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A fuzzy cognitive mapping approach for the assessment of public-goods governance in agricultural landscapes

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ABSTRACT

In Europe, growing concerns about the environmental impacts of agriculture have stimulated the development of more efficient governance options to be included in, or to complement, current agri-environmental policies. However, a significant hurdle for the implementation of enhanced policy tools is the difficult adaptation of promising approaches, such as collective contracts and private-based payments for environmental services, to the locally specific, socio-economic and institutional contexts of different European regions. In this study, we apply a participatory approach based on the Fuzzy Cognitive Mapping technique, in assessing different policy mechanisms, including improved monetary incentives and the potential for an enhanced design of agricultural landscape governance. Our analysis specifically assesses the interactions between rural society, public goods and policies under different, locally relevant economic and social scenarios. The study is carried out in the Marchfeld, an intensive agriculture case-study area in Eastern Austria, which features a number of environmental problems. The work is based on a two-year-long process including focus groups, mind mapping and scenario co-development, as well as individual interviews with local stakeholders.

The results show that integrating private or public, collective or performance-orientated monetary incentives with other non-monetary mechanisms like farmers' partnerships or enhanced awareness building are evaluated as central to an effective agri-environmental governance system. Moreover, the results highlight that different futures have major effects on the effectiveness of mechanisms: in a purely market-driven context, tools based on collaborations among farmers are likely to be ineffective and monetary incentives are less efficient. On the other hand, positive social pressures and the influence of non-monetary governance initiatives expected in a sustainability-driven scenario are able to catalyse an efficient adoption of environmental-friendly practices, also at lower monetary rates. Based on the results, we discuss the problem of public goods in agricultural landscapes, and the relevance of such ancillary factors as social infrastructure, awareness and marketing, in supporting the effectiveness and feasibility of public-goods 'governance'.

1. Introduction

Since the second half of the 20 th century, the Common Agricultural Policy (CAP) has been designed to deliver a more efficient and competitive EU agriculture. In recent decades, however, the combination of incentives, technological progress and the premise of cost reduction in agricultural production, has had undesirable effects on the provision of public goods, which has generated growing social concerns regarding agricultural management (Foley, 2005). To cope with the negative impacts of agricultural activities, agri-environmental schemes (AES) have been introduced in the CAP as the main tool in aiming for a more environment-friendly agricultural approach. Nonetheless, the efficiency of such schemes is often discussed at both academic and decision-making levels (Primdahl et al., 2003; Pe'er et al., 2014). In the current policy debate, new and comprehensive mechanisms – for example, including and combining regulations, private and public-based incentives and standards, and non-monetary tools – are considered crucial in tackling the revised priorities for managing rural lands and supporting a balanced provision of public goods from agricultural landscapes (Hodge, 2001). Nonetheless, such public-goods 'governance' relies on a range of human-environment interactions which forms an intricate network of feedbacks on different spatial and temporal scales

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and generates complex relations with policies and global-scale processes (van Zanten et al., 2014; Plieninger and Bieling, 2012). Indeed, market, policies and societal mechanisms drive the demand and supply of public goods, but the effectiveness of different governance tools and settings is typically related to local features and the different consequences of landscape management on the regional or even local socio-economic context (Schaller et al., 2018).

Several approaches have been identified and proposed for enhancing the environmental performance of rural areas. For instance, collaboration (Prager et al., 2012), adaptive co-management (Berkes, 2017), integrated landscape approaches (Freeman et al., 2015), and the involvement of local stakeholders in the policy-design process are suggested as promising pathways for sustainable change (Cash et al., 2003). However, the identification of enabling factors for the development of successful arrangements in the current policy framework and in different socio-ecological contexts is still challenging (Darnhofer et al., 2017). Taking a 'governance perspective' has been advocated as a necessary step for the improvement of public-goods delivery from agricultural landscapes (Runhaar et al., 2016). That allows considering economic aspects linked to revenues and incentives in combination with other forms of drivers, objectives, initiatives and actors, which characterise and influence the performance of different governance tools (de Snoo et al., 2013). Different arrangements of these tools are able to create favourable conditions for a more effective environmental management and thus should be considered in explaining the adoption and success of environment-friendly agricultural practices (Raymond et al., 2016). For instance, governance tools linking to collective schemes concern soft aspects beyond monetary motivations like social capital that impact on the dynamics within farming communities and that are difficult to consider and evaluate (Burton and Paragahawewa, 2011; Pretty, 2008).

The complexity of delivering an efficient design of governance tools involves many aspects: a first issue regards the adaptation of general schemes to the intrinsic variability of farming systems and ecological conditions, whereas a second aspect entails the understanding of how such schemes integrate with the range of local institutions that characterise the different European regions (Zasada et al., 2017). For instance, the evaluation of the interactions of local-scale aspects as human/social capital, learning and awareness with exogenous and broader factors like the market is particularly challenging (Cockburn et al., 2018). To cope with such challenges, several approaches are proposed: while landscape is suggested as the privileged scale of analysis, the involvement of stakeholders in transdisciplinary approaches is considered necessary for tackling the design of agri-environmental policies (Balvanera et al., 2017). Including stakeholders follows the principle that the design of governance tools should consider the stakeholders' divergent values and beliefs (Cash et al., 2003). In addition, transdisciplinarity allows grasping the complexity of socio-ecological systems and accounting for case-specific knowledge in an analytical framework (Guimarães et al., 2018). Therefore, the inclusion of stakeholders in the analysis of the mechanisms supporting the success of different governance options is growing as a mean to enhance the effectiveness and acceptability of policy agendas with local-scale expertise and opinions (Reed et al., 2009). Along with the growing importance of stakeholder involvement in addressing questions of environmental policy design and assessment, various stakeholder-based participatory modelling and non-modelling approaches have been evolving in the last decades, "usually related to supporting decision making, policy, regulation or management "(Voinov and Bousquet, 2010), and suited to identify and evaluate effects of mechanisms designed for solving given environmental challenges. Among techniques, such as system dynamics, Bayesian Belief Networks, or agent-based modelling, Fuzzy Cognitive Mapping (FCM) is becoming a widespread participatory modelling tool. The FCM method was originally developed in the 1980s, combining Neural Networks and Fuzzy Logic with the aim of reproducing the behaviour of a system composed of concepts linked to cause-effect relationships (Axelrod, 1976; Kosko, 1986). The usefulness of FCM lies in its ability to represent complex systems using scarce or vague information available and the relevant presence of non-tangibles through a framework of analysis similar to human reasoning (Gray et al., 2017). A major advantage of FCM is that it does not aim to predict real-value parameter estimates (for which data-intensive, process-based models would be required); rather, it gives relative results which indicate how variables could change and provides a plausible understanding of why such changes might unfold when considering the interactions among different policy options (Hobbs et al., 2002). FCM models are usually employed as strategic tools in the form of stand-alone or integrated techniques, targeting the comprehension (rather than the prediction) of potential patterns and conditions (Verkerk et al., 2017). In particular, applications of FCM are effective in the analysis of complex systems, where the inclusion of emergent behaviour and resilience thinking commonly hampers real-world assessments (Norberg and Cumming, 2008; Van der Sluis et al., 2018). Indeed, FCM-based approaches are increasingly used for integrating qualitative expert knowledge and the combination of different data sources and perspectives applied to the analysis of managed systems (Diniz et al., 2015). FCM is also considered a valuable tool for linking qualitative narratives and semi-quantitative modeling (Jetter and Kok, 2014), and for enabling the simulation of policy impacts in human-managed systems under different scenarios (Murungweni et al., 2011). Moreover, FCM is suggested particularly useful in supporting agricultural policy design, a policy area in many cases confronted by strongly diverging perceptions on management measures and objectives, and therefore often addressing so-called wicked problems (Christen et al., 2015; Kuhmonen, 2018).

The objective of this paper is the assessment of different governance tools for the delivery of public goods from agricultural landscapes. The study is based on the development of a FCM as the modelling technique and a two-year long participatory process involving a local stakeholder board. The work evaluates the consequences on public goods related to the interactions between incentives, supporting mechanisms and social aspects in a specific case-study region (Marchfeld, Austria). In particular, the study aims to provide insights into the effectiveness of different monetary and non-monetary-based policy tools in facilitating the adoption of more sustainable practices under locally relevant socio-economic scenarios.

2. Material and methods

2.1. Description of the case-study region

The case-study region (CSR) Marchfeld is a flat agricultural area in the north-east of Austria. It is located in the sedimentary basin between the Eastern Alps and the Carpathian Mountains and covers ca. 70,800 ha. The region is characterised by a semi-arid climate with hot, dry summers and cold winters, and an annual precipitation rate of between 500 and 600 mm y^{-1}[1] .

The Marchfeld is situated on one of the largest contiguous groundwater resources in Austria, with a water volume of more than 1 billion m^3. The groundwater is located in the cavities of a giant aquifer consisting of gravels and sands underground. With a groundwater gradient of around 0.4‰, the groundwater flows distinctively slowly from WNW to ESE, leading to an extremely long retention period of several decades.[2]

The good soil conditions (deep and fertile chernozem soils) and the possibility of groundwater-fed irrigation provide the basis for an intensive agricultural management system, taking place on a utilised agricultural area (UAA) of about 50,800 ha. The main agricultural focus

[1] http://ehyd.gv.at/# (accessed on 07 December 2018).
[2] http://www.marchfeldkanal.at/home.htm (accessed on 09.December 2018).

is on arable cash-crop production, taking place on 98% of UAA and involving 95% of farms. In addition, over the last few decades, organic arable cash-crop farming has become noticeably present in the region, with a share of 12% of farms and an annual rate of increase of about 2%. Until now, about 25% of the agricultural area is managed under irrigation[3] .

The CSR's proximity to two European capitals (Vienna and Bratislava), of which Vienna in particular outlines relevant dynamics of economic and population growth, leads to a multitude of conflicts and claims common to several European rural areas, such as growing recreational demands, urban outmigration and linked land-use competition among infrastructures, urban sprawling and food supply.

2.2. Participatory design of alternative options for public-goods governance

As basis for the design and assessment of specific governance mechanisms for local public good provision, a participatory process was carried out in 2016 and 2017 with a selected group of 20 regional stakeholders. The stakeholders were invited to join a board continuously participating in the debate on the improvement of agricultural policies for the delivery of public goods for the duration of the study. The debate involved a session of four workshops and several individual interviews (Fig. 1; cfr. Appendix A). In the first workshop, the discussion focused on the general notion of public goods from agriculture and on the identification of major issues and sensitivities concerning the most relevant public goods provided in the CSR. In the second workshop, a broader range of potential governance tools and success criteria in terms of their effectiveness in enhancing the provision of the relevant public goods in the CSR were defined: initially, the current governance of public goods and its failures, as well as possibilities for improvements, were discussed. In practical terms, the stakeholders were then asked to identify the factors at play in the regional public-goods system in the Marchfeld, integrate the current governance mechanism into this system and depict the range of cause-effects between the different mechanisms at play. As a participatory method, in the second workshop mind mapping was employed as a way of developing a mutual understanding of the conflicts between society and agriculture, as well as of the entry points of steering mechanisms concerning the delivery of public goods (Roberts et al., 2018) (see Annex 1). Based on the results of the first two workshops, in the third workshop, the stakeholders were asked to focus on the specific and most relevant public goods at stake for the CSR and elaborate an operational mix of governance mechanisms and initiatives able to improve public-goods provision by fostering the implementation of effective agricultural-management practices. Particular emphasis in the elaboration of the governance mix was placed on meeting the criteria of success for governance (targeting, effectiveness, efficiency and legitimacy), as identified in the second workshop (Schaller et al., 2017).

The major public-goods issue acknowledged by the regional stakeholders and experts was the functionality of agricultural soils in the Marchfeld. The stakeholders identified soil not only as the essential asset for agricultural production, but also as a basis for the provision of other important public goods such as climate stability (soil as a CO_2 sink) and groundwater quality. Soil was also considered under current threat because of intensive agricultural management combined with the CSR climatic conditions and urban-sprawling dynamics. Relevant concerns were outlined also for groundwater quality –in particular, because of the high level of nitrate and pesticide pollution following decades of intensive agriculture and the low precipitation rates leading to insufficient dilution and reservoir turnover. For this reason, groundwater treatment is currently necessary in many parts of the Marchfeld to reach the compulsory value standards for potable water.

To improve soil functionality and consequently also generate a positive impact on groundwater quality, the stakeholders identified changes of the agricultural management as paramount. The envisioned changes focused on the adoption of Conservation Agriculture (CA) techniques (Garcìa-Torres et al., 2003), including minimum tillage, intercropping, residues remain after harvest, and adapted crop rotations to increase soil health and reduce pollution. The set of practices included possible use in conventional or organic farming systems, even though the latter would have required adaptations to avoid the use of herbicides (Petersen et al., 2000). The adoption of these practices was also considered part of a strategy able indirectly to improve the biodiversity of the region. Indeed, the introduction of flowering cover crops for pollinating species and the shift towards reduced tillage were considered positive for increasing soil biodiversity. On the other hand, the availability of a wider range of landscape habitats was deemed positive for game fauna and other species.

Based on existing programmes in the Marchfeld and in other parts of Europe (e.g. Franks, 2011), two monetary incentive schemes were identified by the stakeholders to facilitate the adoption of the improved CA techniques. The first scheme was a public-private governance initiative involving a collective bonus based on voluntary agreements. The bonus included a payment per hectare as in the framework of the agri-environmental schemes of the CAP, which gradually increases with the clustered area under soil-friendly management. That mechanism was expected to motivate farmers to encourage other/neighbouring farmers to take part in the scheme, although concerns regarding coordination and collaboration were also expected in the context of the CSR. The second monetary scheme was a private self-governance form of sale guarantee combined with a result-based premium for measurably enhanced humus content in the soils. The self-governance mechanism was inspired by an existing scheme promoted by a local NGO, together with a supply-chain firm as a payment for an ecosystem services programme called 'Healthy Soils for Healthy Food'. In this programme, farmers were committed to adopting CA practices and rewarded by the supply-chain firm with a sale guarantee and a payment per CO_2 t stored in the ground, as measured through a monitoring programme led by the NGO. The sale guarantee included in the self-governance scheme was considered a strong leverage point in motivating the farmers (perhaps even more than payments per area), whereas the humus-monitoring programme was believed able to generate a monitoring effect (Targetti et al., 2014) and stimulate the interest of farmers to register achievements in soil quality.

In addition to these monetary incentives, the stakeholders identified non-monetary initiatives able to support and enable the adoption of improved soil practices. The first mechanism represented the establishment of a regional collaborative partnership. That initiative was arranged as a local working group aimed at facilitating practice change, providing up-to-date knowledge and training, and the sharing of technology and machinery among farms. The partnership was depicted as an institution involving interested farmers, the Austrian Ministry of Agriculture and the National Association of Organic Farming (Bio-Austria). The participation of the machinery ring was also seen as providing the technical and machinery support necessary for implementing the CA measures. Experts and scientists were also included in the partnership to provide technical and up-to-date scientific knowledge. The partnership was expected to work on a voluntary basis and therefore without public support except for some necessary organisational/logistical funding. The further supporting tools identified by the stakeholders were regional labelling and marketing such as farm certification and branding, and awareness campaigns. As regards the non-monetary initiatives, the local partnership was expected to increase the targeting of the schemes to the local context and develop the farmers' ability to collaborate and adopt new practices, whereas the marketing and awareness campaign tools were considered necessary to generate a positive context of social (and consumer) demand towards environment-friendly agriculture and public-goods provision in general.

[3] http://www.marchfeldkanal.at/09main13h.htm (accessed on 07 December 2018).

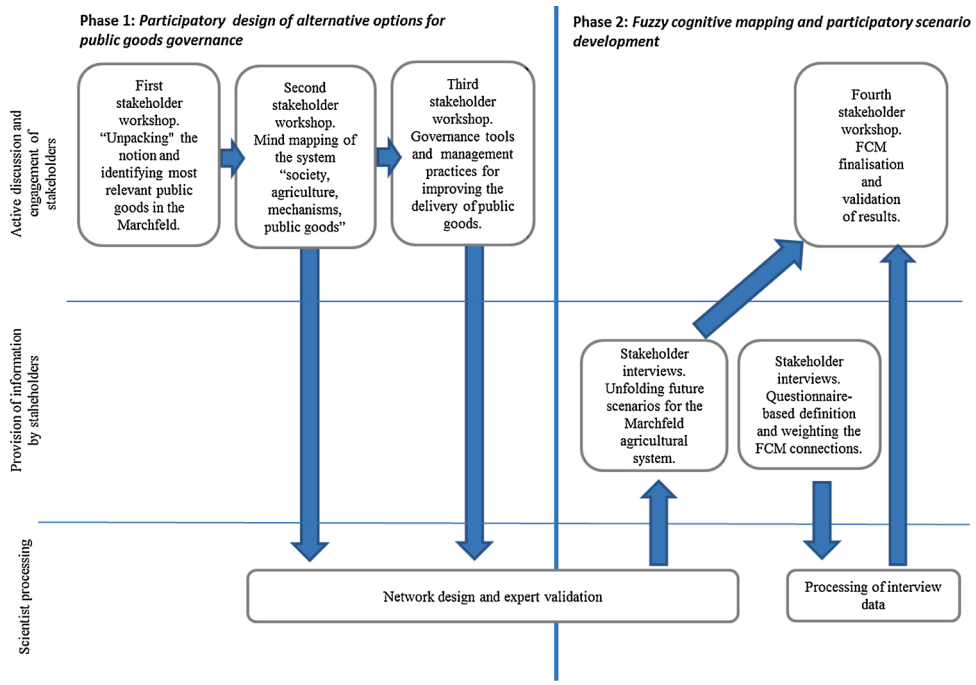


Fig. 1. Participatory process for the development of improved public-goods governance in the Marchfeld. A stakeholder board of 20 stakeholders was involved in four meetings, and two individual interview sessions. The process also involved a processing step validated by researchers with specific expertise of the Marchfeld. Source: (own elaboration).

2.3. Fuzzy cognitive mapping and participatory scenario development

The development of FCM for the analysis of the public-goods governance in the Marchfeld region followed the discussions carried out in the first three stakeholder meetings. While the first and third workshops defined public-goods issues, as well as agricultural management and governance strategies, the mind maps generated in the second stakeholder workshop provided a range of concepts, as well as cause-effect links between governance mechanisms, actors and public goods. On the basis of these mind maps, a basic cognitive map was sketched (Fig. 2). The basic map was based on the *concepts* as identified by the stakeholders. A concept was defined as an element or a factor playing a relevant role in the system, for example 'Agriculture' or 'Quality of Groundwater'. The concepts were subsequently connected following the indications provided by the stakeholders during the mind mappings. Concepts and connections were then included in clusters following a qualitative aggregation procedure (Özesmy & Özesmy 2004). The aggregation in clusters was based on the definition of an encompassing factor (for instance, soil fertility, groundwater quality, and landscape quality were merged into a 'Public goods'cluster) able to simplify the map visualisation for the subsequent stakeholder evaluation.

Legend:

Clusters:

Public Goods: The cluster of 'public goods'comprises the three main concepts at stake in the case-study region: soil functionality, translated by the stakeholders into the soil fertility due to optimal humus contents, water quality and the quality of the landscape in terms of its biodiversity and habitat function.

Society's Awareness: The cluster 'society's awareness'comprises the four main groups of rural actors that have been highlighted by the experts (namely, agriculture, hunters, new inhabitants and the rest of society). It is important that the concept does not address these actor groups as persons, but rather the awareness and attitude of this group of actors towards the different, most relevant public goods in the Marchfeld.

Factors of Adoption: The cluster 'Factors for the Adoption of Conservation Agriculture Practice' includes four concepts: motivation of adoption, ability of adoption, demand for adoption and legitimacy of adoption. It should be noted that the first two concepts (motivation and ability of adoption) are exclusively associated with the awareness of agriculture towards public-goods provision, as the motivation and ability of agriculture to adopt management changes is assumed to be the basic requirement which goes hand-in-hand with successful implementation.

Adoption of Conservation Agriculture Practice: The cluster describes the implementation of soil conserving and humus-accumulating management practices, namely direct-/Mulch sowing, intercropping, harvest residues remain on field and adapted crop rotation.

External Factors: This cluster includes a number of factors identified by the experts, having an influence on either/or the factors of adoption and directly the provision of public goods. Most relevant external factors are society's willingness to pay for public goods, the profitability of management changes, organic farming, other policies and soil-type.

Governance Mechanisms: The cluster of governance mechanisms includes all financial and supporting mechanisms as designed by the stakeholders in the third workshop.

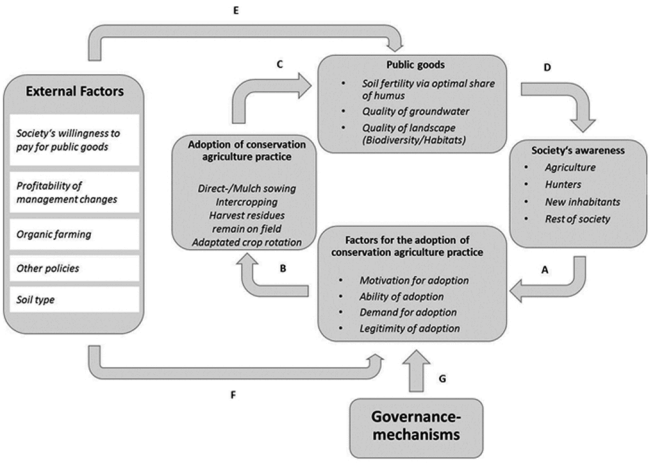
Connections:

Connection A: The awareness/sensitivity of the rural society as a whole towards the regional public goods at stake influences the adoption factors, including the motivation of farmers. The influence includes aspects related to pressure ' from the community on farmers, and the role played by the governance mechanisms in stimulating or de-stimulating adoption.

Connection B: The interaction between the adoption factors determines a higher or lower uptake of the conservation agriculture practices.

Connection C: The uptake level of the CA agricultural practices in the region has an impact on the provision of public goods.

Connection D: The (perceived) improvement or decrease in the quality of public goods has an effect on the rural society's awareness towards them, which induces higher or lower pressure on the adoption



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Connection B: The interaction between the adoption factors determines a higher or lower uptake of the conservation agriculture practices.

Connection C: The uptake level of the CA agricultural practices in the region has an impact on the provision of public goods.

Connection D: The (perceived) improvement or decrease in the quality of public goods has an effect on the rural society's awareness towards them, which induces higher or lower pressure on the adoption of improved agricultural practices depending on society's differing awareness of different public goods.

Connection E and F: External factors like the willingness to pay for public goods and the cost-efficiency of the improved practice play a relevant role on the adoption factors. Moreover, public-goods provision also depends on external factors such as soil type and expansion of the organic community.

Connection G: Governance mechanisms affect the factors for the adoption of soil-conserving management, e.g. monetary incentives compensate farmers' losses due to management changes and therefore increase motivation and the ability to take part.

Fig. 2. Basic cognitive map elaborated from the mind-mapping exercises in the first three stakeholder workshops. Source: (own elaboration).

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The basic map served to reproduce the general cause-effects between society public goods and the different mechanisms at play as discussed in the stakeholders' workshops. The basic map was discussed and validated with researchers and experts of the CSR agricultural system and a questionnaire was designed and tested. The questionnaire comprised, on the one hand, the basic map as an explanatory overview. On the other, it included a detailed representation of the connections between the individual concepts. Weights were elicited to synthetize the magnitude and the direction of the connections in the network was achieved by means of individual interviews with 10 stakeholders who were selected from the stakeholder board to cover the range of affiliations and knowledge present in the stakeholder group. The interviews consisted of a general presentation of the basic map, and a structured discussion aimed at assigning a value (ranging from 0 = no impact to 6 = decisive impact) to the drafted connections linking the concepts. The interviewees were also invited to add and modify the connections between the different concepts, whenever they deemed it relevant. Finally, the stakeholders were asked to perform a pairwise comparison to weigh the impact of the clusters as a whole (e.g. the relative impact of 'External Factors' and 'Adoption of CA Practice' on the cluster 'Public Goods'). This step was introduced to facilitate a balanced weighting between concepts belonging to different categories (Kok, 2009; Saaty, 2013). The network derived from the questionnaires was subsequently analysed by means of graph-theory indicators (e.g. hierarchy level, centrality, out-degree and indegree values) and inference techniques (Özesmi and Özesmi, 2004).

The development of scenarios relied on stakeholders' narratives collected through a second round of individual interviews. The scenarios focused on contrasting global drivers (namely, dominant-market liberalisation vs. regional sustainability strategies) and their potential impacts downscaled to the regional context of the Marchfeld. Three general scenario contexts, namely Business As Usual (BAU), Market-driven Development (MKT), and Sustainability-driven Development (SUST), devised on the basis of the literature, were discussed (Nakicenovic et al., 2000; O'Neill et al., 2017; Schaller et al., 2017). The scenario discussion concerned a reasoned unfolding of existing patterns, drivers and trends in the Marchfeld to design plausible trajectories of changes in agricultural production (in terms of intensity), as well as socio-economic and environmental conditions. (A more detailed description of the general scenario narratives, as well as a description of the scenarios for the Marchfeld, is provided in Appendix B.)

The connections between the main scenario elements (socio-economic development, agricultural production and the state of the agri-

ecosystem) and the concepts included in the aggregate network were discussed in the fourth and last stakeholder meeting. The network was presented and a discussion was elicited to reach: a) agreed connections between the scenario factors and the concepts; and b) values depicting the scenario impacts on the network. During the same workshop, a preliminary FCM inference was presented to discuss and validate the results (cfr. Appendix C). The validation was based on providing different model settings (i.e. different inference approaches), discussing and interpreting the results concerning public-goods governance under the different scenarios and to collect feedbacks from the stakeholders to allow for the final calibration of the FCM.

The FCM inference was carried out by running the individual stakeholder models independently and averaging the final results. This approach was selected to attribute the same value to each singular opinion and to keep track of the different stakeholders' views (Forman and Peniwati, 1998). Bootstrapping was employed as a statistical test to account for the variability of the questionnaires on the accuracy of results. Finally, we employed the FCM as a quasi-dynamic simulation model (Jetter and Kok, 2014) to evaluate the effects of different levels of monetary incentives on public goods and adoption factors (Andreou et al., 2005). This exercise was aimed at getting insights into the efficiency of the collective and private-based governance strategies and, in particular, at comparing their different effectiveness under projected trajectories of socio-economic changes.

3. Results

The network outlined by the stakeholders for the CSR featured a low hierarchy value of the network (average hierarchy value $= 4 \cdot 10^{-4}$; Table 1) which indicates how the governance dynamics at landscape level involve an intricate system of cause-effect mechanisms (Özesmi and Özesmi, 2004) (cfr. Appendix A). The adoption of CA practice, adoption factors and monetary incentives resulted in the concepts with the highest overall weight in the network, as evidenced by their centrality scores. In particular, the high centrality of the private self-governance scheme was mainly related to a high outdegree value, whereas indegree and outdegree of the collective bonus were more balanced. Beside the monetary incentives, the local collective partnership initiative was perceived as a governance element featuring a number of connections in the cognitive map and the highest centrality among the non-monetary initiatives.

The connections outlined in the stakeholders' questionnaires were framed in an aggregate structure depicting the public-goods governance network (Fig. 3). Two major loops can be disentangled in the network. The first loop (in blue in the figure) is directly related to the network developed in the three stakeholder workshops and depicts the relation between adoption factors, the adoption of CA practices, the effects on public goods, and the awareness of rural actors toward public goods. The second loop (in red in the figure) was identified by the stakeholders during the questionnaires and concerns the links between the monetary and non-monetary governance initiatives. The other concepts in the network act mainly as transmitters which are directly influenced by the scenario factors.

The equilibrium values calculated for the BAU scenario provide a first analytical step sketching an overview of the stakeholder understanding of the governance perspective in the Marchfeld (Fig. 4). Values at equilibrium of monetary and non-monetary tools were relatively close, highlighting how the latter were considered important factors in driving the governance system. The range of differences resulting from the 10 questionnaires was however particularly wide for the governance mechanisms (except for the awareness-campaign factor), underlining an important divergence among the stakeholders' views. Conversely, the expected impact of adoption and adoption factors in the network was homogenous across the stakeholders. Overall, the impact of the rural actors' awareness towards public goods in driving the network was evaluated as less important in comparison to other elements such as the motivation of farmers and their ability to adopt improved practices. However, the different values of the impact of rural actors in the network pointed to a rather different opinion of the stakeholders as to the role played by the wider rural society on the governance of public goods.

The difference in equilibrium values under the different scenarios is remarkable (Fig. 5). In the MKT scenario, public goods, agriculture, farmers' motivation and ability, and some governance tools reached lower equilibrium values. This result was interpreted by the stakeholders as an effect of the market logic featuring MKT, in which a strong focus on efficiency and cost reduction would put high pressure on global markets to compete. MKT results also outlined a lower efficacy of regional marketing in valorising the regional food-supply chain. In contrast, rural society's (except farmers) awareness and interest towards public goods were expected to be higher in both scenarios, in comparison to the BAU. This effect was linked by the stakeholders with: a) the progressive deterioration of public goods in the MKT scenario, attracting greater attention from hunters and new rural dwellers, and b) the expected general higher awareness in the SUST scenario, generating more interest in the adoption of CA practices across rural society. These effects are also consistent with the higher relevance resulting in both MKT and SUST for the awareness campaign tool. In the SUST scenario, collective bonus and the local partnership are clearly more important than in MKT in leveraging the improvement of public goods. A further result concerns the limited difference between soil and water quality between BAU and SUST scenarios. This result was confirmed by the stakeholders as they generally attributed a long-lasting legacy of intensive-agriculture practices on these public goods. For instance, based on the long groundwater-retention phase, the stakeholders estimated in decades the time required for the decaying of pollutants in the huge groundwater reservoir of the Marchfeld. Scenario effects on landscape and habitats were more promptly linked to the change in agricultural practice. In particular, the MKT scenario denoted a significant drop of landscape-related conditions.

The quasi-dynamic simulation focusing on the monetary schemes revealed different expected effectiveness for different incentive levels under the three scenarios (Fig. 6). This difference was particularly evident at the lower-intensity level of monetary incentives, where the effectiveness in terms of public-goods provision in the SUST scenario is clearly higher than in the other two scenarios. From the quasi-dynamic simulation, it is obvious that monetary incentives are less effective in the MKT scenario. The simulation also highlighted that, due to their lower effectiveness, higher rates of monetary tools were far more needed in the MKT scenario to cope with environmental degradation. Lower incentive rates were effective in the SUST scenario, whereas the potential of low incentive rates to limit agriculture impacts on public goods resulted as irrelevant in the MKT scenario. This result was particularly evident for landscape quality.

4. Discussion

Applying a participatory approach for the assessment of governance tools for the improved provision of public goods in the CSR and weighing mutual influences and the efficiency of these mechanisms, brought to the fore a variety of factors of failure or success. In general, the FCM elaborated the stakeholder view of the CSR and outlined clearly that an adoption of more sustainable practices is strongly driven by monetary incentives. However, the results also clarify that a range of less tangible processes linked to local society, perception of public goods and non-monetary initiatives steer a more efficient embracing of environment-friendly practice change.

The high centrality value reached by farmers' motivation in the adoption factor cluster demonstrates how that aspect is a central issue in the governance of public-goods provision from agricultral landscapes. This may appear obvious, but the emerging connections between farmers' motivation and ability towards public-good-friendly

Table 1
Fuzzy Cognitive Mapping description based on graph theory. Average values of outdegree, indegree and centrality (standard deviation values are in *italics*) are presented for the network elements. Outdegree is the sum of the connection weight outsourcing from a factor, indegree is the sum of the connection weight entering into a factor. Centrality is calculated for each concept as the sum of indegree and outdegree (Ozesmi and Özesmi, 2004). Source: (own elaboration).

Matrix hierarchy value: $4 \cdot 10^{-4}$ (range $2 \cdot 10^{-4}$; $8 \cdot 10^{-4}$)

Cluster	Concept	Acronym	Outdegree		Indegree		Centrality	
Society's awareness (Marchfeld)	Agriculture	Far	1.61	*0.4*	0.72	*0.2*	2.33	*0.5*
	Hunters	Hun	0.78	*0.3*	0.53	*0.2*	1.31	*0.4*
	New inhabitants	Nct	0.52	*0.4*	0.58	*0.2*	1.09	*0.5*
	Rest of (rural) society	Rpo	0.60	*0.4*	0.44	*0.2*	1.04	*0.5*
Adoption factors	Motivation for adoption	Mot	0.84	*0.2*	4.22	*0.5*	5.06	*0.6*
	Ability of adoption	Abi	0.71	*0.1*	2.83	*0.5*	3.53	*0.6*
	Demand for adoption	Dem	0.53	*0.3*	3.53	*0.9*	4.06	*1.1*
	Legitimacy of adoption	Leg	0.45	*0.2*	3.22	*1.3*	3.67	*1.4*
CA practice adoption	CA practice adoption	Ado	1.33	*0.3*	2.47	*0.5*	3.80	*0.6*
Public goods	Soil fertility via optimal share of humus	Soi	1.13	*0.4*	1.35	*0.3*	2.48	*0.5*
	Ground water quality	Wat	1.01	*0.4*	1.21	*0.3*	2.22	*0.3*
	Landscape quality (biodiversity/habitats)	Lan	0.57	*0.2*	1.08	*0.3*	1.65	*0.5*
Monetary incentive schemes	Collective bonus	Col	2.21	*0.8*	1.25	*0.7*	3.46	*1.1*
	Private-governance scheme (private retailer)	Sel	2.23	*0.7*	0.86	*0.7*	3.08	*1.3*
	Local collective partnership	Loc	2.03	*0.7*	0.34	*0.2*	2.36	*0.7*
Non-monetary initiatives	Regional marketing/ labelling	Mar	1.26	*1.1*	0.55	*0.5*	1.80	*1.3*
	Awareness campaign	Awa	1.34	*0.8*	0.07	*0.2*	1.40	*0.9*
Soil type	Soil type	Sty	1.10	*0.3*	0.00	*0.0*	1.10	*0.3*
Cost efficiency of CA practice	Cost efficiency of CA practice	Cef	0.96	*0.3*	0.00	*0.0*	0.96	*0.3*
Organic farming community	Organic farming community	Org	1.35	*0.7*	0.10	*0.0*	1.45	*0.7*

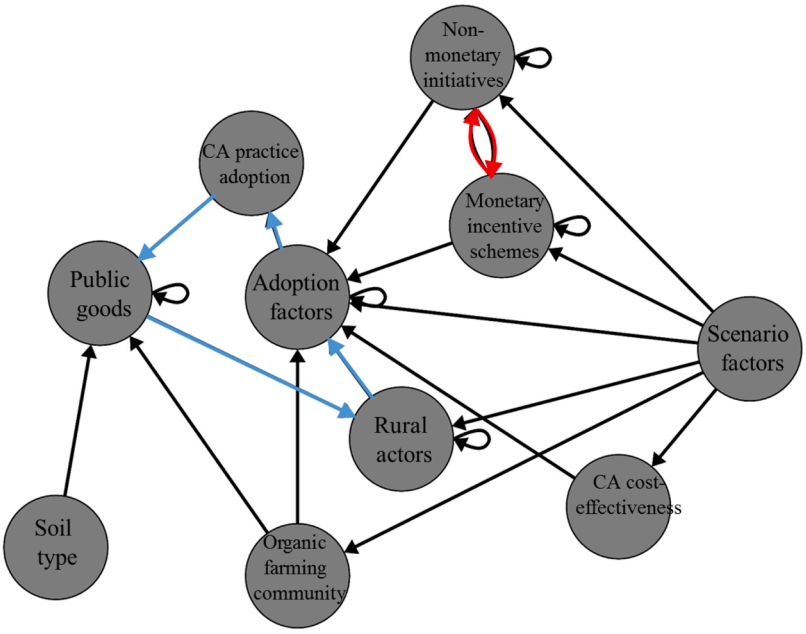

Fig. 3. Aggregated network of the fuzzy cognitive mapping as resulting from the stakeholders' laboratories and questionnaires. Scenario factors are: 'Agricultural Production', 'Agro-ecological Conditions', 'Socio-economic Development'. Two main loops were evidenced by the stakeholders during the network co-development: "Public goods, Rural actors, Adoption factors, CA practice adoption, Public goods" and "Non-monetary initiatives, Monetary inititatives, Non-monetary inititatives" (respectively blue and red arrows in the web version of this article). The factors included in the network clusters are presented in Table 1 (cfr. Appendix A for the disaggregated network). Source: (own elaboration).

management practices are less trivial: The stakeholders stated that higher motivation determines higher interest and consequently higher ability. This result indicates that governance tools able to link motivation with ability could trigger important synergies. For instance, in an intensive agricultural area such as the Marchfeld, where attitude and motivation of farmers is strongly oriented towards production, an improved governance of public goods should include innovative solutions towards sustainable productive agriculture rather than focusing on AES measures targeted at reducing the productive potential and ruling out technology. This is relevant because AES often tend to take a backward-looking approach, for example focusing on traditional practices. During the participatory process, the shift towards more sustainable practices was indissolubly linked with the ability to adopt innovative approaches able to combine production with public goods and the building of new collaborative institutions. However, the stakeholders' consideration of the potential of increasing ability through the learning processes attached to the collective bonus and the private-based scheme (i.e. because of self-monitoring and neighbouring effects) was less straightforward. This does not mean that those impacts are negligible but rather that their effects probably refer to a medium and long-term timeframe and depend on farmers' individual attitudes. As a general perspective, the results from the CSR suggest that CAP objectives such as innovation and efficiency should not generate contrasts with the target of public goods. In a context of projected budget reduction for the CAP (COM 2017 713), this is even more relevant as the consideration of rural-society dynamics and actors will be far more necessary to ensure a cost-effective design of policies able to promote natural-resource management in agricultural landscapes.

In the FCM, a high number of interactions driving the effectiveness of the governance tools - that would have been disregarded in more

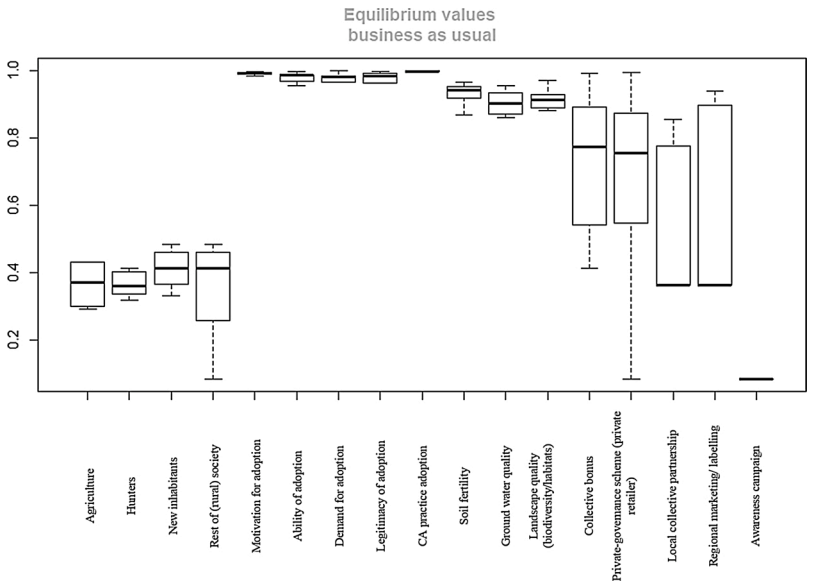

Fig. 4. Values at equilibrium for the Business as Usual scenario. The Box-plot outlines median, inter-quartiles, and the range of minimum and maximum values at equilibrium of the Fuzzy Cognitive Mapping elements as resulting from the 10 questionnaires. Source: (own elaboration).

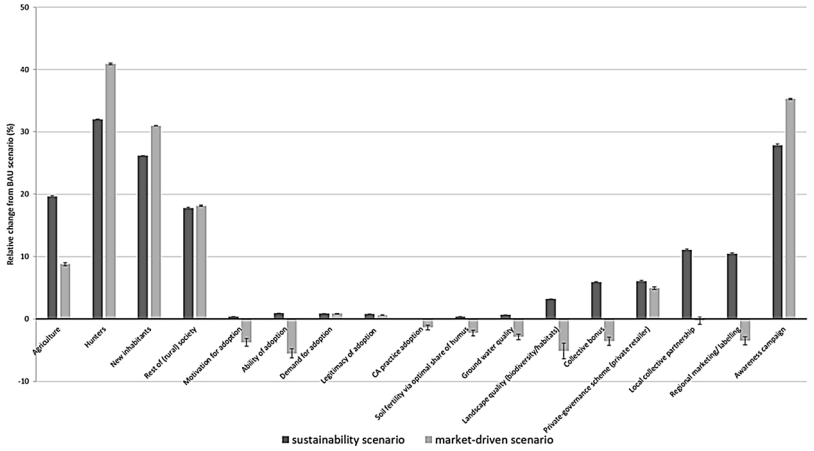

Fig. 5. Comparison of equilibrium values among the three scenarios. Differences are presented as relative change of the equilibrium values under the market-driven and sustainability scenarios in respect to the Business as Usual scenario. Bars indicate 95% confidence intervals from bootstrapping with 1000 replicates and replacement. Source: (own elaboration).

standard economic evaluations - could be identified. For instance looking at the non-monetary incentives, the high centrality attributed to the local partnership highlights the pivotal role of local social networks in comparison to more drafted mechanisms such as regional marketing and awareness campaigns. In the CSR, the potential infrastructure development and/or the access to knowledge and technologies (i.e. machinery and electrical grid development) attached to the local partnership was an important leverage for the successful establishment of that institution. In this regard, it is interesting to notice the complementary role of the local partnership and the awareness campaigns on the concepts included in the adoption factors cluster: In the network, the local partnership has a high influence on three of the four concepts (namely motivation, ability and legitimacy), whereas the awareness campaigns has a strong influence on the demand. Looking at the monetary incentives, the high centrality of the collective bonus highlights the relevance attributed to that governance tool in the network. However, the impact of the collective bonus results strongly dependent on the scenarios. For instance, its relevance was clearly lower under the market-based scenario.

The variability of opinions between stakeholders is clearly related to the wide range of expertise. In particular, it should be noted that a wide variety of knowledge addressed the governance tools and their effectiveness in affecting the adoption of conservation practices. Nonetheless, several network concepts denoted a converging perception between the stakeholders. For instance, the impact of the four adaptation factors on improving the final adoption of CA was consistently evaluated across all stakeholders. On the other hand, other concepts outlined a wider variability between the stakeholders. For example, some stakeholders considered the organic-farming community as an impediment to promote CA adoption because of the related problems of weed management in organic systems. Other stakeholders were of the opposite opinion assuming higher motivation, attitude and management ability in the organic community towards practices able to enhance the soil health. This confirms that identifying an optimal governance of public goods pertains to the domain of wicked problems and the efficiency of a policy intervention might be affected by a plethora of local features (Guimarães et al., 2018). Even though different governance settings may be considered optimal by different stakeholders, adopting a transdisciplinary approach helped to reveal the range of aspects linked to the different socio-economic, environmental and agricultural settings that

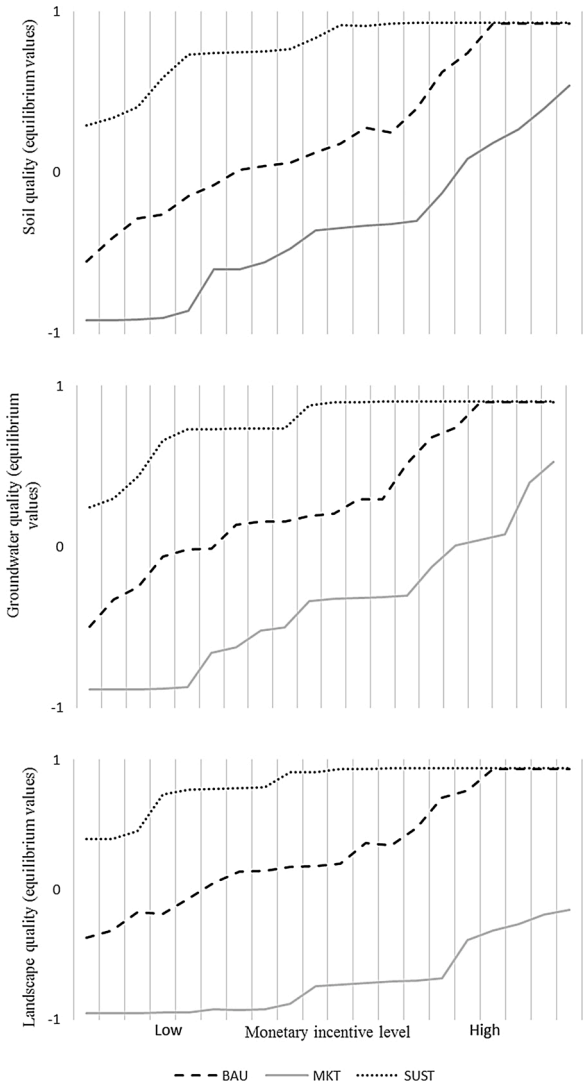

Fig. 6. Quasi-dynamic simulation. Results of soil, groundwater, and landscape/habitats quality. Equilibrium values for different monetary-incentive levels and under the three socio-economic scenarios. Results are presented for increasing progressively higher levels of 'Collective Bonus' and 'Self-governance' schemes. Source: (own elaboration).

concur with the success or the failure of a governance tool.

Another relevant result of the study concerns the loop between the local rural actors' awareness of public goods change, the demand of environment-friendly agriculture and the practice adoption, as a mechanism able to play a certain influence on agriculture impacts on the landscape[4] . Our results endorse the presence of expectations in rural societies which can generate pressure on agricultural management and consequently stimulate the adoption of environment-friendly practices (Cumming et al., 2014). However, in the Marchfeld this pressure alone was not sufficient to have the necessary momentum to drive farmers' behaviour and it was strongly affected by the different scenario contexts. It is evident from the results though, that underestimating such social processes in the design of agricultural governance systems might lead to erroneous and incomplete evaluations, as these soft dynamics can act as catalysts of a smart public goods management. The FCM results on the diverging expectations and capacities of different sectors of the rural society to perceive the state and the changes of the public goods, are also interesting. In the CSR, hunters resulted as the rural actors with significant attention paid to public goods due to their interest towards a better game fauna management. That is outlined by their high values at equilibrium in both scenarios. Since many farmers are also hunters in the CSR, a deeper understanding of the role of hunter associations could therefore deserve further attention in the Marchfeld. In contrast, the role of the other rural actors denotes a lower capacity to link their perception with public goods and generate actual pressure on improving agriculture management. For policy design, the identification of key actors might be crucial as these actors can represent entry points for successful governance mechanisms. Moreover, these results support theoretical approaches advocating the necessity to reconnect people's perceptions and community governance with the biosphere. Promoting an inclusive co-management of the landscape should thus be very carefully considered in the design of agricultural policies (Carpenter et al., 2006; Chapin et al., 2010).

In this context, it is relevant to consider the temporal scale. The stakeholders strongly outlined that the time lags between adoption of environmental practices and effects on public goods such as soil and water quality were a relevant hurdle for the implementation of local interventions. FCM are typically unable to provide results which fit to a specific timeframe and that should be considered as a peculiar limitation of the study. Nonetheless, the model clearly highlights the stakeholders' vision concerning the difficulty of improving the delivery of public goods (at least in the short-/medium-term considered) in an intensive agricultural area as the Marchfeld. In our participatory model, the prompter effect of the improved practices adoption on the landscape was the main pulling on public goods perception. That could suggest the usefulness to design AES packages targeting at the same time fast- and low-changing public goods. For instance, the private-based tool included the measurement of soil parameters following a result-based payment approach. That approach is acknowledged to steer the attention of farmers towards the potential improvement of environmental services such as soil fertility (Burton and Schwarz, 2013). However, the time lag between CA implementation and soil improvement was perceived by the stakeholders as a major bottleneck hampering the effectiveness of the private-based incentive scheme.

Comparing the potential effects of two scenarios, the model revealed a rising social pressure on public-goods provision from agriculture for both the MKT and SUST cases. Positive pressure towards public goods provision was also expected from the growing organic-farming movement. That may be linked with a higher market demand for sustainable products which was expected by the stakeholders in the SUST scenario. Nevertheless, that higher pressure from rural society was translated into a limited difference in the adoption-factors cluster in comparison to BAU. This suggests that the stakeholders perceive a clear disconnection between rural society's will and actual agriculture management in the Marchfeld. However, the higher effectiveness attributed to the collective bonus and the local partnership under the SUST scenario suggests that such a disconnection has a strong leverage on these tools and their weight for improving public-goods governance. Our results also outline a general stakeholders' scepticism regarding the capacity of monetary measures alone as a panacea for the public-goods issue. In other words, as demonstrated in the SUST scenario, a smart and cost-effective governance of public goods can be achieved if the general socio-economic context is supportive and integrated with the agri-environmental objectives. Indeed, the positive context envisaged in the SUST scenario supported a stronger impact of non-monetary tools that in turn explains why –in that scenario - lower monetary incentives are considered strong enough to catalyse the adoption of environment-friendly agricultural production.

The MKT scenario reflects a greater difficulty in counterbalancing the negative externalities of agriculture by means of policies and mechanisms in that socio-economic context. This difficulty is contextual

[4] Here we refer to landscape as defined by the European Landscape Convention as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (European Landscape Convention, 2000).

to the market logic featuring the MKT scenario, in which the stakeholders expected a strong focus on efficiency and cost reduction to be able to compete in global markets. This is confirmed by a projected lower efficacy of regional marketing in valorising the regional food-supply chain. In these conditions, the stakeholders identified the lower interest of farmers towards collaboration and the related lower potential for collective-bonus initiatives as a major hurdle for a successful landscape governance of public goods. Our results therefore stress how exasperated pressure from markets on cost reduction and efficiency of agricultural production may jeopardise the efficiency of public-goods governance and squander the existing potential for the adoption of environmental practices. Our results strongly support the common idea that market-driven production will likely increase the environmental impacts of agriculture and require stronger monetary incentives to internalise the rising costs of agriculture externalities (Tilman et al., 2002). That stakeholders' vision was summarised by the need for a consistently higher budget earmarked for agri-environmental policy to counteract the negative pull of the MKT scenario on agricultural externalities. However, in a market-driven scenario such higher budgetary availability for the environment would likely not be present. Moreover, the lower efficacy of monetary incentives in the MKT could involve the need for a shift towards regulations to avoid the consequences of environmental degradation. However, a regulation-dominated scenario was not included in our evaluation.

In addition, the results from the Marchfeld support the link between social capital and individual actions related to the environment (Pretty and Ward, 2001). This aspect is related to the reported positive influence of social relations on the adoption of new technologies and practices including CA (Knowler and Bradshaw, 2007). In the CSR, the attitude of landowners towards collaboration under the different scenarios was reported as a relevant factor by the stakeholders and thus an important driver of change. The importance of strengthening the existing collaborative context through local partnership was also stressed. Indeed, the individual interest of farmers in getting involved, learning about environment-friendly practices, confronting and adapting their practices through neighbouring effects was a keystone of the stakeholder narrative about the collective-bonus mechanism. In particular, the stakeholders were confident about the success of the local partnership initiative and a collective governance tool was seen as highly possible in the Marchfeld. The success of the partnership was mainly linked to the range of additional benefits for farmers (in particular, access to infrastructure development and shared machinery). In economic terms, we could define these additional benefits as a means of overcoming the transaction costs incurred by the local actors involved (Beckmann et al., 2009). Among these benefits, the possibility to accede to the additional monetary bonus granted by the collective CA adoption was clearly considered an important leverage by the stakeholders (Zavalloni et al., 2018).

5. Conclusions

The development of the FCM aimed to deliver results specifically linked to the context of the Marchfeld and meaningful for local decision-making. Nonetheless, some conclusions can have a wider validity for public-goods governance and can therefore be useful in different agricultural regions.

The FCM approach allowed the unpacking of a wide range of aspects which influence the effective design of governance mechanisms for public-goods provision. In particular, soft factors like the presence of local social networks, the perception and awareness of public goods, and farmers' motivation for and ability to adopt CA would have been disregarded in more standard economic evaluations which are normally based on tangibles and hard-data sources. Even though soft issues may have a more limited impact on farmers in comparison, for example, to monetary incentives, their consideration helped to interpret and take into consideration the relative weight of the interconnections between the components of the system.

Monetary incentives were considered the main leverage to steer towards environment-friendly agriculture, but also the way in which local institutions respond, integrate, and organise incentives was relevant. This is dependent on human and social capital, and the effectiveness of governance is thus strongly dependent on the socio-economic scenario. For instance, an excessive market-orientated scenario was expected to generate a race to the bottom with detrimental effects on the environment and on the general interest towards good management of production factors (including soil) which is usually acknowledged to farmers' communities (e.g. Vanclay, 2004). Therefore, our results advocate that the discussion around governance based on monetary incentives should integrate a range of ancillary factors and preserve a link with local consumers (e.g. via regional markets) to limit the drawbacks accompanying an export-led agriculture such as the disconnection between markets and externalities of production (Pretty 2012). In this respect, the definition of an agri-environmental-practice package able to enhance a bundle of public goods resulted as a successful strategy in the CSR because it was linked to different stakes affecting different actors in society and to different time-scales. This strategy seemed to help reinforce the links between rural society and agricultural management and it underlined further the need to consider ongoing rural changes and their connection with rural vitality as a facet of the governance of public goods.

The centrality of the local partnership initiative was important for effective governance in the Marchfeld. The possibility of providing additional benefits (e.g. potential infrastructure development, access to technologies, etc.) for the farmers involved was an important leverage acknowledged by the stakeholders for the successful establishment of the partnership. Nonetheless, heterogeneous ideas were present among the stakeholders concerning the effectiveness of governance initiatives and the attitude of different farmers to adopting CA practices. That limits the translation of our results in an operational context, but it also highlights the range of opinions and ideas about the issue.

Finally, it is significant how in this study the emphasis for the development of public-goods governance was not in contrast with innovative approaches. AES design in an intensive agricultural area such as the Marchfeld should be able to incentivise innovative solutions towards productive and sustainable agriculture, instead of introducing measures only targeted at reducing the productive potential and ruling out technology. In particular, the potential of incentives to steer the motivation of landowners and facilitate the adoption of environment-friendly practices should be considered together with their long-term impacts on learning and ability. Those aspects are indeed relevant for facilitating the transition towards the knowledge-intensive systems which are considered necessary for improving agricultural sustainability in the future (Tittonell et al., 2016).

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Conflict of interests

The authors declare no conflict of interests and wish to thank the local stakeholders for their active participation in the meetings and interviews. The comments of two anonymous reviewers on an early version of the paper are gratefully acknowledged.

Authors' contribution

S.T. contributed to the development of the participatory approach and the interviews, developed the methodology, interpreted the results,

and wrote the manuscript. L.L.S. leaded the participatory approach, the interviews, supported the writing and revisioning of the text, and developed with S.T. the network mapping. J.K. supervised the research, contributed to the development of the methodology and interpretation of the results. All the authors contributed to conceive the original research idea.

Fig. A2. Mapping process (own picture).

Appendix A

A Participatory design and evaluation of alternative options for public-goods governa

5. Approaching the notion of public goods and identifying major public-goods issues

The participatory process of the development of alternative governance mecha ld in the Marchfeld on 24.02.2016 and involved six regional stakeholders. The worksho fying (see Fig. 1) and mapping the main public-goods issues in the region (see Fig. 2) (Marconi et al., 2016; Novo et al., 2015 and Novo et al., 2017). The identification of public-goods issues followed a common discussion round, after which each stakeholder named the three most important issues from their personal point of view. The mapping of public-goods issues was carried out on the basis of a topographic map, where specific areas of public-goods provision have been indicated (Figs. A1 and A2)

Sketching weaknesses of current governance system and governance options for improvement

The intention of the next step of participatory design of governance option was to learn which governance-related deficiencies lead to mismatches between demand and supply of public goods on a local level and how mechanisms need to be improved so that deficiencies can be overcome. The expected outcomes of this step were i) gathering insights into the most important failures and mismatches of the current governance systems, ii) developing criteria for good governance mechanisms, and ii) elaborating an overview on the system of relationships determining the local PG issues (including the relevant PGs at stake, the local actors, as well as the factors affecting agriculture/forestry and the production of PGs). In order to address the objectives, a second local workshops was held on 20 June 2016. To reach Outputs **i)** and **ii)**, the failures of the current governance systems, as well as the criteria for good governance have been identified in common round-table discussions at the workshops. As regards Output **iii)**, the identification of the system between actors, mechanisms and PG provision was discussed on the basis of mind maps/systems diagrams of the main public-goods issue (s) in the region. At the workshop, the stakeholders commonly elaborated on relationships and factors representing and driving the system (Fig A3)

Designing mechanisms for improved PG provision

The expected outcomes of the step of designing alternative options for public-goods governance were specific governance mechanisms or mixes of mechanisms, optimised to solve the local public-goods issue and reach the defined target levels. In our study, the design of the mechanisms was part of the activities of a third local stakeholder workshops, which was held on 20 April 2017 and involved 14 stakeholders. As the focus of these workshops was particularly on governance development, importance was attached to including stakeholders from the level of decision and policy- making, agriculture, forestry, trade/value chain, as well as the conservation sectors. The design of specific governance mechanisms took into account the suggestions of mechanisms from the preceding workshop's mind map and sixpredefined criteria of good governance mechanisms. The activity was carried out in the form of group exercises at the workshops. Based on the results of the preceding second workshop, before the third workshop the research team prepared tablecloths, on which they picked up and described again the most relevant 'Public-goods/governance mechanisms pairs' which had already been identified. Making use of these descriptions, the stakeholders/experts re-discussed the suggested GMs and recorded their discussion results directly onto the media provided for the exercise.

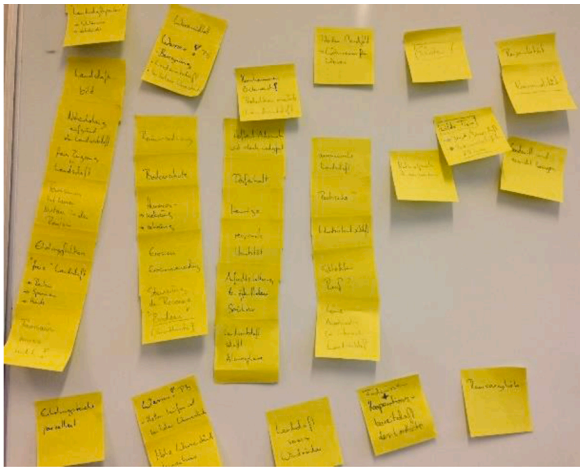

Fig. A1. Identification of main public-goods issues and sensitivities in the Marchfeld (own picture).

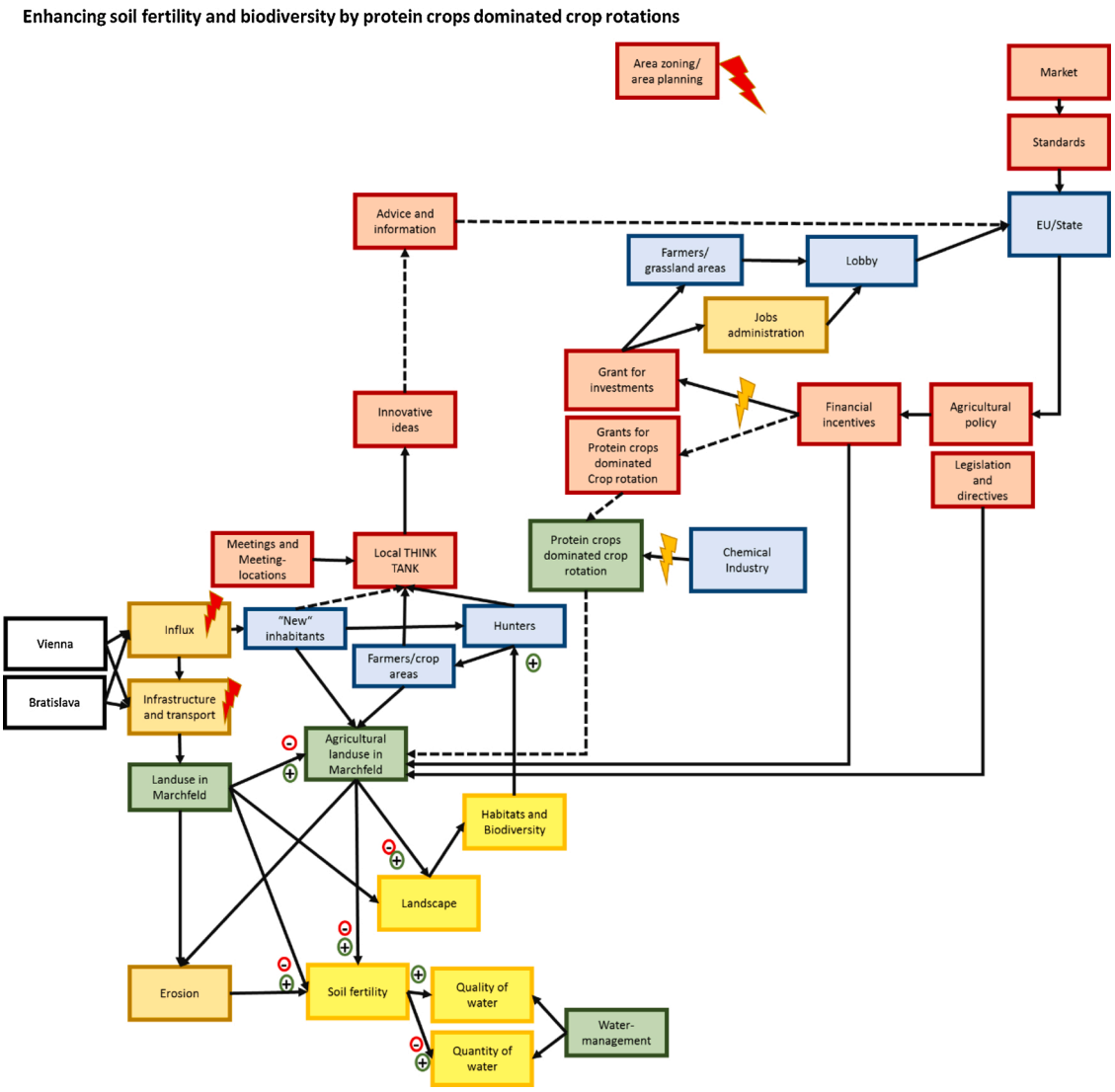

Fig. A3. Mind map for the public-good soil fertility as designed by the stakeholders in the second workshop.

Stakeholder interviews for building the FCM

For building the final FCM and for eliciting weights, first a basic cognitive map was developed by using the information from the second stakeholder workshop mind map. This mind map was developed into a questionnaire, in which the connections between the individual concepts of the basic mind map were visualised as drafted connections. In 10 individual interviews, carried out in the first half of 2016, stakeholders were asked to validate or change/amend the drafted connections and weigh the effects of the connections: First of all, they had to decide if the connection is stimulating (+) or (de-stimulating (-); secondly, they had to estimate the strength of the effect on a scale from 0 (no effect) to 6 (decisive effect). An example is shown in (Fig. A4)

Whole FCM network as derived from the stakeholders' questionnaires (developed with the Mental Modeler on-line tool, see www.mentalmodeler.org).

Appendix B

Development of scenarios

8. Developing general scenario narratives

Three general future-scenario narratives, describing possible social, economic, technological and policy pathways at a global level under a business-as-usual, market-driven and sustainability-driven development, have been developed based on a literature review (Schaller et al., 2017) . They mainly included the scenario narratives of Nakicenovic et al. (2000), which was used a basis for further elaborations, e.g. by adding further narratives such as status quo ("Middle of the road") by (O'Neill et al., 2017) or by developing special foci on, for example, land use (Ewert et al., 2005) or agricultural management (EPRS, 2016). As general scenario narratives, a business-as-usual scenario (BAU), inspired by O'Neill et al.'s (2017) "Middle of the road" scenario, a market-driven (MKT) scenario where the provision of environmental public goods is rather neglected (economic) and a sustainability-driven scenario (SUST), where the provision of environmental public goods is in the focus of development, were considered. In the

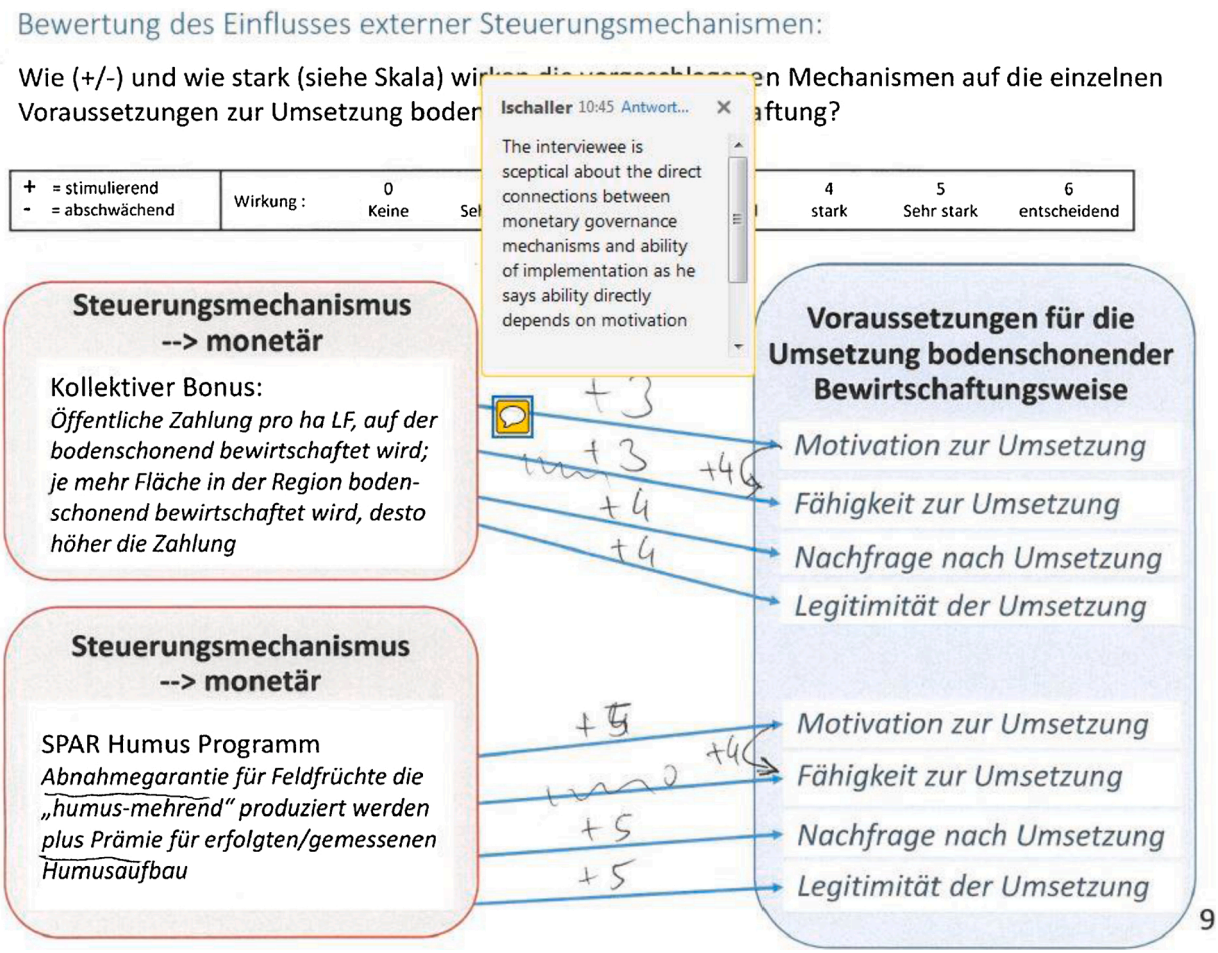

Fig. A4. Example of weighting exercise. Here, the connections and their strength between monetary and non-monetary governance mechanisms and the factors for adoption were discussed and weighted. It is worth noting that the interviewee weighted all connections as stimulating (+), with weights between strong (3) and decisive (6). It can also be seen that the interviewee doubted the connection between governance mechanisms and ability of adoption, including instead a strong connection between motivation and ability of adoption.

scenarios, the development directions of global and local are disregarded, but at a case-study level they could be re-introduced as preferential dimensions for sub-scenarios if relevant in the respective CSR. No scenarios on the development of the Common Agricultural Policy were considered in the general narratives – as the aim of the exercise is to learn, how policy has to react under the conditions of the single scenarios. Table comprises the three general scenario narratives. The scenarios are designed for a medium-term perspective (10–20 years) (Table A1)

Table A1
PROVIDE narratives on socio-economic and natural development.

Scenario	Business as Usual (BAU)	Sustainability-driven (Sust)	Market-driven (Mkt)
Climate change	as given (two-degree increase will be not achieved)	max two-degree increase	significantly more than two degrees
Population increase	as given (moderate)	low	high
Consumption patterns and willingness to pay for public goods	as given (low willingness to pay for public goods)	significant willingness to pay for public goods	no willingness to pay for public goods
Prices of inputs, particularly oil	as given (moderate)	high, clearly reflecting scarcity	low, not reflecting long-term scarcity
market price volatility	as given (high)	moderate	extreme
Technical progress	as given (without fundamental breakthroughs)	significantly, clearly environmental oriented	extraordinary, clearly market oriented

In order to give a deeper insight into the underlying rationality of our scenarios, in the following paragraph we offer a short narrative description of the general scenarios.

Scenario narrative 'Business as Usual' (BAU)[1)]

'The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Most economies are politically stable. Globally connected markets function imperfectly. Global and national institutions work toward but make slow progress in achieving sustainable development goals, including improved living conditions and access to education, safe water, and health care. Technological development proceeds apace, but without fundamental breakthroughs. Environmental systems experience degradation, although there are some improvements and overall the intensity of resource and energy use declines. Even though fossil fuel dependency decreases slowly, there is no reluctance to use unconventional fossil resources. Global population growth is moderate and levels off in the second half of the century as a consequence of completion of the demographic transition.'

[1)] quoted and italic marked text taken from the scenario narrative 'Middle of the road'', published by O'Neill et al. (2017)

Scenario narrative 'Sustainability driven' (SUST)[2)]

'The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Increasing evidence of and accounting for the social, cultural, and economic costs of environmental degradation and inequality drive this shift. Management of the global commons slowly improves, facilitated by increasingly effective and persistent cooperation and collaboration of local, national, and international organizations and institutions, the private sector, and civil society. Educational and health investments accelerate the demographic transition, leading to a relatively low population.' Measures to reach the common global climate-change goals on emission mitigation are consequently implemented; the maximum two-degree increase in temperature is paradigm. 'Consumption is oriented toward low material growth and lower resource and energy intensity'. Technical progress is clearly orientated towards the 'development of environmentally friendly technologies'. Due to the internalisation of external effects, the prices of natural resources, in particular of fossil fuels, are high and clearly express scarcity. Clear regulations and international agreements structure markets and reduce price volatilities.

[1)] quoted and italic-marked text taken from the scenario narrative 'Sustainability-Taking the green road', published by O'Neill et al. (2017)

Scenario narrative 'Market driven' (MKT)[3)]

'Driven by the economic success of industrialized and emerging economies, this world places increasing faith in competitive markets […] to produce rapid technological progress […]. Global markets are increasingly integrated, with interventions focused on maintaining competition'. The 'push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy.' 'Market dynamics play a central role […] and the economy is booming. People rely heavily on technology and witness rapid technological developments'. Since rapid technological progress also enhances the opportunities to exploit natural resources, the prices of fossil fuels and other resources will stay low or even decrease (at least within the next decade). As a consequence, carbon dioxide emissions are significantly increasing and the goal of a maximal two-degree increase in temperature clearly risks being not achieved. Global population increase will continue, although it may peak and decrease later on. There is high demand for agricultural products, but the willingness to pay for public goods is almost not given, since people 'place trust in technological development and the mechanisms of the market to solve problems'.

[1)] quoted and italic-marked text taken from the scenario narrative 'Economic optimism/Fossil-fueled development—Taking the highway', published by O'Neill et al. (2017) and from the scenario narrative 'Scenario 1 – Economic Optimism', published by EPRS (2016)

Development of local scenarios

The general scenario narratives were adapted to the local context of the Marchfeld by integrating the knowledge of six local stakeholders who were interviewed in June and July 2017. In the first step of the interviews, the general-scenario narratives were introduced to the interviewees. In the following, guided by a scenario questionnaire, stakeholders identified the main effects of the single-scenario narratives on the specific situation in the case study, namely on agricultural production, natural conditions, socio-economic conditions, price developments and resulting market conditions (see Fig. A5).

The answers of the six respondents have been collated and local- and context-specific scenarios for the Marchfeld have been elicited:

The BAU scenario was defined by current dynamics with stable conventional arable production and a slight growth in organic production. In that scenario, climate change was expected to aggravate water scarcity and groundwater pollution, inducing the introduction of adapted crops in the rotations and irrigation, where possible.

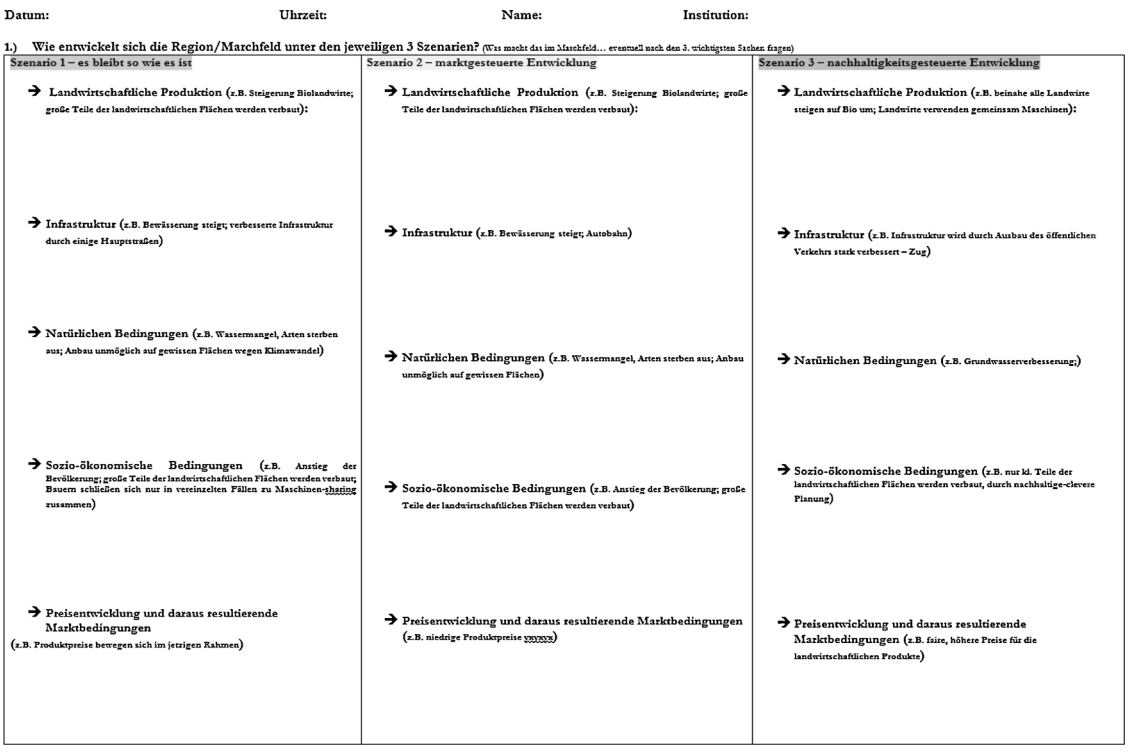

Fig. A5. Questionnaire for the development of local scenarios.

Under the MKT scenario, higher global competition was considered as leading to lower prices for agricultural products and lower costs for agricultural inputs. Conventional arable production in the Marchfeld was thought to increase together with the intensification of irrigation, whereas organic farming was expected to drop and be more dependent on public incentives. General interest for voluntary efforts to achieve ecologically sound management was expected to reduce significantly. Groundwater quality under the MKT scenario was expected to decrease due to the combined effect of intensive production and climate change: the increased use of agricultural inputs will aggravate groundwater pollution, whereas reduced rain will slow the groundwater-reservoir turnover. The strong growth of the population, in combination with the presence of large farms, will further lead to strong land pressure which will have a negative effect on rural vitality due to the structural changes in the agricultural sector.

Under the SUST scenario, regulations in the direction of ecologically sustainable management will force conventional farms to focus on ecologically sound management practices. At the same time, the share of organic farms will increase and the ecological status of the region will improve progressively. Climate-friendly soil-management techniques will increase humus accumulation and carbon sequestration in the soil. This will consequently lead to an increase in groundwater quality; however, it will be slow.. New marketing strategies and rising demand for sustainable high-quality products will make it possible to generate an adequate income, so farm structure in the Marchfeld will remain stable.

Appendix C

Development of the FCM model

The FCM included a range 23 concepts $C = \{C_1, C_2, \ldots, Cn\}$. Each connection between the concepts is characterised by a weight $w_{ij} \varepsilon [-1; +1]$ synthetising the magnitude and direction of the impact of concept C_i on concept C_j in the network. The weights derived from individual interviews assigned a direction (+ for a stimulating effect or – for a de-stimulating one) and intensity (ranging from 0 = no impact to 6 = decisive impact) to the connections. The FCM inference followed the generic update function proposed by Kosko (1986) and modified by Stylios and Groumpos (2004) to allow for the presence of transmitter concepts which are not influenced by other concepts in the model (Felix et al., 2017).

$$C_i^t = f_i\left(\sum_j^n \left(w_{ji} * C_j^{t-1} + C_i^{t-1}\right)\right) \quad (1)$$

A transfer function was also applied to regulate at each iteration the transmission between concepts and to clamp the concept values into a specific value interval (-1; +1 in our case). The choice of the function depended on the problem at hand and required the participation of stakeholders to provide a deeper understanding of the system under investigation. In our model, we selected the logistic-transfer function commonly used for qualitative and quantitative scenarios (Felix et al., 2017).

$$f(x) = \frac{e^{2x} - 1}{e^{2x} + 1} \quad (2)$$

The function was considered able to reproduce the relationship between the concepts, on the basis of the interpretation of the interviews with the stakeholders and of our understanding of the involved processes, while at the same time avoiding the needs of fine-expert assessment with risks of generating overwhelming cognitive-stress problems (Kuhnert et al., 2010). Nevertheless, the specific connection between public-goods and rural-society awareness required further adjustments, as the experts acknowledged unequivocally the presence of a bi-modal interaction: namely, the stakeholders identified an inverse relation between public-goods level and society awareness whenever the public-goods quality was under a certain threshold (i.e. higher awareness expected in case of public- goods deterioration), and a stable relation over a certain level of public-goods quality. In the model calibration, the issue was solved introducing an 'if-then' step in the connection between public-goods and society awareness, activating an inverse logarithm function below an arbitrarily selected public-goods threshold value and assigning a stable value (directly depending on the weight assigned by the stakeholders) over that public-goods threshold.

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