increase of "swarm" parameter improves the performance of the algorithm. Fully and partially compensatory approaches have an initial phase of stabilization, thereafter optimum is reached. No-compensatory approach demonstrates a more linear trend and an early optimization of results. However, for the specific case study, with the application of "swarm" value equal or greater than 35, optimized scenario shows the best ranking in all cases and confirms the validity of DEPS algorithm in NLP modelling.

Figure 6 highlights the sharing of policy resources among the key concepts in optimized scenario. The semi-quantitative nature of FCM suggests how the term "policy resources" does not necessary mean "economic resources" but should be interpreted as a combination of actions aiming at mitigate the socio-econom-

Figure 3. Distance from ideal point of the concepts for each scenario.

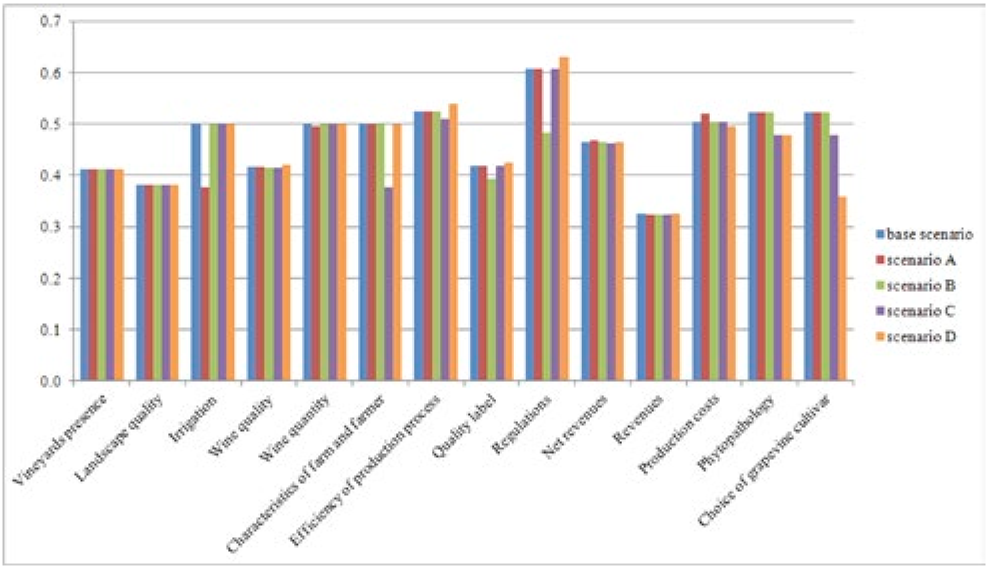
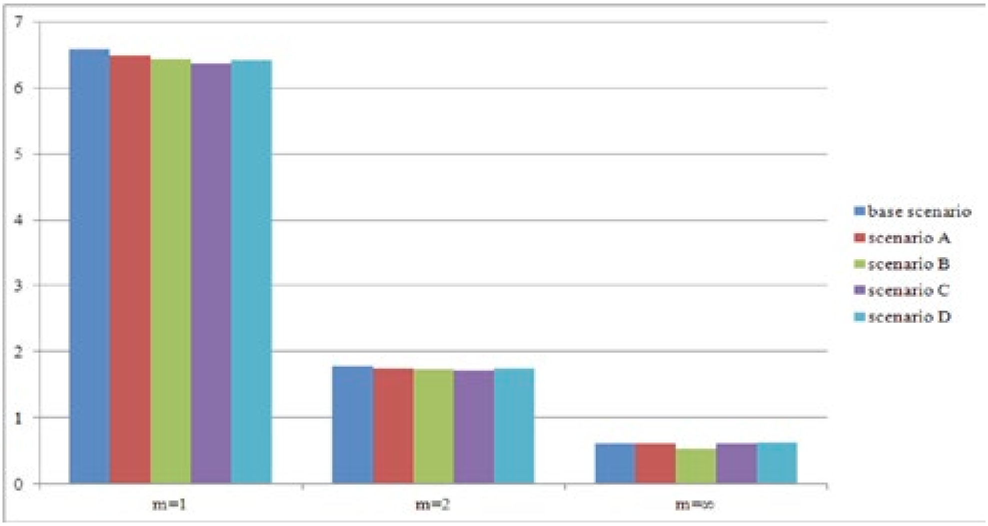


Figure 4. Scenario distance from ideal point for different metrics.



ic damage due to climate change. After a first stabilization sequence (up to a "swarm" index equal to 35 - Figure 6), the point of equilibrium and the best results for the optimized scenario are reached with following resources partition: irrigation (1.18%), characteristics of farm and farmer (0.03%), regulations (98.59%),

Figure 5. Ranking of optimized scenario according to “swarm” of DEPS algorithm and metric.

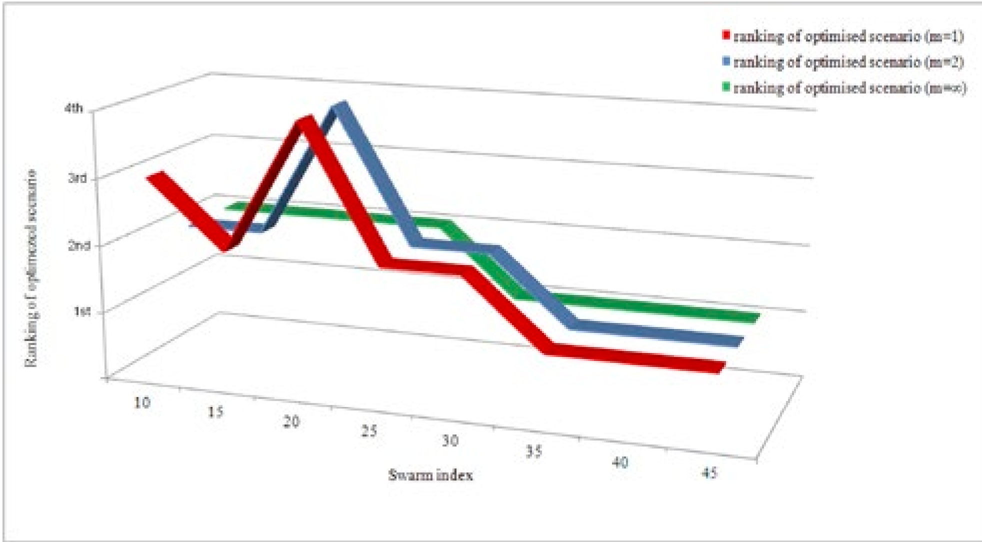
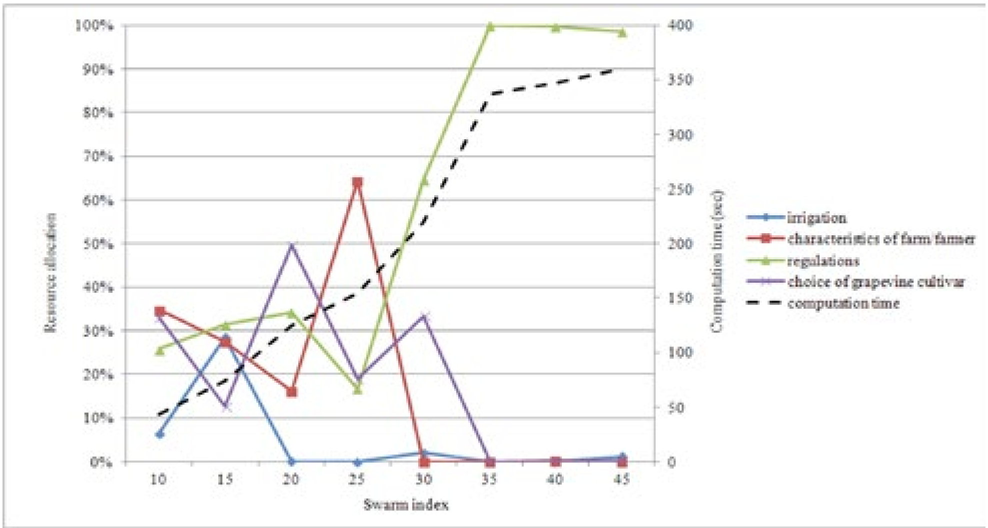


Figure 6. Resource allocation for mitigation of socio-economic damage in optimized scenario and computation time.



change of grapevine cultivar (0.20%). Obviously, the optimization of the results and the stabilization in the allocation of the different measures need an increasing computation time that seems to assume the trend of a sigmoid function.

Conclusions

Potential socio-economic impacts on the Tuscan viticulture sector due to climate change were analysed by means of a Fuzzy Cognitive Map (FCM). Different scenarios were identified and compared to each other using the compromise programming technique. Furthermore, optimization of FCM was defined applying a nonlinear programming (NLP) approach based on Differential Evolution Particle Swarm (DEPS) algorithm.

Results highlight how farm innovation and farmer training represent the most important actions for both the fully and the partially compensatory approach in case of policy intervention. Qualitative parameter related to the final product and the economic variables seem to be among the most sensitive variables of the system, in case of climatic alterations. Within these results, a tangible possibility of shifting specific vineyards from a territory to other ones and/or to introduce different cultivars suitable for areas characterized by increased aridity conditions might pose a serious risk to the maintenance of the high quality of the regional wines. As matter of fact, if totally no-compensatory approach or optimization of FCM were applied, the introduction of policy measures appropriate for the protection of the denominations and of their product specifications appear to be the best solution for the Tuscan wine chain.

From a methodological point of view, the combination of those factors characterized by a high complexity and the introduction of the stakeholders' opinion on the evolution of the system make the FCM an appropriate tool to be used as a decision support. The results given by the optimized scenario confirm the validity in the application of NLP and DEPS algorithm. The validation of soundness and efficiency of the algorithm is, however, time-dependent and an higher number of FCM concepts and links could lead to a significant computation time.

Among the potential improvements of this research, the introduction of additional scenarios might represent one. For instance, the influence of direct incentives in favour of marketing operation, or the testing of innovative field production practices and other IPCC scenarios could be examined. Lastly, due to the semi-quantitative nature of FCM, an in-depth evaluation of resources allocation must be carried out to define typology and partitioning between legislative and economic intervention.

References

Ackermann, F., Eden, C. and Cropper, S. (2004), "Getting started with cognitive mapping", 7th Young OR Conference, University of Warwick, pp. 65-82. URL: http://www.banxia.com/pdf/de/GettingStartedWithCogMapping.pdf

Alonso, A.D. and O'Neill, M.A. (2011), "Climate change from the perspective of Spanish wine growers: a three-region study", British Food Journal, Vol. 113 No. 2, pp. 205-221.

Battaglini, A., Barbeau, G., Bindi, M. and Badeck, F.W. (2009), "European winegrowers' perceptions of climate change impact and options for adaptation", Regional Environmental Change, Vol. 9, pp. 61-73.

Below, T.B., Mutabazi, K.D., Kirschke, D., Franke, C., Sieber, S., Siebert, R. and Tscherning, K. (2012), "Can farmers' adaptation to climate change be explained by socio-economic household-level variables?", Global Environmental Change, Vol. 22 No. 1, pp. 223-235.
Bernetti, I., Menghini, S., Marinelli, N., Sacchelli, S. and Alampi Sottini, V. (2012), "Assessment of climate change impact on viticulture: economic evaluations and adaptation strategies analysis for the Tuscan wine sector", Wine Economics and Policy, Vol. 1, pp.73-86.
Bindi, M., Fibbi, L., Gozzini, B. and Orlandini, S. (1996), "Modelling the impact of future climate scenarios on yield and yield variability of grapevine", Climate Research, Vol. 7, pp. 213-224.
Caffarra, A., Rinaldi, M., Eccel, E., Rossi, V. and Pertot, I. (2012), "Modelling the impact of climate change on the interaction between grapevine and its pests and pathogens: European grapevine moth and powdery mildew", Agriculture, Ecosystems and Environment, Vol. 148, pp. 89-101.
Chen, S.J. and Hwang, C.L. (1992), Fuzzy multiple attribute decision making: methods and applications. Springer-Verlag, Berlin.
De Salvo, M., Raffaelli, R. and Moser, R. (2013), "The impact of climate change on permanent crops in an Alpine region: A Ricardian analysis", Agricultural Systems, Vol. 118, pp. 23-32.
Ferrarini, A. (2011), "Some steps forward in semi-quantitative networks modelling", Network Biology, Vol. 1 No. 1, pp. 72-78.
Fraga, H., Malheiro, A.C., Moutinho-Pereira, J. and Santos, J.A. (2012), "Future scenarios for viticultural zoning in Europe: ensemble project ions and uncertainties", International Journal of Biometereology, DOI: 10.1007/s00484-012-0617-8.
Grifoni, D., Mancini, M., Maracchi, G ., Orlandini, S. and Zipoli, G. (2006), "Analysis of italian wine quality using freely available meteorological information", American Journal of Enology and Viticulture, Vol. 57 No. 3, pp. 339-346.
Hadarits, M., Smit, B. and Diaz, H. (2010), "Adaptation in viticulture: a case study of producers in the Maule region of Chile", Journal of Wine Research, Vol. 21, Nos. 2-3, pp. 167-178.
Holland, T. and Smit, B. (2010), "Climate change and the wine industry: current research themes and new directions", Journal of Wine Research, Vol. 21, Nos. 2-3, pp. 125-136.
IPCC - Intergovernmental Panel on Climate Change (2007), Climate Change 2007, Cambridge University Press, New York.
Jones, G.V. and Storchmann, K. (2001), "Wine market prices and investment under uncertainty: an econometric model for Bordeaux Crus Classés", Agricultural Economics, Vol. 26 No. 2, pp. 115-133.
Jones, G.V., White, M.A., Cooper, O.R. and Storchmann, K. (2005), "Climate change and global wine quality", Climatic Change, Vol. 73, pp. 319-343.
Keller, M. (2010), "Managing grapevines to optimise fruit development in a challenging environment: a climate change primer for viticulturists", Australian Journal of Grape and Wine Research, Vol. 16, pp. 56-69.
Khadra, R., D'Agostino, D.R. and Lamaddalena N. (2009), "Analisi dinamica degli scenari futuri sulla gestione delle risorse idriche in un bacino dell'Italia meridionale", IX Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria, Ischia Porto, memoria 2-21. URL: http://www.aiia.it/images/Atti/IX_Ischia/2-21.pdf
Kok, K. (2009), "The potential of Fuzzy Cognitive Maps for semi-quantitative scenario development, with an example from Brazil", Global Environmental Change, Vol. 19, pp. 122-133.
Kontogianni, A.D., Papageorgiou, E.I. and Tourkolias, C. (2012), "How do you perceive environmental change? Fuzzy Cognitive Mapping informing stakeholder analysis for environmental policy making and non-market valuation", Applied Soft Computing, Vol. 12, pp. 3725-3735.
Kosko, B. (1986), "Fuzzy Cognitive Maps", International Journal of Man – Machine Studies, Vol. 24, pp. 65-75.
Lereboullet, A.L., Beltrando, G. and Bardsley, D.K. (2013), "Socio-ecological adaptation to climate change: a comparative case study from the Mediterranean wine industry in France and Australia", Agriculture, Ecosystems and Environment, Vol. 164, pp. 273-285.

Lopolito, A., Nardone, G., Prosperi, M., Sisto, R. and Stasi, A. (2011), "Modeling the bio-refinery industry in rural areas: a participatory approach for policy options comparison", Ecological Economics, Vol. 72, pp. 18-27.

Malczewski, J. (1999), GIS and multicriteria decision analysis, New York: John Wiley & Sons Inc.

Mechler, R., Hochrainer, S., Aaheim, A., Salen, H. and Wreford, A. (2010), "Modelling economic impacts and adaptation to extreme events: insights from European case studies", Mitigation and Adaptation Strategies for Global Change, Vol. 15 No 7, pp. 737-762.

Mira de Orduña, M. (2010), "Climate change associated effects on grape and wine quality and production", Food Research International, Vol. 43, pp. 1844-1855.

Moriondo, M and Bindi, M (2009), Cambiamenti climatici e ambiente vitivinicolo: impatto e strategie di adattamento, Final report, Department of Agronomy and Land Management, University of Florence, Florence.

Moriondo, M., Pacini, C., Trombi, G., Vazzana, C. and Bindi, M. (2010), "Sustainability of dairy farming system in Tuscany in a changing climate", European Journal of Agronomy, Vol. 32, pp. 80-90.

Moriondo, M., Bindi, M., Fagarazzi, C., Ferrise, R. and Trombi, G. (2011), "Framework for high-resolution climate change impact assessment on grapevines at a regional scale", Regional Environmental Change, Vol. 11, pp. 553-567.

Özesmi, U. and Özesmi, S.L. (2004), "Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach", Ecological Modelling, Vol. 176, pp. 43-64.

Papageorgiou, E.I. and Groumpos, P.P (2005), "A new hybrid method using evolutionary algorithms to train Fuzzy Cognitive Maps", Applied Soft Computing, Vol. 5, pp. 409-431.

Papageorgiou, E.I., Markinos, A.T. and Gemtos, T.A. (2011), "Fuzzy cognitive map based approach for predicting yield in cotton crop production as a basis for decision support system in precision agriculture application", Applied Soft Computing, Vol. 11, pp. 3643-3657.

Parsopoulos, K.E., Papageorgiou, E.I., Groumpos, P.P., and Vrahatis, M.N. (2004), "Evolutionary computation techniques for optimizing Fuzzy Cognitive Maps in radiation therapy systems", Lecture Notes in Computer Science, Vol. 3102, pp. 402-413.

Reckien, D., Wildenberg, M. and Bachhofer, M. (2013), "Subjective realities of climate change: how mental maps of impacts deliver socially sensible adaptation options", Sustainability Science, Vol. 8, pp. 159-172.

Ruml, M., Vuković, A., Vujadinović, M., Djurdjević, V., Ranković-Vasić, Z., Atanacković, Z., Sivčev, B., Marković, N., Matijašević, S. and Petrović, N. (2012), "On the use of regional climate models: implications of climate change for viticulture in Serbia", Agricultural and Forest Meteorology, Vol. 158-159, pp. 53-62.

Schultz, H.R. (2000), "Climate change and viticulture: a European perspective on climatology, carbon dioxide and UV-B effects", Australian Journal of Grape and Wine Research, Vol. 6, pp. 2-12.

Schultz, H.R. (2010), "Climate change and viticulture: research needs for facing the future", Journal of Wine Research, Vol. 21, Nos. 2-3, pp. 113-116.

Schultz, H.R. and Jones, G.V. (2010), "Climate induced historic and future changes in viticulture", Journal of Wine Research, Vol. 21, Nos. 2-3, pp. 137-145.

Shou, W., Fan, W. and Liu, B. (2012), A Data-Based Fuzzy Cognitive Map Mining Method Using DE-SQP Algorithm, In: Communications in Computer and Information Science, Asia Simulation Conference 2012, Shanghai, China, October 27-30, 2012. Proceedings, Part III, pp 37-43.

Stock, M., Gerstengarbe, F.W., Kartschall, T. and Werner, P.C. (2005), "Reliability of climate change impact assessments for viticulture", Acta Horticulturae, Vol. 689, pp. 29-39.

Storn, R. and Price, K. (1997), "Differential evolution - a simple and efficient heuristic for global optimization over continuous spaces", Journal of Global Optimization, Vol. 11, pp. 341-359.

Tomasi, D., Gaiotti, F. and Tempesta, T. (2010), "The importance of landscape in wine quality perception", In: Landscape and its emotional role in wine quality, Proceedings of VIII International Terroir Congress, June 14th-18th, Soave (VR), Italy. URL: http://terroir2010.entecra.it/atti/VIIICongress.html

Veale, R. and Quester, P. (2008), "Consumer sensory evaluations of wine quality: the respective

influence of price and country of origin", Journal of Wine Economics, Vol. 3 No 1, pp. 10-29.
Webb, L.B., Whetton, P.H. and Barlow, E.W.R. (2007), "Modelled impact of future climate change on the phenology of winegrapes in Australia", Australian Journal of Grape and Wine Research, Vol. 13, pp. 165-175.