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Villanueva, A.J
Gómez-Limón, J.A.
Arriaza, M.
Nekhay, O.

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ANALYSING THE PROVISION OF AGRICULTURAL PUBLIC GOODS: THE CASE OF IRRIGATED OLIVE GROVES IN SOUTHERN SPAIN

Villanueva, A.J.[1,*], Gómez-Limón, J.A.[2], Arriaza, M.[1], Nekhay, O.[3]

[1] Institute of Agricultural Research and Training (IFAPA), Centre Alameda del Obispo, Apdo. 3092, E-14080 Córdoba, Spain. E-mails: anastasioj.villanueva@juntadeandalucia.es; manuel.arriaza@juntadeandalucia.es

[2] Dpt. of Agricultural Economics, University of Córdoba, Puerta Nueva s/n, 14071 Córdoba, Spain. E-mail: jglimon@uco.es

[3] Dpt. of Economics, University Loyola Andalucia, C/ Escritor Castilla Aguayo, 4, 14007 Córdoba, Spain. E-mail: onekhay@uloyola.es

ABSTRACT

The analysis of the joint production of private and public goods (PGs) from farming activities is a fertile research field. These joint production processes are typically characterized by a high level of complexity derived from the intense relationship between the production of both kinds of outputs. An integrated approach is strongly recommended to study the provision of agricultural PGs and the design of public intervention in this sector. Here, we propose a theoretical framework to apply an integrated approach using the Analytic Network Process (ANP) to analyse the production of PGs by agricultural systems to support public decision-making concerning the design and implementation of agricultural policies. We introduce a novel approach in applying ANP through double direction of the influences among elements, allowing us to identify the most influenced PGs and the most influential farmer's decisions. This methodological approach is empirically applied to a particular farming system; the irrigated olive groves (IOG) of Southern Spain. Results show that the PGs most influenced by olive growers' decisions are soil fertility, visual quality of agricultural landscapes and farmland biodiversity. In addition, the most influential factors affecting the PGs provision are the structural factors, namely farm size and tree density, and, to a lesser extent, management factors dealing with fertilization, soil and irrigation management. These results are useful for supporting agricultural policy decision-making to enhance an adequate management of this farming system concerning PGs production.

KEY WORDS: Agricultural multifunctionality, Public goods, Irrigated olive groves, ANP, Andalusia (Spain).

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[*] Correspondence to: Anastasio J. Villanueva, Instituto de Investigación y Formación Agraria y Pesquera (IFAPA) - Department of Agricultural Economics and Sociology. Avda. Menéndez Pidal s/n. 14080 Córdoba Spain, Tel.: +34 671532668, Fax: +34 957016043, e-mail: anastasioj.villanueva@juntadeandalucia.es

1. Introduction

The joint production of private and public goods by agriculture is a fertile research field in agricultural and environmental economics (Rossing et al., 2007; Renting et al., 2009). Works in this field usually have the main objective of supporting public decision-making, considering the provision of public goods (PGs) (and public "bads") as a key concept in the design and implementation of agricultural policies in developed countries (OECD, 2001; 2003), and particularly in the European Union (EU) (Cooper et al., 2009; EC, 2010). In fact, numerous researchers and analysts assert that only by orienting such policies to an adequate provision of PGs could public intervention be efficient from the social welfare point of view (DLAE, 2009).

On the supply side, most of the studies in which agricultural PGs production has been analysed have focused on one or a few of them, thus using *partial approaches* in their analysis (e.g., Boardman et al., 2003; Nilsson, 2009). The use of partial approaches can barely capture the abundant and complex interrelationships that characterize the joint production of private and public goods in agriculture[1]. This complex nature of the joint production processes in agriculture calls for the use of *integrated approaches* in order to analyse them (Renting et al., 2009). This is due to these approaches enabling the identification and incorporation of such complexity in the analysis of agricultural PGs production. Consequently, a growing number of studies are using integrated approaches in this field. Worthy of highlighting are those that use modelling (e.g., Rossing et al., 2007); indicator sets (e.g., Fleskens et al., 2009); or geographical information systems (e.g., Darradi et al., 2012), among others. However, further research is still needed with regards to the application of an integrated approach in the analysis of agricultural PGs production (Zander and Groot, 2007).

Among methodologies that incorporate an integrated approach to the analysis of agricultural multifunctionality, the Analytic Network Process (ANP) is one of the most promising. This is because it allows interdependencies between different relevant elements of the system studied to be considered (Saaty, 2005). In any case, as with any other integrated approach, its use requires a theoretical framework including a clear definition of each PG provided by the system and a priori set of relations explaining these production processes. Traditionally, theoretical frameworks used for integrated approaches do not fully take into account farmers' decision making (Rossing et al., 2007). Here, we propose a new framework based on the causality of producers' decision-making at farm level. Thus, both PGs provided by an agricultural system and their relationship with farmers' decisions have been defined, allowing us to build up a network enabling an ANP application. Furthermore, we implement ANP through a dual approach which whilst it represents a novelty in the application of the method, allows us to take full advantages of it. Hence, the usefulness of both the theoretical framework proposed and ANP, for the analysis of such joint production is proved here through their application to a particular case: the agricultural system of irrigated olive groves (IOG) for olive oil production in Andalusia, Southern Spain.

The main objective of this work is the development of an integrated approach to analyse the production of PGs by agricultural systems to support public decision-making concerning the design and implementation of policies aimed at the governance of the farming sector. For this purpose, the paper has been developed as follows. The next section is devoted to the description of the theoretical framework used for this approach. In the third section, the agricultural system (IOG in Andalusia) considered as the pilot case study is described. In the fourth section the methodology is described, focusing on the ANP application, the data gathering and the experts' knowledge aggregation procedure. The fifth section presents and discusses the main results obtained, focusing on the PGs more sensitive to olive growers' decisions, and thus, to the implementation of policy

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[1] Likewise, it is worth noting that such joint production is subjected to numerous interrelationships among not only private and public goods productions but also the productions of the PGs themselves (OCDE, 2001).

instruments. Finally, in the sixth section the main policy implications derived from the results are discussed, and the main conclusions of the work outlined.

2. A theoretical framework to analyse agricultural public goods

A theoretical framework has been developed to identify the PGs provided by agricultural systems consisting of an adaptation of the widely known DPSIR framework (EEA, 1999), due to its adequacy given its causal and system-oriented approach. Within this framework, a farmer produces a PG when his/her decisions entail some modification to the attributes of the environment (providing them to be non-excludable and non-rival) that changes the social welfare. Here, we consider the environment in a broad sense, that is, formed by natural (climate, water, biodiversity, etc.) and socio-cultural (cultural heritage, rural viability, etc.) attributes. Consequently, farmers produce a *public good* when they modify one of these non-rival and non-excludable attributes and social welfare increases as a result; and, on the contrary, a *public bad* occurs when such modification results in a social welfare reduction. In terms of the DPSIR framework, the natural and socio-cultural attributes of the environment can be considered as *states* (*PGs-State*). When some of these non-excludable and non-rival *states* are modified as a result of farmers' decision-making and this modification entails some variation of social welfare, a *pressure* (*PG-Pressure*) is produced.

Here, we are interested in these *PGs-Pressure* produced as a result of farmers' decision-making. Applying such theoretical framework, main *PGs-Pressure* (and their concerned *PGs-State*) produced by farming activities have been identified. Such PGs are listed in Table 1, distinguishing between environmental and socio-cultural ones and highlighting the main anthropogenic factors involved in their production. It is worth mentioning that each of the 14 *PGs-Pressure* (and thus each of the 11 *PGs-State*) has different degrees of non-rivalry and non-excludability, as well as different scales of consumption. Additionally, it is also interesting to highlight that they can be strictly a public good (e.g., contributions to the national food supply), strictly a public "bad" (e.g., water pollutant emissions) or a good or "bad" depending on the farmers' decision (e.g., soil fertility).

This theoretical framework can be applied at different scales. For example, it can be used to analyse the multifunctional performance of plots, farms, agricultural systems (landscape or ecological units), or, even, regions where agricultural activities are prominent. However, in order to analyse the production of PGs, agricultural systems can be considered as the most appropriate scale, as it is the most relevant one from the agricultural policy perspective (Andersen et al., 2007). This is why this spatial scope has been chosen here on which to perform the empirical analysis.

3. Case study description: Irrigated olive groves (IOG)

Although the multifunctionality of olive groves systems has been widely studied, previous works have not given special attention to the differential characteristics of the IOG. Actually, works in this field are mainly focused on mountainous olive groves (Fleskens et al., 2009) or on making comparison among different agricultural production techniques (conventional, organic and integrated) (Parra-López et al., 2008a; Guzmán et al., 2011), but without giving such special attention to this particular olive system. Only a few works have analysed multiple functions of the IOG, but they have used other approaches, namely assessing sustainability (Gómez-Limón and Arriaza, 2011) or eco-efficiency (Gómez-Limón et al., 2012). However, there are no studies specifically analysing the provision of the PGs from IOG.

Here, we analyse the provision of PGs from IOG that produce olives for olive oil production in Andalusia (Southern Spain)[2], the world's main olive oil production region, producing roughly 35% of the world's output, approximately half of it from IOG (EC, 2012). The analysis of Andalusian IOG is highly pertinent due to its enormous expansion during the last two decades and the relevant environmental and socio-cultural impacts of this process. In fact, in the last 20 years IOG has become the most important irrigated agricultural system in the region, consuming a significant share of its water resources and occupying around half a million hectares, which represents approximately half of the current irrigated area of Andalusia (Gómez-Limón et al., 2013). This is particularly noteworthy bearing in mind that the olive has traditionally been a non-irrigated crop. This expansion has been possible primarily due to Spain's entry into the EU and the implementation of the European Common Agricultural Policy (CAP), which promoted the productivity (irrigation) of olive groves (de Graaff and Eppink, 1999; Gómez-Limón and Arriaza, 2011). Likewise, the development and improvement of drip irrigation and groundwater abstraction techniques have also contributed to such expansion, along with the fact that olive groves require less water than other crops to achieve a reasonable and stable level of production (Testi et al., 2009).

Nevertheless, coupled with this process of expansion and intensification of olive production, some negative environmental impacts have been produced. Among them, it is worth mentioning soil erosion, biodiversity loss, water resources overexploitation, non-point water pollution and the deterioration of traditional landscapes (Beaufoy and Pienkowski, 2000; Gómez, 2009)[3]. However, new irrigated olive groves have also resulted in positive impacts from the economic and social points of view, as they are highly value-added and labour-intensive agricultural systems (Viladomiu and Rosell, 2004). Furthermore, it is finally worth noting that olive groves have an important value associated to their material and immaterial cultural heritage, though the IOG expansion does not appear to have positively impacted it (Guzmán, 2004). All these impacts, positive and negative, have been especially relevant in those municipalities characterized by olive monoculture (counting more than 300 of the 771 municipalities of Andalusia according to CAP, 2007). Therefore, this expansive trend together with its environmental and social relevance demands a deeper understanding from the perspective of its multifunctional performance.

IOG in Andalusia represent an easily identified and differentiated agricultural system (Gómez-Limón et al., 2013). This system is mainly located in areas with low and moderate slopes, where traditional rainfed olive groves (ROG) have been transformed into irrigated ones during the last two decades. This transformation has been fuelled by the enhanced profitability as a result of the increase of yields. According to the information collected by Gómez-Limón and Arriaza (2011), shown in Table 2, the net income in IOG is statistically higher than in ROG (€1,550 and €1,267 per hectare and year, respectively), given the higher yield of the former (6,106 kg/ha·year) than that of the latter (4,659 kg/ha·year). However, as commented previously, such higher yields are reached by means of intensifying olive production. Actually, as is also shown in Table 2, IOG consumes as average statistically more energy (4,661 Mcal/ha·year, mainly due to machinery requirements) and herbicides (839 g Glyphosate-equivalent/ha·year) than ROG (2,579 Mcal/ha·year and 580 g Glyphosate-equivalent/ha·year, respectively), apart from the evident higher use of water in IOG (686

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[2] Olive groves, rainfed or irrigated, can be oriented to produce olives either for olive oil or table olives. It is worth mentioning that more than 90% of Andalusian olive groves are specialized in olive oil production (CAP, 2008). Taking into account that relevant differences (in olive varieties, crop management, etc.) exist between both kind of olive groves, probably also affecting the production of PGs, this research is only focused on IOG whose olive production is oriented to obtain olive oil.

[3] Associated with olive production it could also be mentioned another environmental problem related to olive mill wastes from olive oil industry. However, this has not been considered in this work as this is not directly related with IOG system (olive production). Moreover, it must be pointed out that although there were serious problems in the past regarding the management of olive mill wastes (e.g., waste-dumping), this issue has been mostly solved during the last decade with new regulation, new technologies (two-phase systems) and the wide use of their olive mill wastes for biomass energy, composting or extracting oil in other specific industries.

m^3/ha·year). Also, IOG apparently uses more nitrogen fertilizers (61.8 kg N/ha·year) than ROG (52.7 kg N/ha·year), but this cannot be confirmed statistically.

Regarding water use, it is also noteworthy that IOG is characterized by the use of drip irrigation methods (in more than 90% of its area) using low water doses. Slightly more than half of the water used in IOG is abstracted from aquifers. For this reason it is not surprising that farmers have to pay a relatively high price for such irrigation water (0.15 €/m^3), as they are usually charged by high pumping costs. A further detailed description of the IOG use of irrigation water can be found in Gómez-Limón et al. (2013).

4. Materials and Methods

4.1. Analytic Network Process

Analysing the PGs produced by the IOG requires an integrated approach and this can be achieved by the ANP, a multicriteria technique evolved from the well-known Analytic Hierarchy Process (AHP). In comparison to AHP, the main innovation of the ANP consists of the possibility of analysing elements throughout a net structure that takes into account the existing interactions among them (Saaty and Takizawa, 1986). It is for this reason that, when the problem is characterized by numerous interdependencies as is the case of agricultural PGs production, the use of ANP is recommended over the use of AHP. For the operational implementation of the method it is suggested that the following steps must be observed (Saaty, 2005):

a) *Network preparation*. The basic units of the network are *elements* or nodes that are aggregated into *clusters*. The design of the network is one of the key points for achieving the right solution to the problem. Each element and, consequently, cluster should be clearly defined in order to avoid misunderstandings of any kind. Each of the elements can influence other elements of the network, including interdependencies among elements of the same cluster (inner dependences) or interdependencies among elements of the other clusters (outer dependences). Expert consultation is the best way of validating designed ANP networks and their interdependencies.

b) *Matrix of interactions*. In order to clarify the interdependences among elements they can be represented in a matrix of interactions. This is a squared matrix where all the elements of the network are represented both in rows and columns. In the matrix of interactions, entries ($a_{i,j}$) take the value of 1 if the element i (row) influences the control element j (column), and 0 otherwise. An example of this matrix can be observed in Table 1 of the Annex A.

c) *Preparing the questionnaire*. With the matrix of interactions, we know which elements of the same cluster influence each of the control elements. In order to know how much an element influences the control element (i.e., its *weight*), its influence on the latter is primarily compared to the influences produced on the control element by other elements of the same cluster. For this purpose, pairwise comparisons among elements of the same cluster are made with regards to the control element, to obtain their influence *weights* on the latter. Thus, the interviewee answers pairwise comparisons among the elements (of the same cluster) that influence the control element by judging which element influences the most and to what extent. To obtain these *judgments* (i.e., direct interviewee's answers to the pairwise comparisons), a linear scale that ranges from 1 to 9 is the most widely used, where 1 means an equal influence and 9 means an extremely higher influence of one element over the other. Then, the questionnaire is formed by questions that correspond to all the groups of pairwise comparisons among the connected elements of the network. As in the AHP, the weight of each element is obtained calculating the eigenvector of the matrix of judgments of each group of pairwise comparisons.

d) *Unweighted supermatrix calculation*. In this stage all the weights obtained from the interviews are introduced in the initial supermatrix (the unweighted supermatrix). Whether only one unweighted supermatrix is obtained for a group of interviewees or one for each of the interviewee depends on the aggregation method chosen (see section 4.4).

e) *Weighted supermatrix calculation*. The unweighted supermatrix is not usually stochastic. To normalize it, it is multiplied by the *cluster weights matrix*. The latter is calculated from pairwise comparisons among clusters, in a similar way to that described for the elements comparisons. After obtaining the weights of the clusters (cluster weights matrix) this matrix is multiplied by the unweighted supermatrix resulting in the weighted supermatrix, which is stochastic.

f) *Limit supermatrix calculation*. This last stage consists of the multiplication of the weighted supermatrix by itself *n* times until it is stabilised ("brought to the limit"). The resulting matrix is called the limit supermatrix. In mathematic terms this last operation is expressed as: $\lim_{n \to \infty} W^n$, *W* being the weighted supermatrix. The main property of the limit supermatrix is that all of its columns are equal one to another, so it is idempotent (i.e., a matrix which, when multiplied by itself, yields itself). The numbers in the limit supermatrix are the *priorities* or global weights and represent the main outcome of the ANP method application.

4.2. ANP application: the dual approach

A growing number of the ANP method applications in the different fields have been observed during recent years (Sipahi and Timor, 2010). However, applications of ANP in the analysis of the PGs produced by agriculture are quite rare. Among them, the only works worthy of mention are those of Parra-López et al. (2008b), where the public demands for the multifunctionality of Dutch dairy landscape are analysed; Nekhay et al. (2009), where soil erosion risk in mountain olive groves is evaluated; Reig et al. (2010), where sustainability of different rice cultivation technologies in Valencia is analysed; and more recently Pérez-y-Pérez et al. (2013), where Protected Designations of Origin (PDOs) of the olive oils in Andalusia are analysed focusing on their production of territorial externalities.

Following the theoretical and operational basis of the ANP method briefly explained in the previous section, the application of the ANP method to our case study has been developed in three steps. The first step was the design of the network, which is key for reaching the right solution to the problem. Thus, several alternative network designs were considered before choosing the one that fits best for the analysis of the PGs production by the IOG through the theoretical framework above commented. The final network consists of three clusters: *Public Goods*, *Structural Factors* and *Management Factors* (see Fig. 1 and Table 3). The last two clusters group elements dependant on farmer's decisions (anthropogenic factors in Table 1) in the long and short term, respectively. In fact, the cluster of *Management Factors* groups the agricultural practices that are decided within a single season, including productive and non-productive decisions, while the cluster of *Structural Factors* includes farmer's decisions that can only be modified in the long term. The inclusion in the ANP of the farmer's decision-making makes a difference in comparison to the previous works cited that used this method in the analysis of agricultural PGs production. Also, according to the theoretical framework followed (see Table 1), the cluster of *Public Goods* contains the most relevant *PGs-Pressure* for our case study. For this purpose we have shortlisted the most relevant *PGs-Pressure* from Table 1, excluding animal welfare, wildfire risk, air pollution and rural social capital from the analysis due to their relatively low relevance in the IOG agricultural system. The exclusion of these PGs from the analysis (furthermore ignoring low relevance elements in the ANP network) aims not to make the ANP questionnaire too long, as it is frequently pointed out as a weakness of the applications of this technique.

The arrows connecting the clusters in Fig. 1 reflect the influence of their elements in other cluster's elements (for example, the influence of each of the *Management Factors* on each of the *Public Goods* produced). Also, some elements included within the different clusters may influence other elements of their same cluster. This is represented by using an arrow that connects each cluster with itself.

Once clusters and elements are defined, the second step consists of establishing feedback and dependency connections among them (elaborating the matrix of interactions). This was done through a deliberative process that ended with the consensus among the authors and a significant proportion of the panel of experts consulted to support this research (see section 4.3). In Table 1 of Annex A, the primary matrix of interactions obtained from this process is shown. For instance, entry $a_{14,5}$ (where the *Soilma* row intersects with the *BIODIVER* column) is equal to 1 because *Soilma* (Soil management) influences *BIODIVER* (Biodiversity in olive groves) or, in other words, IOG farmer's decision-making regarding soil management influences its "production" of biodiversity.

In the use of the network and its related matrix of interactions (introduced in Fig. 1 and Table 1 of the Annex A, respectively) we include a novelty in comparison to the standard ANP application. Basically, this novelty consists of using the same network through a dual approach, thus defining two matrices of interaction: i) the *matrix of received influences*; and ii) the *matrix of influences exerted*. The reasoning behind this is that, as Saaty (2008) explains, there are two approaches of the interactions, namely "being influenced" and "influencing" (equivalent to our "received influences" and "influences exerted", respectively) and, depending on the way the user understands the problem, one way or another should be chosen, taking into account that this choice would condition final results. Due to the specificity of our research we are interested in the outcomes of both procedures: the result from the *received influences* approach shows the PGs productions that can be more influenced by structural and management factors; whereas the *influences exerted* approach reveals which farmer's decisions are more influential regarding such production. Thus, we decided to use both approaches and that is what we call a dual approach in applying the ANP.

In the Table 4, the main differences between both approaches are outlined. As is shown in this table, Fig. 1 actually represents the ANP network for the *received influences* approach; the same figure would represent the ANP network for the *influences exerted* approach if opposite direction arrows were applied (it is worth noting that the cause-effect relationship is the same for both approaches, although the analysis is focused on the effects/PGs and causes/factors in the former and the latter, respectively). The matrix of interactions of Table 1 in Annex A corresponds to the *influences exerted* approach, whereas that matrix transposed would represent the matrix of interactions for the *received influences* approach. It is also worth clarifying the groups of element comparisons for each of the two approaches. As is shown in Table 4, for the *influences exerted* approach, for example, several management factors influence the production of *BIODIVER*, namely *Harvest*, *Fertima*, *Irrima*, *Soilma*, *Pestco* and *Funcelem* (see also Table 1 in Annex A). Then, through answering the corresponding pairwise comparisons among such factors (to obtain the direct influence exerted by each of them on the production of such PG) part of the expert's unweighted matrix of such approach is filled. On the contrary, for the *received influences* approach, for example, the production of several PGs -namely *BIODIVER*, *CARBON*, *WATERPOL*, *FLOODRI*, *SOILFER*, *EMPLOY*, *FOODSEC* and *LANDSCA*- is influenced by *Soilma* (see Table 1 –transposed- in Annex A). Then, through answering the corresponding pairwise comparisons among such PGs (to obtain the direct influence received by each of them from *Soilma* factor) part of the expert's unweighted matrix of such approach is filled. We consider that the use of this dual approach is especially useful when both types of outcomes are pursued by the researcher.

In the third step, results were calculated. Firstly, 28 unweighted supermatrices were obtained from each of the fulfilled questionnaires (one per interviewed expert); 14 supermatrices of "received influences" and another 14 of "influences exerted". Secondly, each of these unweighted supermatrices was multiplied by their corresponding cluster weights matrix to obtain weighted supermatrices. Thirdly, weighted supermatrices were brought to limit (i.e., multiplied by itself *n* times until it is stabilised) to calculate limit supermatrices. All these steps were done using the *SUPER DECISIONS 2.2.3.0* software especially developed for AHP/ANP problems solution (for further details see Saaty, 2005). In this way the results for each of the questionnaires (each expert) were calculated (14 for "received influences" and 14 for "influences exerted").

4.3. Data gathering

The data gathering consisted of interviewing our panel experts using two questionnaires that directly elicited from the two matrices of interactions used (one for each approach), formed by the following pairwise comparison question-types:

a) Example for the *matrix of received influences*: *"Biodiversity of the olive groves*" (*BIODIVER*) and "*Soil fertility*" (*SOILFER*) are both influenced by farmer's decisions concerning "*Soil management*" (*Soilma*); which one is more influenced by those decisions and to what extent?
b) Example for the *matrix of influences exerted*: Farmer's decisions concerning "*Pest and disease control*" (*Pestco*) and "*Soil management*" (*Soilma*) influence "*Biodiversity of the olive groves*" (*BIODIVER*); which one has more influence on it and to what extent?

A linear scale was used for answering the pairwise-comparisons, as is usual in AHP/ANP exercises (Saaty, 2005). This scale ranges from 1 to 9, where 1 means an equal influence and 9 means an extremely higher influence of one element over the other.

Before interviewing all experts included in the panel used, pilot tests of the two questionnaires were done by fulfilling and discussing their contents with the experts consulted for network design verification. As a result of the test, correct understanding of the questions was checked. Furthermore, these tests allowed us to reduce the number of connections among the elements, omitting the least relevant, which also served to reduce the questionnaire.

Finally, regarding the composition of the panel of experts consulted, first it is worth mentioning that because of the relative complexity and long lasting interviews of the ANP questionnaires and the relative low number of true experts available for providing useful information, empirical studies based on ANP applications usually use a low number of interviewees. This research is not an exception in this sense, being the data gathering based on the information provided by 28 specialists, 14 of those were interviewed for each of the two questionnaires developed. This panel of expert has included 6 olive production researchers (AGR), 8 researchers in ecology and environmental sciences (ENV), 7 researchers in economics and other social sciences (ECO), as well as 7 agricultural training and extension specialists (TEC), all of them directly involved in irrigated olive growing systems. The reason motivating the use of these 4 types of experts is to cover the different knowledge fields regarding irrigated olive growing. Thus, we have considered that the integration of their "partial knowledge" allows us approaching to a "complete knowledge" of the agricultural system considered and its production of PGs. Hence, we have considered that aggregating their priorities obtained through the ANP technique is a reasonable enough approach to obtain relevant results worth to be discussed.

Due to the length of the questionnaires (over two hours each) and limited time availability of the experts contacted, they could answer only one of the questionnaires developed. Thus, the panel of experts was randomly divided into two groups, each of those groups responding to one of these questionnaires. The interviews were carried out between January-March 2013.

4.4. Aggregation method

When a group decision making process using AHP/ANP is applied a method for the integration of experts' knowledge (or individuals' preferences, etc.) is needed in order to achieve a general assessment. There are two main methods for aggregating experts' knowledge in AHP/ANP: the aggregation of individual priorities (AIP) and the aggregation of individual judgments (AIJ). The AIP consists of aggregating the results (priorities) from the experts, having calculated one limit supermatrix for each of the experts (here, 28 limit supermatrices, 14 for each approach). The AIJ consists of the direct aggregation of the experts' answers (judgments) to each of the questions included in the questionnaire in order to obtain only one unweighted matrix (here, it would be 2 unweighted matrices for the whole panel of experts, one for each approach). As previously stated, this matrix is normalized by the cluster weights matrix to obtain the weighted matrix that is multiplied by itself *n* times until it is "stabilized", resulting in the limit supermatrix that would represent the priorities (results) of the panel of experts (see section 4.1). Given that we have used a dual approach; the use of AIJ would result in two limit supermatrices, one for each approach.

According to the procedure explained above, the AIP method was used, obtaining 14 different results (one per expert) for each of the two approaches used (*received influences* and *influences exerted*). The choice (AIP instead of AIJ) was made following Forman and Peniwati (1998), that recommends its use when experts are considered as acting as individuals (we interviewed them separately) instead of as a unit. These authors also recommend the use of arithmetic or geometric mean when experts are considered to be of equal importance (as is the case here). We use the former mean because it better fits our problem since extreme values (i.e., zeros) were frequent once the experts' priorities were obtained.

5. Results and discussion

In this section we discuss the results concerning the PGs produced by the IOG from the *received influences* approach, and the structural and management factors from the *influences exerted* approach.

5.1. Public goods

Fig. 2 and Table 5 present the results related to the influence capacity of olive growers regarding the PGs provision. We will refer to the aggregated results (the arithmetic mean) due to no statistical differences (p-value>0.05 for the Kruskal-Wallis test) among the ranking of PGs done by the four groups of experts (AGR, ENV, ECO and TEC) being found. In any case this lack of significance must be handled with caution given the low number of observations (experts). Further research in this line would be requested to obtain more conclusive results.

The final weights obtained show that productions of the PGs most modifiable by farmer's decisions at farm level in IOG are soil fertility (*SOILFER*), visual quality of agricultural landscapes (*LANDSCA*) and farmland biodiversity (*BIODIVER*), retaining 24.3%, 18.0% and 17.1%, respectively, of the total influence produced by olive growers' decision-making in this agricultural system. Other PGs whose provision can be affected by these farmers' decision-making are carbon balance (*CARBON*, 10.5%), irrigation water consumption (*WATERCON*, 9.9%) and the contribution to food supply (*FOODSEC*, 7.6%). The olive growers' capacity to influence the production of the other PGs considered is rather limited, with less than 5% in each case.

There are two other points worth commenting on from a descriptive point of view. First, environmental PGs considered as a whole are influenced by olive growers' decision-making to a greater extent than socio-cultural PGs (69.8% and 30.2%, respectively). Second, the four most influenced PGs by IOG producers are of "public good/bad type", that is, depending on what decisions the olive grower makes, a public good or bad will be produced. This can be explained by considering that these PGs are the ones with the widest range of possible production levels, as opposed to "strictly good" (e.g., *FOODSEC*) or "strictly bad" (e.g., *WATERPOL*) PGs, where the amount produced can vary between narrower thresholds.

Not surprisingly, the production of *SOILFER* appears as the most modifiable PG production. In fact, it is commonly acknowledged that Andalusian olive groves present very severe erosion problems, partially because of inadequate farmers' soil management (Gómez and Giráldez, 2009), especially when farms are located on steep or moderate slopes. Thus, the use of soil conservation practices are strongly recommended to control erosion rates (i.e., the production of *SOILFER* is highly dependent on olive growers' decision-making). This is particularly true concerning the use of cover crops (*Soilma*), with regards to not only erosion control (Gómez et al., 2009), but also other soil benefits such as increasing and conserving soil organic matter (Castro et al., 2008), N and K contents (Nieto et al., 2013), among others. Additionally, fertilization management (*Fertima*) also impacts soil fertility, particularly regarding K soil content (Fernández Escobar, 2009).

Likewise, *LANDSCA* is notably influenced by olive growers' decisions. Three types of decisions are strongly related to its production (Arriaza et al., 2004): i) the elimination (or conservation) of natural infrastructures or functional elements; ii) the adoption (or not) of cover crops and their corresponding management alternatives; and iii) the appearance (or not) of anthropogenic elements that could have (negative) visual impacts (e.g., visible irrigation infrastructures). In the long term, decisions regarding size (*Size*) also influence *LANDSCA* (Arriaza et al., 2004). In addition, experts have also pointed out tree density (*Density*) as a determinant factor of visual quality of IOG landscapes, though this relationship has not yet been studied in detail. It may well be observed that these types of decisions are exclusively made by olive growers and can modify IOG landscapes as a result.

BIODIVER is another PG with a highly modifiable production, fundamentally through olive growers' decisions regarding soil management (*Soilma*), pest and disease control (*Pestco*) and practices related to functional elements (*Funcelem*). Once again, the use of cover crops becomes prominent in the provision of environmental PGs by IOG, in this case *BIODIVER*. This agricultural practice has a positive impact on soil microbial activity (Moreno et al., 2009) and birds, among others (Duarte et al., 2009). However, there are alternative cover crop practices which may result in different effects on farmland biodiversity in IOG, as experts have pointed out. For instance, farmers can opt for different types of cover crops (e.g., spontaneous or sown), spread it partially (i.e., between tree lines) or totally over the plot and/or employ different control options (mowing and/or applying herbicides) (Barranco et al., 2008). Therefore, different alternatives of cover crop management can result in different impacts on biodiversity (and also on other PG like *SOILFER*, *CARBON* and *WATERPOL*). Apart from cover crops, some other practices that positively impact biodiversity could be highlighted: the maintenance of margin vegetation useful for birds (Duarte et al., 2009), other macrofauna (Pereira and Rodríguez, 2010) and entomofauna (Cárdenas et al., 2006) survival, especially when hedgerows are presented (Rey, 2011); and burying of drip lines when fertigation is used, preventing bird poisoning (Duarte et al., 2009). Regarding long term growers' decisions, in the experts' opinion, tree density (*Density*) and, to a lesser extent, olive variety (*Variety*) appear to have a remarkable influence on *BIODIVER* as well. However, most of the interviewed experts acknowledge that IOG farmland biodiversity needs more research to fill existing knowledge gaps.

Since permanent crops are usually distinguished as part of LULUCF ("Land Use, Land-Use Change and Forestry") activities, some comments about the PG regarding carbon fixation (*CARBON*) are deserved. Olive trees serve as carbon sinks and the use of irrigation water can help to enhance such function. Actually, irrigated olive trees assimilate more carbon than rainfed ones (Testi et al., 2009), but there appears to be a certain trade-off between both carbon assimilation and water use efficiency, as highlighted by Villalobos et al. (2012). Apart from irrigation management, other factors such as tree density (*Density*) or grove age appear to influence such assimilation (Nardino et al., 2013). Regarding tree fixation exclusively, it is clear that farmers' decisions have an important influence on it. This statement could also be applied to soil fixation. Indeed, farmers have a high potential to enhance soil fixation in their olive groves (González-Sánchez et al., 2012). Indeed, the use of cover crops in Mediterranean olive groves has proved to be a suitable strategy to increase the carbon storage into the soil (Castro et al., 2008).

With respect to other PGs, it is also noteworthy to discuss the results related to *WATERCON*, *WATERPOL*, *FOODSEC* and *EMPLOY*, for their relevance in other irrigated agricultural systems (Gordon et al., 2010).

WATERCON is commonly cited as the main negative environmental impact ("public bad") of this type of agricultural system (UN, 2012), especially in semi-arid regions like Andalusia, where water is a scarce resource. This is why one would expect that this PG was relevant when analysing the water consumed by this agricultural system in the region (IOG consumes around 22% of total water demand in Guadalquivir river basin, the most important one in Andalusia). However, the current low influence capacity of olive growers regarding *WATERCON* can be explained considering the productivity of water in olive groves compared to the other existing crops in the region. As Berbel et al. (2011) show, olive is the crop grown in the Guadalquivir river basin that uses irrigation water in a most economically efficient way (best economic results –profits– per cubic meter of water consumed). In fact, as these authors estimate, the productivity of the irrigation water in olive –measured by the Residual Value Method– is the highest one in such basin, reaching €0.55/m^3 while the average productivity of the irrigation water in this basin is only €0.31/m^3. Behind this fact, there is a remarkably low water consumption per hectare in the IOG system (frequently less than 1,000 m^3/ha·year, compared to an average of 4,000 m^3/ha·year for the whole irrigated area in the basin, according to CHG, 2012), because of both a low water requirement of olive groves and a wide use of efficient irrigation technologies such as drip irrigation and deficit irrigation techniques (Fereres et al., 2011). Thus, if water scarcity in the region became more acute, other irrigated crops different to olive groves would be expected to reduce or stop irrigation to re-balance water demand and supply. Taking into account the facts commented above, it can be understood why experts consulted have agreed that there is barely room for olive growers to modify the provision of this PG (that is, to reduce water consumption per hectare)[4].

Another unexpected result obtained is related to the relatively low influence capacity of the olive growers' decisions regarding *WATERPOL* (4.1%). It is not easy to interpret such a result when literature warns about the water pollution caused by olive growing in Andalusia, especially because of herbicide (Hermosín et al., 2013) and nitrate (Fernández-Escobar et al., 2012) use. However, regarding herbicides, such authors recognize the downward trend of their concentrations in water bodies since some of these agrichemicals have been forbidden by EU authorities (e.g., atrazine, simazine or diuron) as well as the enhanced efforts of farmers' training programmes. Furthermore, the wide use of low residual herbicides (namely, Glyphosate) currently made by IOG farmers along with the low doses usually applied are also behind such a low scoring for *WATERPOL* as far as herbicides emissions are concerned. With regards to nitrates, it is first worth mentioning that olive tree is not a highly nitrogen demanding crop. Actually, the use of nitrogen fertilizers displays low figures (52.7 and 61.8 N kg/ha·year in ROG and IOG, respectively; see Table 2) compared to other crops (i.e., cereals). Hence, although Fernández-Escobar et al. (2012) advise that an excessive use of nitrogen fertilization in olive growing could generate water pollution problems, nitrates emission in olive growing do not appear to be severe. Proof of that is that there is a low percentage of the area of the Nitrates Vulnerable Zones (NVZ) located in Andalusia associated with olive growing systems,

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[4] In any case, it is also true that in some specific areas where irrigated olive groves has become in a monoculture which over-exploits local aquifers (e.g., La Loma aquifer, located in the upper Guadalquivir Valley, CHG, 2012), a reduction in IOG water consumption turns to be unavoidable.

while the most part of them are associated with other herbaceous and perennial irrigated crops (i.e., those mostly based on cotton, maize, vegetables or citrus) (see CHG, 2012, where Andalusian NVZ are detailed). Moreover, as far as IOG is concerned, as most of the experts outlined, it is likely that the localized fertilization associated with the use of fertigation in IOG facilitates the uptake of nitrogen for olive trees more easily than traditional (non-localized) soil fertilization usually used in ROG, thus making the nitrogen emissions less likely. All these facts explain the logic behind the unexpected low score obtained for *WATERPOL*.

Another function commonly pointed out regarding irrigated agricultural systems is their positive contribution to the food supply (*FOODSEC*). In the case of IOG, such a statement is evident, due to yields of 1.5 to 2 times higher than ROG. Yet, according to experts, when it comes to exploring to what extent irrigated olive yield could be increased, it appears to be rather difficult to achieve such an increase without negatively affecting the production of other PGs, namely environmental ones. In any case, among the alternatives to increased olive oil yields without such negative impacts, experts suggest a moderate increase in tree density (*Density*) as a useful option.

Referring to *EMPLOY* (3.6%), despite olive systems being widely cited as labour intensive (Viladomiu and Rosell, 2004), and particularly mountainous ones (Rocamora-Montiel et al., 2013), an improvement in the provision of this PG is barely achievable. As in other economic sectors, on-going technological progress (pursuing lower production costs) is resulting in a substitution of labour to capital in IOG, the olive harvest being a good example of this progress. Furthermore, in the experts' opinion, labour use per hectare has a relatively scarce variation among irrigated olive farms, especially when they have the same olive tree density (a feature that strongly determines mechanization).

5.2. Structural and Management Factors

As can be observed in Fig. 3 and Table 6, the *Structural Factors* are more influential than the *Management Factors* regarding the production of the PGs[5]. In particular, 84.6% of the production of such goods depends on the olive grower decision-making in the long term (*Structural Factors*). Among these factors, it is worth highlighting farm size (*Size*), tree density (*Density*) and olive variety (*Variety*).

Since *Density* and *Size* are clearly the most influential factors, it is relevant to explain their influence in detail. In this sense it is important to highlight that these two structural factors influence the production of PGs both directly and indirectly through their influence on *Management Factors*. Regarding tree density, it must be pointed out that this is a typical indicator of extensification/intensification of olive growing (Viladomiu and Rosell, 2004). Hence, there is a certain consensus among the panel of experts regarding the negative relationship between *Density* and environmental PGs production in IOG, with the exception of *CARBON* (see Table 7). On the contrary, higher *Density* is associated to higher yields, resulting in an enhanced provision of *FOODSEC* (Barranco et al., 2008). Furthermore, high tree density frequently implies higher labour requirements (e.g., phytosanitary treatments or pruning), also involving an improvement in the provision of *EMPLOY* (Viladomiu and Rosell, 2004).

Table 7 about here

In relation to *Size*, experts highlight that larger farms usually perform better than smaller ones regarding environmental PGs, given the former are more efficient in inputs use (Gómez-Limón et al., 2012) and are more prone to adopt conservation practices (Rodríguez-Entrena and Arriaza, 2013).

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[5] Similarly to PGs, no statistical differences (p-value>0.05 for the Kruskal-Wallis test) have been found among the four groups of experts regarding the rankings achieved for the structural and management factors. Then, only aggregated results are considered as far as the explanation of such factors is concerned.

According to the experts' opinion, this statement is also valid regarding socio-cultural PGs like *FOODSEC* and *HERITAG*, but not to *EMPLOY* and *LANDSCA*. Thus, as *Size* increases, IOG production of each of the last two PGs decreases. In the case of *EMPLOY*, labour use per hectare is typically reduced when *Size* increases as a result of the usual capital-labour substitution (Amores and Contreras, 2009), as in many other agricultural systems. In the case of *LANDSCA*, larger farms reduce landscape heterogeneity, thus reducing its visual quality (Arriaza et al., 2004).

Variety appears as the third most important factor for the provision of PGs. However, a majority of the experts have acknowledged a lack of scientific and technical information regarding its influence on some of the most influenced PGs productions (*CARBON*, *BIODIVER* and *WATERCO*N). In fact, no literature has been found about this topic. This lack of specific information for this structural factor has probably made experts to provide poorly founded judgments in the corresponding ANP comparisons. As some of them have commented to authors after the questionnaire was replied, they answered these comparisons just taking into account that *Variety* and *Density* factors are highly related. Basically, traditional local varieties such as Picual or Hojiblanca are associated with low *Density* groves (extensive olive growing positively affecting the provision of environmental PGs – except *CARBON*– and some socio-cultural PGs like *LANDSCA* and *HERITAG* but negatively impacting the supply of other socio-cultural PGs like *FOODSEC* and *EMPLOY*), while new imported varieties as Arbequina are related to more modern and higher *Density* olive groves (intensive olive production with an opposite impact on the provision of PGs). Thus, as *ceteris paribus* effect of *Variety* was really ignored, the score achieved by this factor is probably upward biased by the high relevance of *Density*. In order to overcome this problem, it seems obvious that more research is needed in this field, and the influence of this particular structural factor should be re-evaluated.

Following the experts' opinion, referring to *Technique* it is worth mentioning that there is hardly any difference between the provision of the PGs by integrated and conventional IOG, resulting in a low final score. This result differs from those obtained by Parra-López et al. (2008a) to a certain extent. Although they did not distinguish between rainfed and irrigated olive groves, they found some differences in the multifunctional performance of conventional and integrated techniques, especially concerning environmental functions. However, the growing cross-compliance requirements, particularly after the 2009 CAP reform, could well be behind such a discrepancy, having reduced the main differences between both techniques. Actually, also in Andalusia, Rocamora-Montiel et al. (2013) reported that environmental performance between conventional and organic mountainous olive groves have narrowed as a result of the implementation of such growing cross-compliance requirements. In spite of this, they also claimed not only the environmental but also the socio-economic performance of the organic olive groves to be superior. In this sense, a higher rating of *Technique* would have been expected if the organic olive groves system had been considered in the analysis. However, it was not included due to its scarce presence in irrigated olive groves.

Regarding the *Management Factors*, the most influential short term decisions made by the producer in terms of PGs production are: fertilization (*Fertima*), irrigation (*Irrima*) and soil managements (*Soilma*) (see Table 6). These three factors influence the production of at least six PGs, coinciding in five of them, namely: *BIODIVER, CARBON*, *FOODSEC*, *WATERPOL* and *EMPLOY*. Other influential *Management Factors* are harvest (*Harvest*) and pruning (*Pruning*) practices, but with a relatively lower influence. Surprisingly, pest and disease control (*Pestco*) does not appear to be an influential factor. In part, due to its substantial influence on only one PG (*BIODIVER*) and also because of the low intensity and low variability in the pest control treatments that olive growers carry out.

As regards non-productive *Management Factors* (*Funcelem* and *Praherit*), no influence in the production of agricultural PGs is observed, mainly due to the absence (or notable scarcity) of the elements or components associated with each factor (buffer strips, margin vegetation, terraces, etc.) on irrigated olive farms (Gómez-Limón and Arriaza, 2011). Likewise, experts find mostly unnoticeable heritage elements, such as buildings, or others, such as different practices associated with the traditional production of olive oil. In fact, this may well be the reason for the low figures obtained pertaining to not only *Praherit* but also *HERITAG*.

6. Policy discussion and conclusions

From a multifunctional point of view, public intervention in agriculture is only justified in order to minimize market failures (OECD, 2001 and 2003), that is, to bridge the existing gaps between the supply and demand of agricultural PGs. Thus, a broader analysis than that made here is needed to identify public intervention priorities regarding agricultural PGs. In particular, such broader analysis should include an assessment of social demands of each one of those goods as well as an analysis of other alternative ways of provision (from other agricultural systems or other productive sectors such as forestry). Unfortunately, this full policy analysis exceeds our research objective. In any case, from the supply analysis performed here some valuable conclusions can be obtained for policy decision-making.

The theoretical framework together with the double analysis made here, that is, the study of the more influenced PGs provided by IOG and the more influential decisions made by IOG farmers, have allowed us to identify some remarks to enhance a higher efficiency of the policies concerning an adequate provision of such PGs. In this sense, firstly, it is worth pointing out that policy impact would be higher if it were focused on the most influenced PGs (*SOILFER*, *LANDSCA*, *BIODIVER* and *CARBON* for IOG). However, if policy priorities (based on society's demand) are related to other less influenced PGs (e.g., *WATERPOL* or *EMPLOY* in our case study), policy-makers should be warned that there is little room for effective incentives and the achievement of the objectives proposed would be costly. In such cases the cost of providing an adequate amount of PGs could be higher than the improvement in social welfare, discouraging any public intervention (OECD, 2003). Taking this into account, we focus the policy discussion on the four most influenced PGs produced by IOG.

Given the analysis performed here, it is pertinent to distinguish between the implications concerning agricultural structural policy (i.e., oriented to modify the *Structural Factors*) and agricultural management policy (i.e., oriented to modify the *Management Factors*).

Regarding agricultural *structural policy*, our results suggest the convenience of encouraging the implementation of its associated instruments from the PGs provision point of view (a similar finding is reported by Atance et al., 2006, who analyse the multifunctionality of other Spanish agricultural systems). However, these measures are usually very costly for public budgets and their impacts are only visible in the long term. Yet, this must not preclude policy-makers from designing and implementing such policies. This is especially true when, apart from for the provision of PGs, the restructuring of farms is also required in order to be competitive and keep the business running, as is the case of olive growing in Andalusia.

As is widely acknowledged (Gómez-Limón and Arriaza, 2011; AEMO, 2012; EC, 2012), olive growing is operating under economic pressure because of highly aggregated production and low market prices of olive oil. Under this framework, restructuring is unavoidable for many olive farms, particularly those with a smaller size, low tree density or various stems per tree. In these cases, economic viability would require the increasing of both tree density (with one stem per tree) and size (plot and/or farm), thus making further mechanization possible (especially with regards to harvesting). A priori, some of these initiatives could be co-financed (among the farmer, European and national funds) through some measures of the Pillar II of the CAP, in particular, through Measure 121 (*Modernization of agricultural holdings*) of the current European Agricultural Fund for the Rural Development (in fact, a similar measure is expected to be included in the future CAP; see EC, 2013). To get approval, an economic assessment of the co-financed investment from the farmer is generally required. Given the significant influence of the *Structural Factors* on IOG PGs production, complementing such analysis with further analysis concerning the impact on this production would be strongly recommended. Such analysis could take the form of an *Environmental and Social Impact Assessment* (*ESIA*) and would ensure that olive growers' PGs provision (as a whole) is not negatively affected. Given the results shown in Table 7, *ESIA* should be particularly recommended when the structural change resulted in a very high tree density (thus, compromising the environmental PGs production while boosting the production of some of the socio-cultural PGs, namely food security and, to a lesser extent, employment). Additionally, for carrying out *ESIA*, a wide array of indicators should be set, similar to that used by Gómez-Limón and Arriaza (2011).

Regarding agricultural *management policy*, it is also recommended to enhance measures relating to them. Specifically, there are two types of CAP measures that are worth discussing from the PGs provision perspective: the agri-environmental schemes (AES) of the current (and future) CAP and cross compliance and the future green payment (see EC, 2013).

AES are incentive-based and co-financed tools that provide payments to EU farmers for voluntary environmental commitments. It is commonly acknowledged that these schemes represent an appropriate approach within the CAP measures as far as (environmental) PGs provision is concerned, as they require being more objective oriented and site and/or system specific (i.e., targeting and tailoring, respectively). Nevertheless, in practice, two main criticisms are usually pointed out regarding AES (ECA, 2011). First, they are usually oriented to vague objectives. Second, their design and implementation frequently do not rely on a correct understanding of the joint production processes. Such knowledge is of particular importance, given most of the environmental PGs present complementary relationships in their production (OECD, 2001). In the case of IOG, this "multicomplementarity" amongst its PGs production has been outlined in previous paragraphs, particularly for the most influenced ones (i.e., *SOILFER*, *LANDSCA*, *BIODIVER* and *CARBON*). Indeed, this has been identified in previous studies of olive growing made from the PGs perspective (Rodríguez-Entrena et al., 2012). Finally, for the sake of policy efficiency, in most cases AES should be oriented to the production of various PGs, providing them to have complementarity in their production processes (Hart et al., 2011). This new extended AES could be implemented through "territorial farm contracts" (TFC) (Gafsi et al., 2006), that could require a previous diagnosis of the farm (enhancing tailoring) and should include particular targets defined for each of the PGs concerned. Actually, through the use of TFC, the integrated approach can be more easily translated in terms of policy design and implementation (e.g., see Hart et al., 2011). In any case, the gaining in precision associated with the implementation of such policy tools (TFC and *ESIA*) would entail increasing transaction costs which would have to be careful assessed, ensuring they are not disproportionate.

Regarding *cross compliance* and the *green payment scheme*, some comments can be outlined. With these tools of the Pillar I of the CAP, the EC tries to give more importance to the objective of producing (environmental) PGs by agricultural systems (Matthews, 2012). This is why both tools consist of complying with some environmental requirements in order to receive the basic payment and further ones to do so in the case of green payment. However, some authors have indicated that both tools reflect a poor targeting and tailoring to the PGs provision (Swinbank, 2012). Neither a flexibilization of these requirements (such as that included in the final CAP reform agreement, see EC, 2013) appears to be recommended for an adequate promotion of PGs provision, even more so if such an implementation is made EU-wide. This seems obvious in the case of permanent crops, such as IOG.

Finally, it is worth highlighting that the theoretical framework, together with the methodology proposed, are demonstrated as being useful with regards to the analysis of agricultural PGs provision. In particular, the dual approach double ANP (of *received influences* and *influences exerted*) implemented in the ANP application has been found to be helpful from the agricultural policy perspective, identifying the two sides of the problem, namely the most influenced PGs and the most influential farmer's decision concerning their production. This type of analysis could be similarly implemented in other agricultural systems in order to adequately define policy priorities and support the design and implementation of the related measures.

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References

AEMO, Asociación Española de Municipios del Olivo. 2012. Aproximación a los costes del cultivo del olivo. Cuaderno de conclusiones del Seminario AEMO. AEMO, Córdoba, 53 pp.

Amores, A.F., Contreras, I. 2009. New approach for the assignment of new European agricultural subsidies using scores from data envelopment analysis: Application to olive-growing farms in Andalusia (Spain). Eur. J. Oper. Res. 193, 718-729.

Andersen, E., Elbersen, B., Godeschalk, F., Verhoog, D. 2007. Farm management indicators and farm typologies as a basis for assessments in a changing policy environment. J. Environ. Manage. 82(3), 353-362.

Arriaza, M., Cañas-Ortega, J.F., Cañas-Madueño, J.A., Ruiz-Aviles, P. 2004. Assessing the visual quality of rural landscapes. Landscape Urban Plann. 69, 115-125.

Atance, I., Gómez-Limón, J.A., Barreiro-Hurlé, J. 2006. El reto de la multifuncionalidad agraria: oferta de bienes privados y públicos en el sur de Palencia. Revista Española de Estudios Agrosociales y Pesqueros 210, 155-200.

Barranco, D., Fernández-Escobar, R., Rallo, L. (Ed.) 2008. El cultivo del olivo. Mundi-Prensa y Junta de Andalucía, Madrid, 846 pp.

Beaufoy, G, Pienkowski, M. 2000. The environmental impact of olive oil production in the European Union: practical options for improving the environmental impact. European Forum on Nature Conservation and Pastoralism y Asociación para el Análisis de la Política Agro-rural. European Commission, Brussels, 73 pp.

Berbel, J., Mesa-Jurado, M.A., Pistón, J.M. 2011. Value of irrigation water in Guadalquivir Basin (Spain) by residual value method. Water Resour Manage 25, 1565-1579.

Boardman, J., Poesen, J., Evans, R. 2003. Socio-economic factors in soil erosion and conservation. Environ. Sci. Policy 6, 1-6.

CAP, Consejería de Agricultura y Pesca. 2007. El Programa de Desarrollo Rural de Andalucía 2007- 2013. Consejería de Agricultura y Pesca, Sevilla, 522 pp.

CAP, Consejería de Agricultura y Pesca. 2008. El Sector del Aceite de Oliva y de la Aceituna de mesa en Andalucía. Consejería de Agricultura y Pesca, Sevilla, 155 pp.

Cárdenas, M., Ruano, F., García, P., Pascual, F., Campos, M. 2006. Impact of agricultural management on spider populations in the canopy of olive trees. Biol. Control 38, 188-195.

Castro, J., Fernández-Ondoño, E., Rodríguez, C., Lallena, A.M., Sierra, M., Aguilar, J. 2008. Effects of different olive-grove management systems on the organic carbon and nitrogen content of the soil in Jaén (Spain). Soil Tillage Res. 98, 56-67.

CHG, Confederación Hidrográfica del Guadalquivir. 2012. Propuesta de Proyecto de Plan Hidrológico de la Demarcación Hidrográfica del Guadalquivir. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid, 454 pp.

Cooper, T., Hart, K., Baldock, D. 2009. The Provision of Public goods Through Agriculture in the European Union. Institute for European Environment Policy (IEEP), London, 351 pp.

Darradi, Y., Saur, E., Laplana, R., Lescot, J., Kuentz, V., Meyer, B.C. 2012. Optimizing the environmental performance of agricultural activities: A case study in La Boulouze watershed. Ecol. Ind. 22, 27-37.

de Graaff, J., Eppink, L.A.A.J. 1999. Olive oil production and soil conservation in Southern Spain, in relation to EU subsidy policies. Land Use Policy 16, 259-267.

DLAE, Declaration of Leading Agricultural Economists. 2009. A Common Agricultural Policy for European public goods. Declaration by a Group of Leading Agricultural Economists. Available in: http://www.reformthecap.eu/posts/declaration-on-cap-reform.

Duarte, J., Campos, M., Guzmán, J.R., Beaufoy, G., Farfán, M.A., Cotes, B., Benítez, E., Vargas, J.M., Muñoz-Cobo, J. 2009. Olivar y biodiversidad. In: Gómez, J.A. (Ed.), Sostenibilidad de la producción de olivar en Andalucía. Junta de Andalucía. Consejería de Agricultura y Pesca, Sevilla, pp. 162-220.

EC, European Commission. 2010. The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future. COM(2010) 672 final.

EC, European Commission. 2012. Economic analysis of the olive sector. European Commission, Directorate-General for Agriculture and Rural Development, Brussels, 10 pp.

EC, European Commission. 2013. CAP Reform – an explanation of the main elements. MEMO/13/621. Available in: http://europa.eu/rapid/press-release_MEMO-13-621_en.htm.

ECA, European Court of Auditors. 2011. Is agri-environment support well designed and managed?. Special report no 7. Publications Office of the European Union, Luxembourg, 75 pp.

EEA, European Environmental Agency. 1999. Environmental indicators: Typology and overview. Technical report No 25. EEA, Copenhague, 19 pp.

Fereres, E., Orgaz, F., González-Dugo, V. 2011. Reflections on food security under water scarcity. J. Exp. Bot. 62, 4079-4086.

Fernández-Escobar, R. 2009. Fertilización. In: Gómez, J.A. (Ed.), Sostenibilidad de la producción de olivar en Andalucía. Junta de Andalucía. Consejería de Agricultura y Pesca, Sevilla, pp. 267-284.

Fernández-Escobar, R., García-Novelo, J.M., Molina-Soria, C., Parra, M.A. 2012. An approach to nitrogen balance in olive orchards. Sci. Hortic.-Amsterdam 135, 219-226.

Fleskens, L., Duarte, F., Eicher, I. 2009. A conceptual framework for the assessment of multiple functions of agro-ecosystems: A case study of Trás-os-Montes olive groves. J. Rural Stud. 25, 141-155.

Forman, E., Peniwati, K. 1998. Aggregating individual judgments and priorities with the Analytic Hierarchy Process. Eur. J. Oper. Res. 108, 165-169.

Gafsi, M., Legagneux, B., Nguyen, G., Robin, P. 2006. Towards sustainable farming systems: Effectiveness and deficiency of the French procedure of sustainable agriculture. Agr. Syst. 90(1-3), 226-242.

Gómez, J.A. (Ed.) 2009. Sostenibilidad de la producción de olivar en Andalucía. Junta de Andalucía. Consejería de Agricultura y Pesca, Sevilla, 470 pp.

Gómez, J.A., Giráldez, J.V. 2009. Suelo. In: Gómez, J.A. (Ed.), Sostenibilidad de la producción de olivar en Andalucía. Junta de Andalucía. Consejería de Agricultura y Pesca, Sevilla, pp. 45-86.

Gómez, J.A., Sobrinho, T.A., Giráldez, J.V., Fereres, E. 2009. Soil management effects on runoff, erosion and soil properties in an olive grove of Southern Spain. Soil Tillage Res. 102, 5-13.

Gómez-Limón, J.A., Arriaza, M. 2011. Evaluación de la sostenibilidad de las explotaciones de olivar en Andalucía. Analistas Económicos de Andalucía, Málaga, Spain, 295 pp.

Gómez-Limón, J.A., Picazo-Tadeo, A., Reig, E. 2012. Eco-efficiency assessment of olive farms in Andalusia. Land Use Policy 29, 395-406.

Gómez-Limón, J.A., Arriaza, M., Villanueva, A.J. 2013. Typifying irrigated areas to support policy design and implementation: The case of the Guadalquivir river basin. Irrig. Drain. 62(3), 322–329.

González-Sánchez, E.J., Ordóñez-Fernández, R., Carbonell-Bojollo, R., Veroz-González, O., Gil-Ribes, J.A. 2012. Meta-analysis on atmospheric carbon capture in Spain through the use of conservation agriculture. Soil Tillage Res. 122, 52-60.

Gordon, L.J., Finlayson, C.M., Falkenmark, M. 2010. Managing water in agriculture for food production and other ecosystem services. Agric. Water Manage. 97, 512-519.

Guzmán, G.I., González de Molina, M., Alonso, A.M. 2011. The land cost of agrarian sustainability. An assessment. Land Use Policy 28, 825-835.

Guzmán, J.R. 2004. El palimpsesto cultivado. Historia de los paisajes del olivar andaluz. Junta de Andalucía, Consejería de Agricultura y Pesca, Sevilla, 440 pp.

Hart, K., Baldock, D., Weingarten, P., Osterburg, B., Povellato, A., Vanni, F., Pirzio-Biroli, C., Boyes, A. 2011. What tools for the european agricultural policy to encourage the provision of public goods?. European Parliament, DG for Internal Policies – Policy Department B, Brussels, 113 pp.

Hermosín, M.C., Calderón, M.J., Real, M., Cornejo, J. 2013. Impact of herbicides used in olive groves on waters of the Guadalquivir river basin (Southern Spain). Agr. Ecosyst. Environ. 164, 229-243.

Matthews, A. 2012. Greening the Common Agricultural Policy post-2013. Intereconomics 47(6), 326-331.

Moreno, B., García-Rodríguez, S., Cañizares, R., Castro, J., Benítez, E. 2009. Rainfed olive farming in south-eastern Spain: Long-term effect of soil management on biological indicators of soil quality. Agr. Ecosyst. Environ. 131, 333-339.

Nardino, M., Pernice, F., Rossi, F., Georgiadis, T., Facini, O., Motisi, A., Drago, A. 2013. Annual and monthly carbon balance in an intensively managed Mediterranean olive orchard. Photosynthetica 51, 63-74.

Nekhay, O., Arriaza, M., Boerboom, L. 2009. Evaluation of soil erosion risk using Analytic Network Process and GIS: A case study from Spanish mountain olive plantations. J. Environ. Manage. 90, 3091-3104.

Nieto, O.M., Castro, J., Fernández-Ondoño, E. 2013. Conventional tillage versus cover crops in relation to carbon fixation in Mediterranean olive cultivation. Plant Soil 365, 321-335.

Nilsson, F.O.L. 2009. Biodiversity on Swedish pastures: Estimating biodiversity production costs. J. Environ. Manage. 90, 131-143.

OECD, Organisation for Economic Co-operation and Development. 2001. Multifunctionality: Towards an Analytical Framework. OECD Publications Service, Paris, 159 pp.

OECD, Organisation for Economic Co-operation and Development. 2003. Multifunctionality in Agriculture: The Policy Implications. OECD Publications Service, Paris, 106 pp.

Parra-López, C., Calatrava-Requena, J., de-Haro-Giménez, T. 2008a. A systemic comparative assessment of the multifunctional performance of alternative olive systems in Spain within an AHP-extended framework. Ecol. Econ. 64, 820-834.

Parra-López, C., Groot, J.C.J., Carmona-Torres, C., Rossing, W.A.H. 2008b. Integrating public demands into model-based design for multifunctional agriculture: An application to intensive Dutch dairy landscapes. Ecol. Econ. 67, 538-551.

Pereira, M., Rodríguez, A. 2010. Conservation value of linear woody remnants for two forest carnivores in a Mediterranean agricultural landscape. J. Appl. Ecol. 47, 611-620.

Pérez-y-Pérez, L., Egea, P., Sanz-Cañada, J. 2013. Valoración de externalidades territoriales en denominaciones de origen de aceite de oliva mediante técnicas de proceso analítico de red. ITEA-Inf Tec Econ Ag 109 (2), 239-262.

Reig, E., Aznar, J., Estruch, V. 2010. A comparative analysis of the sustainability of rice cultivation technologies using the analytic network process. Span. J. Agric. Res. 8, 273-284.

Renting, H., Rossing, W.A.H., Groot, J.C.J., Van der Ploeg, J.D., Laurent, C., Perraud, D., Stobbelaar, D.J., Van Ittersum, M.K. 2009. Exploring multifunctional agriculture. A review of conceptual approaches and prospects for an integrative transitional framework. J. Environ. Manage. 90, S112-S123.

Rey, P.J. 2011. Preserving frugivorous birds in agro-ecosystems: lessons from Spanish olive orchards. J. Appl. Ecol. 48, 228-237.

Rocamora-Montiel, B., Colombo, S., Sayadi, S., Estévez, C. 2013. Los impactos marginales del olivar ecológico de montaña andaluz frente al convencional post-condicionalidad: una visión de los expertos. Revista Española de Estudios Agrosociales y Pesqueros 234, 49-82.

Rodríguez-Entrena, M., Arriaza, M. 2013. Adoption of conservation agriculture in olive groves: Evidences from southern Spain. Land Use Policy 34, 294-300.

Rodríguez-Entrena, M., Barreiro-Hurlé, J., Gómez-Limón, J.A., Espinosa-Goded, M., Castro-Rodríguez, J. 2012. Evaluating the demand for carbon sequestration in olive grove soils as a strategy toward mitigating climate change. J. Environ. Manage. 112, 368-376.

Rossing, W.A.H., Zander, P., Josien, E., Groot, J.C.J., Meyer, B.C., Knierim, A. 2007. Integrative modelling approaches for analysis of impact of multifunctional agriculture: A review for France, Germany and The Netherlands. Agr. Ecosyst. Environ. 120, 41-57.

Saaty, T.L. 2005. Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Costs, and Risks. RWS Publications, Pittsburgh, USA, 352 pp.

Saaty, T.L. 2008. Relative measurement and its generalization in decision making why pairwise comparisons are central in mathematics for the measurement of intangible factors the analytic hierarchy/network process. Rev. Real Acad. Cienc. 102, 251-318.

Saaty, T.L. Takizawa, M. 1986. Dependence and independence from linear hierarchy to nonlinear network. Eur. J. Oper. Res. 26, 228-237.

Sipahi, S., Timor, M. 2010. The analytic hierarchy process and analytic network process: An overview of applications. Management Decision 48, 775-808.

Swinbank, A. 2012. New direct payments scheme: targeting and redistribution in the future CAP. European Parliament, DG for Internal Policies – Policy Department B, Brussels, 67 pp.

Testi, L., Orgaz, F., Argüelles, A., Cifuentes, V. 2009. Riego. In: Gómez, J.A. (Ed.), Sostenibilidad de la producción de olivar en Andalucía. Junta de Andalucía. Consejería de Agricultura y Pesca, Sevilla, pp. 21-44.

UN, United Nations. 2012. World Water Development Report 4. UNESCO, Paris, 866 pp.

Viladomiu, L., Rosell, J. 2004. Olive oil production and the rural economy of Spain. In: Brouwer, F. (Ed.), Sustaining Agriculture and the Rural Economy: Governance, Policy and Multifunctionality. Edward Elgar Publishing Inc, Cheltenham, UK, pp. 223-246.

Villalobos, F.J., Perez-Priego, O., Testi, L., Morales, A., Orgaz, F. 2012. Effects of water supply on carbon and water exchange of olive trees. Eur. J. Agron. 40, 1-7.

Zander, P., Groot, J.C.J. 2007. Multifunctionality of agriculture: Tools and methods for impact assessment and valuation. Agr. Ecosyst. Environ. 120, 1-4.

Table 1
Main public goods (PGs) produced by agricultural systems.

SCOPE	***PG-STATE***	***PG-PRESSURE***	***MAIN ANTHROPOGENIC FACTORS OF THE PRESSURE***
ENVIRONMENTAL	*Global climate*	Carbon balance	GHG emissions (depending on crop/livestock choice, irrigation and soil managements among other practices)
			CO_2 fixation (depending on crop choice, soil management and animal waste management, basically)
	Water	Water pollutants emission	Fertilization, soil and irrigation managements, pest and disease control, stocking density, grazing regime and animal waste management
		Water consumption	Crop choice, irrigation and soil managements
	Natural risks	Practices that influence flood risk level	Crop choice, plot size, soil management, functional elements (e.g., margin vegetation), etc.
		Practices that influence wildfire risk level	Plant residues and soil managements and grazing regime
	Air	Air pollutants (others than GHG) emission	Fertilization, soil and irrigation managements, pest and disease control, stocking density and animal waste management
	Biodiversity	Practices that modify farmland biodiversity	Crop/livestock and variety/breed choices, pest and disease control, soil management and functional elements (e.g., conservation of riparian vegetation)
	Soil	Practices that modify farmland soil fertility	Crop choice, soil, fertilization and irrigation managements, stocking density and animal waste management
SOCIO-CULTURAL	*Viability of the rural territories*	Agricultural employment	In quantity and quality (seasonality, employment of women and young persons), both depending on socio-economic characteristics of the farmer, farm size or dimension, crop/livestock choice, irrigation and soil managements, etc.
		Contribution to rural social capital	Decisions regarding enrolling in collective rural institutions (e. g., cooperatives), participating in training activities, etc. Mostly dependent on socio-economic characteristics of the farmer
	Food security	Contribution to (national) food supply	Food production (depending on crop/livestock choice, stocking density, fertilization, irrigation and soil managements, etc.)
			Practices related to food safety (e.g., implementation of traceability systems)
	Animal welfare	Actions that modify the farm animal welfare	Farming practices that modifies living conditions of farm animals (e.g., balanced breeding)
			Farming practices that modifies the level of animal health (e.g., ensuring farm hygiene using adequate cleaning systems)
	Heritage	Actions that modify the agricultural heritage	Concerning material cultural heritage (e.g., buildings and constructive elements)
			Concerning cultural heritage regarding traditional food elaboration
			Concerning immaterial cultural heritage (e.g., traditions and other identity elements)
	Landscape	Actions that modify the visual quality of farmland landscape	Farm/plot size, crop choice (plant cover, crop diversity, etc.), livestock choice, stocking density, grazing regime, soil management (e.g., cover crops) and conservation of particular elements (hedgerows, terraces, etc.)

Table 2
Output and inputs in irrigated and rainfed olive groves in Andalusia.

	Irrigated olive groves (IOG)		*Rainfed olives groves (ROG)*		*t-test*	
	Mean	*SD*	*Mean*	*SD*	*t*	*p-value*
Net income (€/ha)	*1,550*	*776*	*1,267*	*862*	*-2.58*	*0.011**
Yield (kg/ha)	*6,106*	*1,506*	*4,659*	*2,022*	*-6.25*	*0.000****
Water use (m^3/ha)	*686*	*314*	*0*	*0*	*-21.77*	*0.000****
Energy consumption (Mcal/ha)	*4,661*	*1,238*	*2,579*	*1,161*	*-13.13*	*0.000****
Herbicides use (g Glyphosate eq./ha)	*839*	*670*	*580*	*526*	*-3.19*	*0.002****
Nitrogen fertilization (N kg/ha)	*61.8*	*47.4*	*52.7*	*45.7*	*-1.47*	*0.144*
Number of farms in the sample	*99*		*133*			

* Significance level $p<0.05$.
** Significance level $p<0.01$.
*** Significance level $p<0.001$.

Table 3
Description of the ANP network elements.

Cluster	*Element*	*Brief description*
Public Goods	*CARBON*	*Carbon balance: GHG emissions and carbon sequestration (in trees and soil)*
	WATERPOL	*Water pollution (nutrients, pesticides and soil sediments)*
	WATERCON	*Irrigation water consumption*
	FLOODRI	*Flooding risk at the basin level (or sub-basin level)*
	BIODIVER	*Biodiversity associated to irrigated olive farmlands, excluding off-farm effects*
	SOILFER	*Soil physical, chemical and structural properties regarding its long term fertility*
	EMPLOY	*Rural employment (limited to that produced inside the farm)*
	FOODSEC	*Contribution to food security (olive oil production in quantity and quality)*
	HERITAG	*Rural cultural heritage, including material (constructions, buildings, etc.) and immaterial (traditional food production, traditions, habits, etc.)*
	LANDSCA	*Visual quality of the rural landscape*
Management Factors	*Fertima*	*Fertilization management*
	Irrima	*Irrigation management*
	Soilma	*Soil management (including pruning residues and herbicides managements)*
	Pruning	*Pruning practices at olive groves*
	Pestco	*Pest & disease control (including management of phytosanitary products, except herbicides)*
	Harvest	*Harvesting practices*
	Funcelem	*Practices related to functional elements (hedgerows, riparian vegetation, plot margins, terraces, etc.)*
	Praherit	*Practices related to management of material and immaterial cultural heritage*
Structural Factors	*Technique*	*Cultivation technique, considering only conventional and integrated*
	Variety	*Variety of the olive tree used*
	Density	*Tree density*
	Size	*Farm olive grove area*

Table 4
Brief description of each of the two approaches used for the ANP application.

ISSUES	***RECEIVED INFLUENCES APPROACH***	***INFLUENCES EXERTED APPROACH***
Network	Fig. 1	Fig. 1 with opposite direction of the arrows
Matrix of interactions	Annex A. Table 1 transposed	Annex A. Table 1
Example of question-type	“Biodiversity of the olive groves” (BIODIVER) and “Soil fertility” (SOILFER) are both influenced by farmer’s decisions concerning “Soil management” (Soilma); which one is more influenced by those decisions and to what extent?	Farmer’s decisions concerning “Soil management” (Soilma) and “Pest and disease control” (Pestco) influence “Biodiversity of the olive groves” (BIODIVER); which one has more influence on it and to what extent?
Example of group of element comparisons	*BIODIVER*, *SOILFER*, *CARBON*, *WATERPOL*, *FLOODRI*, *EMPLOY*, *FOODSEC* and *LANDSCA* with respect to *Soilma*	*Harvest*, *Fertima*, *Irrima*, *Soilma*, *Pestco* and *Funcelem* with respect to *BIODIVER*
Results obtained	To what extent each of the PGs production can be influenced by farmers’ decision making, in % of the their total influence capacity on PGs production (Table 5)	From the farmers’ total influence capacity, which part (in %) corresponds to their decisions regarding each factor (Table 6)

Table 5

Influence capacity on the production of Public goods provided by IOG in Andalusia (in % of the farmers' total influence capacity).

Scope	***PG***	***Experts***														***Mean***
		AGR1	***AGR2***	***AGR3***	***ENV1***	***ENV2***	***ENV3***	***ENV4***	***ECO1***	***ECO2***	***ECO3***	***ECO4***	***TEC1***	***TEC2***	***TEC3***	***(std. dev.)***
ENVIRON-MENTAL	*SOILFER*	12.2	19.3	26.8	24.3	22.4	34.6	37.6	19.4	14.1	14.1	30.7	35.0	30.8	18.7	24.3 (8.4)
	BIODIVER	18.1	13.2	18.5	21.9	12.2	8.4	10.8	15.0	14.6	18.1	25.6	21.2	23.3	18.3	17.1 (5.0)
	CARBON	2.5	7.0	7.5	5.5	13.9	28.8	25.6	10.3	7.1	4.4	6.9	12.2	6.8	8.8	10.5 (7.7)
	WATERCON	5.2	11.2	15.6	6.5	11.2	8.2	10.0	12.1	14.2	10.1	10.7	6.9	8.8	8.0	9.9 (2.9)
	WATERPOL	2.8	7.4	3.0	2.8	5.0	3.3	6.0	5.7	3.3	5.3	6.0	0.9	2.7	3.8	4.1 (1.8)
	FLOODRI	2.0	12.7	2.6	3.4	4.5	1.9	2.8	3.1	2.2	4.6	1.8	6.9	4.4	1.7	3.9 (2.9)
	TOTAL	**42.7**	**70.7**	**74.0**	**64.4**	**69.3**	**85.3**	**92.8**	**65.6**	**55.4**	**56.5**	**81.6**	**83.2**	**76.8**	**59.2**	**69.8 (13.7)**
SOCIO-CULTURAL	*LANDSCA*	37.7	13.9	8.0	23.2	17.1	9.5	4.2	23.1	23.9	27.7	11.7	10.8	14.2	27.4	18.0 (9.4)
	FOODSEC	7.3	11.4	12.3	6.3	10.3	3.7	2.1	8.9	13.3	9.8	5.0	3.7	5.1	7.6	7.6 (3.5)
	EMPLOY	10.7	2.8	4.0	5.6	2.4	1.3	0.8	1.7	6.1	4.5	1.5	2.2	2.5	4.3	3.6 (2.6)
	HERITAG	1.6	1.2	1.8	0.4	0.9	0.2	0.1	0.7	1.2	1.4	0.2	0.3	1.4	1.5	0.9 (0.6)
	TOTAL	**57.3**	**29.3**	**26.0**	**35.6**	**30.7**	**14.7**	**7.2**	**34.4**	**44.6**	**43.5**	**18.4**	**16.8**	**23.2**	**40.8**	**30.2 (13.7)**

Table 6

Influence capacity of each of the factors regarding the production of Public goods provided by IOG in Andalusia (in % of the farmers' total influence capacity).

Cluster	**Factor**	***Experts***														***Mean (std. dev.)***
		AGR4	***AGR5***	***AGR6***	***ENV5***	***ENV6***	***ENV7***	***ENV8***	***ECO5***	***ECO6***	***ECO7***	***TEC4***	***TEC5***	***TEC6***	***TEC7***	
MANAGEMENT FACTORS	*Fertima*	0.0	6.3	1.6	16.1	12.5	0.0	4.3	10.1	0.0	0.4	0.0	0.0	3.6	15.9	5.1 (6.1)
	Irrima	0.0	6.3	2.4	14.6	1.8	0.0	5.1	9.0	0.0	0.6	0.0	0.0	4.0	8.8	3.8 (4.5)
	Soilma	0.0	4.9	3.6	4.0	14.6	0.0	4.6	5.6	0.0	0.9	0.0	0.0	4.3	10.5	3.8 (4.4)
	Harvest	0.0	2.9	4.2	0.3	3.9	0.0	5.1	2.2	0.0	0.4	0.0	0.0	4.5	1.9	1.8 (2.0)
	Pruning	0.0	2.9	1.2	1.0	0.9	0.0	0.7	2.2	0.0	0.9	0.0	0.0	1.4	1.9	0.9 (0.9)
	Pestco	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (0.0)
	Funcelem	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (0.0)
	Praherit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0 (0.0)
	TOTAL	**0.0**	**23.1**	**13.1**	**36.0**	**33.7**	**0.0**	**19.9**	**29.2**	**0.0**	**3.2**	**0.0**	**0.0**	**17.8**	**39.1**	**15.4 (15.0)**
STRUCTURAL FACTORS	*Density*	47.7	25.5	22.0	24.1	19.4	48.3	24.6	28.0	46.4	29.4	46.3	46.4	23.8	19.4	32.2 (11.8)
	Size	8.7	43.6	56.5	27.7	35.5	6.5	46.9	27.3	13.4	55.7	13.4	13.4	49.7	32.4	30.8 (17.7)
	Variety	43.6	6.4	6.5	8.6	3.5	45.2	7.9	14.5	40.2	11.4	40.3	40.2	5.8	3.6	19.8 (17.3)
	Technique	0.0	1.3	2.0	3.7	7.9	0.0	0.7	1.0	0.0	0.3	0.0	0.0	2.9	5.5	1.8 (2.4)
	TOTAL	**100.0**	**76.9**	**86.9**	**64.0**	**66.3**	**100.0**	**80.1**	**70.8**	**100.0**	**96.8**	**100.0**	**100.0**	**82.2**	**60.9**	**84.6 (15.0)**

Table 7
Main impacts (direct and indirect) of the main Structural Factors on IOG provision of Public goods.[*]

Factor	***SOILFER***	***LANDSCA***	***BIODIVER***	***CARBON***	***WATERCON***	***Other Public goods influenced***
Density		−	−	+	−	*FOODSEC* +; *EMPLOY* +; *HERITAG* −; *WATERPOL* −.
Size	+	−	+/−	+	+	*FOODSEC* +; *EMPLOY* −; *HERITAG* +.

* Symbol + (−) means that an increase in the structural factor has a positive (negative) impact on the provision of the PG.

Figures

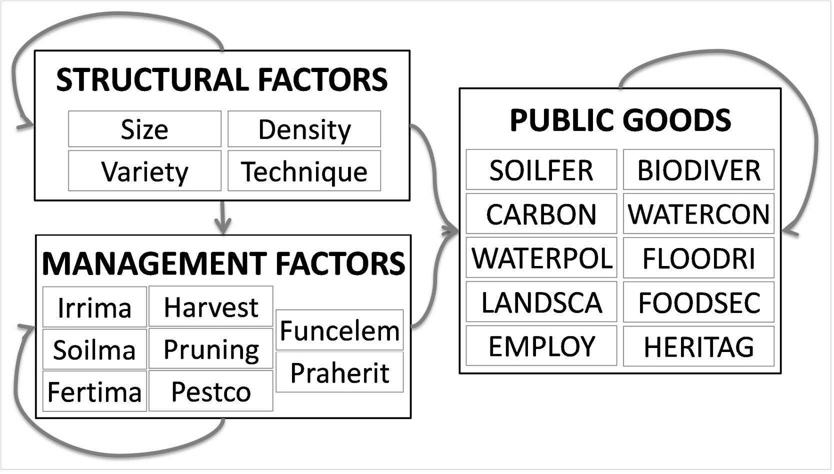

Fig. 1. ANP network for the analysis of IOG Public goods production. The meaning of the elements included in each cluster can be found in Table 3.

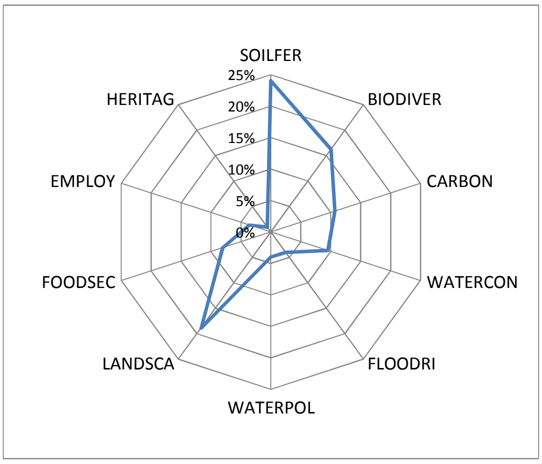

Fig. 2. Influence capacity on the different IOG productions of Public goods (in %).

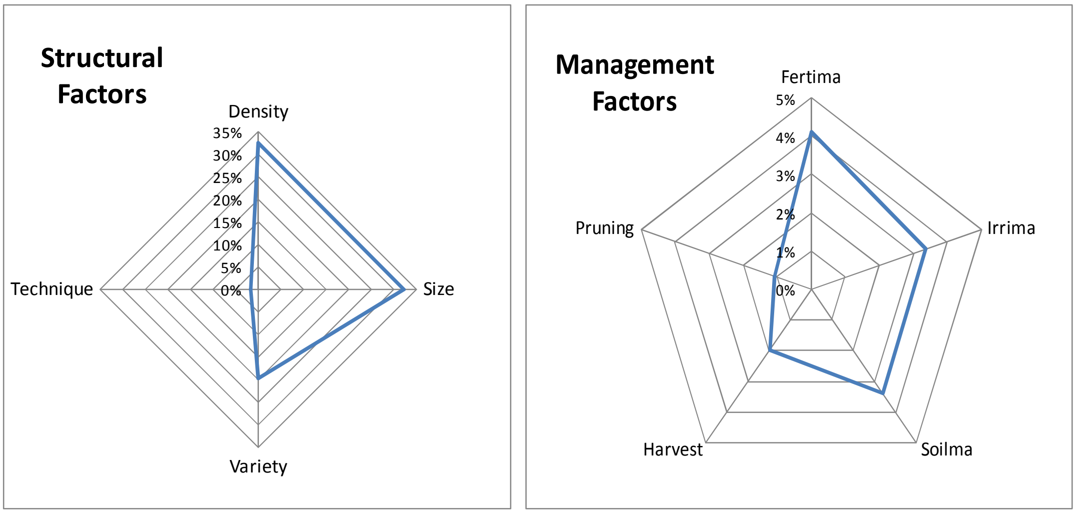

Fig. 3. Influence capacity of Structural and main Management Factors (in %).

Annex A.

Table 1

Matrix of interactions for the influences exerted approach.

		Public goods										*Management Factors*								*Structural Factors*			
		CARBON	*WATERPOL*	*WATERCON*	*FLOODRI*	*BIODIVER*	*SOILFER*	*EMPLOY*	*FOODSEC*	*HERITAG*	*LANDSCA*	*Harvest*	*Fetima*	*Irrima*	*Soilma*	*Pruning*	*Pestco*	*Funcelem*	*Praherit*	*Technique*	*Variety*	*Density*	*Size*
Public goods	*CARBON*	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WATERPOL	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WATERCON	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	FLOODRI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	BIODIVER	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	SOILFER	1	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	EMPLOY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	FOODSEC	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	HERITAG	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	LANDSCA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Management Factors	*Harvest*	1	0	0	0	1	0	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0
	Fertima	1	1	0	0	1	1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0
	Irrima	1	1	1	0	1	0	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0
	Soilma	1	1	0	1	1	1	1	1	0	1	0	1	1	0	0	1	1	0	0	0	0	0
	Pruning	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0
	Pestco	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Funcelem	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Praherit	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0
Structural factors	*Technique*	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0
	Variety	0	0	1	0	0	0	0	1	1	0	1	0	0	0	1	1	0	1	0	0	1	0
	Density	1	0	1	0	0	0	1	1	0	1	1	1	1	1	1	1	0	0	1	1	0	0
	Size	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	1	0	1	0