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Participatory analytic hierarchy process for resource allocation in agricultural development projects

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1. Introduction

In the 2030 Agenda for sustainable development, agriculture plays a central role (Food and Agriculture Organization (FAO), 2017). The transition towards a more sustainable agricultural sector is a transversal challenge worldwide and implies the shift towards renewed approaches to the planning and evaluation of policies and specific interventions (International Panel of Experts on Sustainable Food Systems (IPES-Food), 2016, 2017). The diffusion of a new culture of evaluation in development agendas is believed to be a part of the leverage tool for this much-needed shift (Barbier & Hawkins, 2012).

In this perspective, agricultural development is an important area because of its overall societal impact and fundamental role in reducing poverty and boosting economic growth. Nearly 90 % of the population in many developing countries depend on agriculture and farming for their livelihood, as agricultural production provides income, employment, and food, as well as raw materials for the processing industry and exports (European Union (EU), 2019). Consequently, the problem of choosing the best path towards sustainable development in the agricultural sector is currently central to development cooperation (DC). Agri-environmental and landscape-scale issues are the typical targets of participative and multicriteria decision-making procedures as they involve community resource planning and multidisciplinary knowledge (Dunnett et al., 2018). Consistent with what ensues in the field of impact assessment (Cornwall & Aghajanian, 2017), some authors report that in order to successfully solve the complex real-world problems, multi-criteria group decision-making approaches and multidisciplinary analysis are recognized as reliable and effective (Groselj, 2018). Such tools are required to provide more evidence-based and shared choices, possibly linking interventions from the basic technical level to the top policy level. Shifting from local scale perceptions to a global perspective, stakeholders' interaction may give rise to misunderstanding and conflict over strategic decisions. While several international development organizations emphasize the need to conceive and implement multi-stakeholder development governance systems and spread the practice of evaluation (FAO-CFS, 2015; Mayne, 2008; United Nations Development Programme (UNDP), 2012), we focus on effective methodologies for facilitating the task.

According to several authors, the requested methodologies share features such as the importance of participatory, multi-stakeholder, and multidisciplinary analysis approaches (IPES-Food, 2017).

Participation is a broad concept with multiple definitions. However, a commonality to all the definitions is the role of the community in decision-making (Claridge, 2004). For the scope of this study we adopt the definition proposed by Lane (1995, pp. 181-191): '*Participation means meaningful implication of individuals and groups at all stages of the development process including that of initiating action.*'

A participatory, multi-stakeholder approach approximates the diversity of interests and positions in the target system, attempting not only to spread democratic principles but also to increase the practical likelihood that the proposed actions and plans will be accepted and effectively implemented. In this perspective, and to acknowledge and understand the diversity of values among the different stakeholders, several authors agree that truly participatory and multi-stakeholder decision support systems must include a multidisciplinary assessment of alternatives and choice criteria (UNDP, 2012).

Therefore, interest in participatory and multi-criterial decision-making methodologies (MCDM) in agriculture has been growing rapidly, primarily because these methods are proficient in informing community decision-making (Pazek & Rozman, 2005; Tiwari, Loof, & Paudyal, 1999). Literature shows that the analytic hierarchy process (AHP) (Saaty, 1980), among other techniques and tools, can be used as a 'bottom-up' participatory method, working as a consensus-building tool to enable stakeholders to discuss single criteria and weights to under-

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stand each other's viewpoint in iterative decisions processes. Notably, the analytic hierarchy process is recognized as one of the leading techniques among the family of MCDM or multi-criteria decision aiding (MCDA) methodologies (Emrouznejad & Marra, 2017; Ho & Xin, 2018). One of the main benefits of AHP, especially if implemented as participatory AHP (PAHP), is that it optimizes project multi-ownership which, in turn, leads to better performance from project managers, management, and participants in general (Israel, Schulz, Parker, & Becker, 2002).

The analytical hierarchy process allows to consider both objective and subjective factors in the decision-making process (Aznar, Guijarro, & Moreno-Jiménez, 2011; Russo & Camanho, 2015). Thus, AHP may be relevant in operational fields where community planning and participatory decision-making processes are important for achieving the desired results of development initiatives. The reason for this relevance was assumed a long time ago with Shumway (1981, p. 171) declaring, '… *any ex-ante evaluation procedures are inherently subjective. The only difference is where subjectivity enters and how it is processed. Consequently, the legitimate role of subjectivity in ex-ante evaluation needs to be recognized clearly and respected.'* More recently Palcic and Lalic (2009) suggested that AHP can enhance methods for evaluating project proposals; however, the authors refer to the business sector and we could not find any literature specifically relevant to non-business-oriented initiatives.

In the field of DC, participatory approaches to assessment, research, management, and budgeting have been widely studied and applied over the last few decades (FAO, 2006a; World Bank, 2018). In fact, DC initiatives, in all their relevant phases from planning through implementation, monitoring, and evaluation, face the problem of identifying initiatives that can be successfully and sustainably implemented.

The present study investigates the application of PAHP as a tool for choice criteria elicitation and resource allocation in the framework of operational planning for agricultural development projects in the Dioceses of Goma (or Goma Diocese or GD), Nord Kivu, Democratic Republic of Congo (DRC). We attempt to present AHP as a participatory and multidisciplinary technique. In fact, the practical objective of using AHP in the specific framework of the case study is to elicit a group discussion on priority criteria and to have useful new elements to determine and argue a shared resource allocation pattern. The main research questions of this study are: (1) What are the most important criteria behind the prioritization of interventions aimed at achieving sustainable agricultural development in the Goma Diocese (GD) Nord Kivu, DRC? (2) How should financial resources be allocated on identified priority interventions? (3) What is (if any) the added value of using PAHP?

The rest of the study is structured as follows. Section 2 outlines the research workflow, it describes the case setting of the study and reports about the present and past PAHP/AHP application in agricultural development and DC. Section 3 presents the results and discussion. Section 4 outlines possible conclusions and suggests future research perspectives on the subject.

2. Materials and methods

2.1. Research workflow

As shown in Fig. 1 and detailed in Fig. 2, research workflow was implemented over two years and comprised a preparation phase, participatory work phase (PAHP phase), and desk work phase (AHP phase). Being in the framework of the 'Appui au retour de réfugiés et déplacés par le biais de la sécurisation de terres en Diocèse de Goma' (ARDST) project (see Section 2.4 for case study description), we were able to build the decision path by starting from in-depth data collection aimed at evaluating the agricultural potential of the study area. This was achieved through three field surveys, elicitation of experts through semi-structured interviews,[1] and land use analysis through remote sensing (Author et al., 2019a). The whole decision process was animated through a mixed-methods approach and with the declared goal of widening participation and building a transformative environment where decision makers (DMs) could 'learn by doing'.

The preparation phase produced detailed information background on local agricultural system that resulted in a preliminary list of interventions expected to improve the sustainability of the sector. This list fed the following path. In order to appropriately approach the identification of triggering interventions, the same multidisciplinary team conducted the entire process applying a transformative participatory approach (Groselj, 2018). The participatory part of the path started during the preparatory phase, that is, during a mission in North Kivu (NK) (Goma, February 2018) and by organizing a preliminary training session dedicated to the use of the Simplified Pairwise Ranking (SPWR) (FAO, 2006a; Narayanasamy, 2009; World Bank, 2018) focusing on priorities for intervention in one of the pilot areas of the project[2] ('SPWR phase' in Fig. 2). The working group comprised fourteen people with different backgrounds and expertise: four agronomists, four jurists, three experts in sustainable rural development, one sociologist (professor), one civil engineer, and one cartographer. The participants were selected according to the availability of experts already working in the target zone in the framework of the ARDST project. They have different socioeconomic backgrounds and are not representative of stakeholders' diversity in the region; however, due to their practical experience in local agricultural development they can be considered as approximating all the different perspectives in agricultural development in the target region. The three main objectives of the SPWR session held in February 2018 are: (1) training the team in the use of MCDM methods in a simplified form (SPWR methodology), (2) defining and describing of interventions (alternatives) and criteria/sub-criteria, and (3) refining the preliminary list of interventions and criteria by limiting the scope of the following analysis to the five most relevant alternatives for agricultural development in the study area. This led to a preliminary decomposition of the problem followed by developing a preliminary decision hierarchy.

After the preparation phase, we first implemented AHP as PAHP for eliciting discussion on the relative importance of criteria and sub-criteria versus the global goal. During the third phase, we used AHP as a desk tool to allocate resources according to the weighting of alternatives against the global goal. The different phases are shown in Fig. 1 and the relevant phases are described hereafter.

The PAHP phase allowed the working group to implement a participatory weighting of criteria and sub-criteria behind the target choice and to identify and valorize inconsistent judgements across the group. The AHP final phase allowed for aggregating individual refined priorities into a group consensus priority vector for resource allocation.

For implementing PAHP, the Priority Estimation Tool (PriEsT; Siraj, Mikhailov, & Keane, 2015) was used for calculating individual and local preferences through 'live' calculation and refinement during a meeting held in February 2019 in Goma. The PriEsT is an open-licence platform-independent Java-based tool that implements several prioritization methods and consistency measures.

The PAHP phase was aimed at weighting criteria and sub-criteria. Utilization of PAHP was intended to provide a solid methodologi-

[1] Eight field supervisors managed the work of 24 surveyors in the GD: 'Shirika' survey produced 1005 observations for 131 variables concerning general local agricultural features and land tenure. A 'Concessions' survey produced 2554 observations of 25 variables concerning specific farm issues, 'Agriculture/élevage' survey produced 33 observations for 334 variables concerning agricultural and animal breeding practices. Nearly 35 experts from the local agricultural sector were interviewed during two rounds of semi-structured interviews in the Goma Diocese (GD).

[2] Collectivity of Katoyi, Nord Kivu, Masisi, DRC.

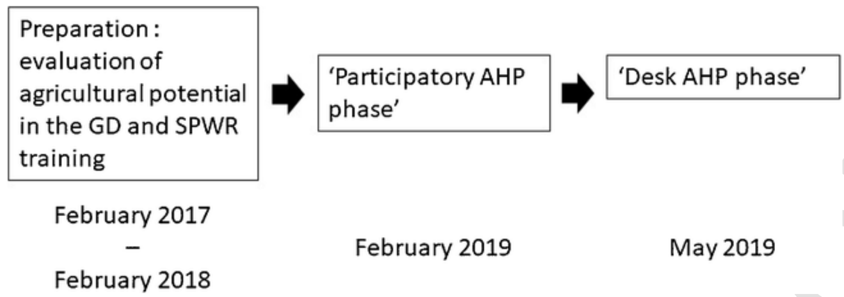

Fig. 1. Study Workflow.

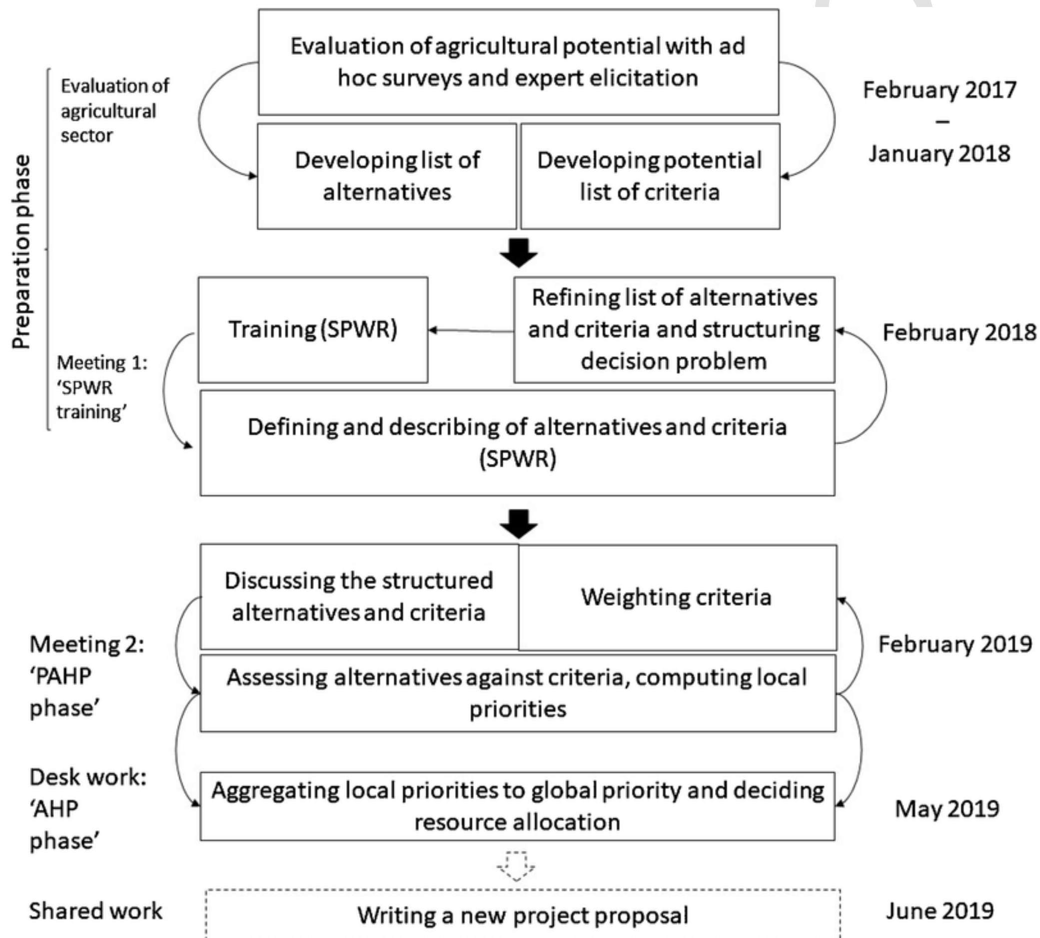

Fig. 2. Decision process structure.

cal structure to the weighting procedure, namely to overcome the problem of potential bias often attributed to focus groups and other participatory techniques when anonymity is not granted along the process. One such type is the so-called 'dominance bias' (Crawford, 1997). This type of bias is produced by the existing differences in terms of communication ability, self-confidence, and authoritativeness among the participants (Sutton & Arnold, 2013).

Among the several methods offered by the PriEsT app for local priorities calculation the geometric mean method (GMM) was selected (Dijkstra, 2013). The local preferences for each participant were recorded during the participatory work session, analysed, and the results were presented in front of the working team. The app helped to identify inconsistencies and adjusted weighting was produced in a two-turn iterative work session.

The AHP analysis was carried out using R (R Foundation for Statistical Computing, version 3.5.0) and Microsoft Excel (Microsoft Office 365) software with the aim of aggregating local priorities to a final and global 'aggregated group priority ranking'. The 'AHP SURVEY' package (CRAN Repository, version 0.4.0) was used to extract local priorities in a structured and automatic form. Microsoft Excel (Microsoft Office 356 version) was then used to aggregate priority vectors and matrixes for each DM and to produce a final aggregated group ranking of weighted alternatives to be used as a resource allocation guide. The GMM was used in computing both the local and global priorities (Dijkstra, 2013).

2.2. Research setting

2.2.1. Case study: Agricultural potential and triggering interventions in the dioceses of Goma, Nord Kivu, Democratic Republic of Congo

The study area lies in the eastern region of the DRC, bordering Uganda and Rwanda, in the Nord Kivu province and it is formalized as the Dioceses of Goma, covering approximately 25,000 sq.km. The whole region is concerned with chronic insecurity due to the presence of several active armed groups (MONUSCO, 2018) in the framework of what is called the 'geologic scandal' of the DRC (International Monetary Fund, 2014).

The study area is characterized by one of the highest population density in Africa (2,211,000 inhabitants, population density of 88.4 inhabitants/km^2) with the youth population (aged 15 years) accounting for 50 %. The average family size is 5.5 individuals per nucleus. North Kivu has a primary school enrolment rate of 53.2 %. From an ethnic point of view, the region of the two Kivus includes three cultural areas: the north-east is populated by ethnic groups of probable Nilotic origin (Alur, Tutsi) combined with ethnic groups of Bantu origin (Hutu), the great agricultural region of Kivu is inhabited by Nande, Shi, Havu and Hunde, Twa, and the forest region is occupied mainly by Bembe, Lega, and other smaller groups (Vansina, 1966).

Very few families have access to drinking water (16.6 %) and electricity (4.3 %), and 99.8 % of the households do not benefit from waste disposal services. Compared with international WHO standards, infrastructure for delivering health services are few and poor: 12 hospital beds per 100,000 inhabitants and 1 doctor per 24,030 inhabitants.

Most of the roads outside the capital and the main cities of the region, with the exception of roads heading towards Kigali (Rwanda), are unpaved clay roads, often interrupted by the varied orography (with altitudes ranging from 1300 m to the tops of volcanoes that reach 3500–4000 m a.s.l.), combined with heavy rain seasons, and the poor maintenance by state authorities.

The economy of North Kivu is based on the primary sector (agriculture, livestock, fishing, forestry, mining), which represents about 49.7 % of the provincial GDP and employs about 80 % of the active population (UNDP, 2009).

According to the FAO (2001), the study area is part of an agroecological zone characterized by a long growing season of nearly 210–365 days per year. The local agricultural system can be framed in the agroecological zones: moving westward from the higher altitudes that lie along the borders with neighbouring Uganda, Rwanda, and Burundi and heading towards the forest, the farming system called 'Highland Perennial' gives way to a 'Forest Based' system. Two production systems exist in this setting: (1) small farmers, practicing subsistence family agriculture on small plots, and (2) large landowners who mainly grow cash crop plantations in monocultural cropping systems for business, or breed cattle in extensive systems.

It follows that the area is characterized by a high poverty rate, and 61 million people are currently living below the US$1.90 per day international poverty line. Overall, this amounts to 60.5 % of the entire population in 2018 (World Poverty Clock, 2019). The operational context for this study is provided by an EU-funded project called ARDST 'Appui au retour de réfugiés et déplacés par le biais de la sécurisation de terres en Diocèse de Goma', led by Caritas Development Goma NGO. The ARDST project is framed in the European strategy for peace seeking and keeping operations in the African Great Lakes region and contributes to the implementation of the Protocol on the Property Rights of Returnees signed at the International Conference of Great Lakes Region (ICGLR) on November 30, 2006. Moreover, the ARDST project follows the guidelines of the European Development Fund National Strategy for the DRC, focusing on the increased diffusion of the state-of-law and augmented sustainability of the agricultural sector (EC, 2013). Among the specific objectives of the ARDST project, our research group was asked to contribute to the strategic evaluation of the agricultural sector aimed at identifying interventions that trigger agriculture and at allocating financial resources within the framework of a new project proposal on the subject. Taking into consideration the need to innovate planning and evaluation methodologies in DC, as expressed by the Congolese government during the official EU-DRC negotiations (EC, 2013) and confirmed by the more general framework of international DC providers (IPES-Food, 2016; Barbier & Hawkins, 2012), we proposed a mixed method evaluation approach and the AHP technique as it has the ability to build more robust decisions and foster participation among the DMs.

2.2.2. The decision structure[3]

The study's target decision is about identifying the most important interventions to be implemented in the agricultural sector. These constitute the alternatives for the decision. As shown in Fig. 3, the decision tree comprises four levels and seventeen factors that are described in Table 1. The global goal is to improve the sustainability of the agricultural sector (DSA) in the GD. In order to better describe the possible contributions to DSA, the concept of sustainability has been divided into three conventional components (Barbier, 1987), which constitute the sub-goals or criteria at level 2. Their comparison against the global goal produces the first weighting level in the decision tree (weights of DEC, DEN, DES). Descending towards the alternatives and to become practical in terms of effects that would impact the mentioned dimensions of sustainability, we were able to define eight sub-criteria (or desirable effects) whose comparison against the criteria produce the second weighting level in the decision tree (weights of RDI, DP, APC, RUAC, LE, AFS, ACP, ARP[4]). Finally, five alternatives for backward intervention constitute the causes of the identified desirable effects towards the achievement of the global goal (FTA, ISA, TPA, ISBP, AM[5]). All these levels of the decision structure were discussed in detail during the preparation phase and first meeting in order to bring the working group to share knowledge and interpretation of the elements of the decision tree.

2.2.3. Criteria and sub-criteria interconnections

During the PAHP phase, that is, during the drafting of the decision structure, an ad hoc focus group was organized to evaluate the relationship existing between the identified criteria and sub-criteria.

Directed graphs were used (Biggs, Lloyd, & Wilson, 1986) to assess and visualize the existence of directed interconnection between the criteria and between the sub-criteria. Obviously, at the criteria level, three factors were found to be completely interconnected as the same definition of sustainability applies to the interconnection between

[3] In this section, we use acronyms for the goal, criteria, sub-criteria, and alternatives: DEC - Durabilité économique or economic sustainability; DEN - Durabilité environnementale or environmental sustainability; DES - Durabilité sociale or social sustainability; RDI - Réduire la dépendance de l'extérieur or reducing external dependencies; DP - Diversifier la production or diversifying production; APC - Augmenter le rendement des cultures or improving crops yield; RUAC - Réduire l'utilisation des agrochimiques or reducing the use of agrochemicals; LE - Lutter contre l'érosion des sols or preventing soil erosion; AFS - Augmenter la fertilité des sols or improving soil fertility; ACP - Augmenter la conservabilité des produits agricoles or improving the shelf life of agricultural products; ARP - Augmenter la rentabilité des produits agricoles or improving the rentability of agricultural products; : FTA - Formation et appui Technique Agricole or technical agricultural training ; ISA - Introduction des Semences Ameliorées (et connaissances) or introduction of improved seeds (and knowledge); TPA - Transformation des Produits Agricoles or processing of agricultural products; ISBP - Intervention de Structuration de la Base Productive or interventions in farmers' organization building ; AM - Accès au marché or access to market.

[4] Please refer to foot note 3 in previous pages.

[5] Please refer to foot note 3 in previous pages.

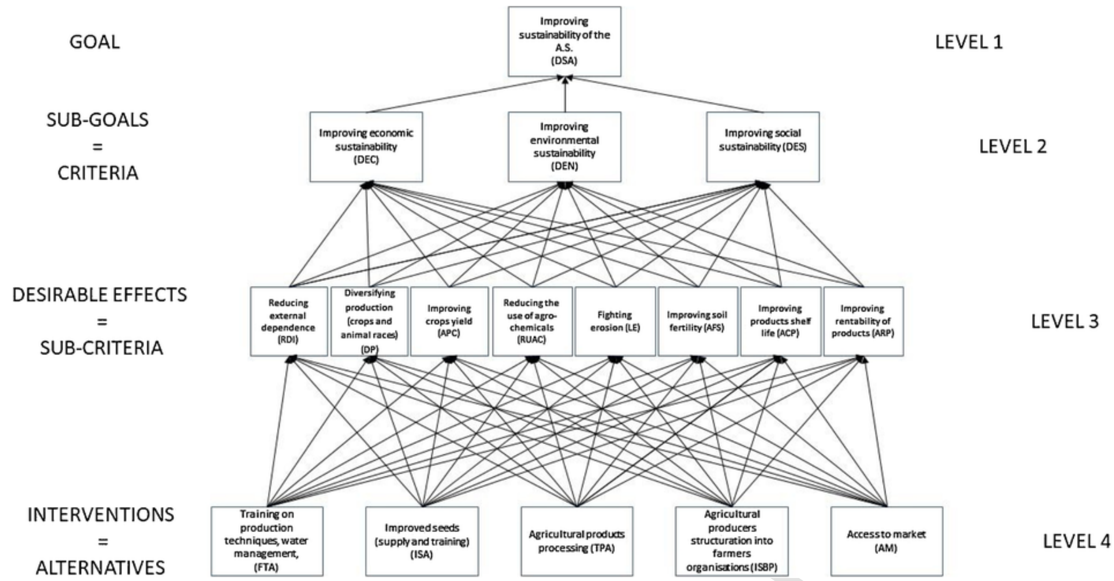

Fig. 3. Decision tree: the goal of the decision is to foster sustainability of the agricultural sector in the GD Sustainability is divided in its three acknowledged dimensions which constitute the main sub-goals or criteria for the decision. Eight desirable effects for the achievement of sub-goals are identified as sub-criteria for the decision. Five alternatives for intervention constitute the alternatives in the target decision. All the elements appearing in the decision tree are described in Table 1.

the three dimensions. Concerning sub-criteria, the focus group produced the directed graph shown in Fig. 4.

Moreover, sub-criteria were classified according to a short list of features that were argued to be useful to frame the existing interconnection. NodeXL Basic Template 2014 for Microsoft Excel (version 1.0.1.381, Social Media Research Foundation) was used to create the directed graph and to calculate graph metrics such as the number of inbound, outbound, and total connections for each vertex. The results are presented in Table 2.

All the effects composing the set of sub-criteria were found to be related to human capital building as capacity building affects local stakeholders' ability to handle all possible improvements in the actual situation. In contrast, only RDI and RUAC were argued to be related to other policy effects: reduction of external dependencies was linked to the market and commercial policies, and the decrease in agrochemicals use was related to the environmental policy. In the context of relationships involved during the production and processing phases of agricultural value chains, the sub-criteria are divided between the targeted production and processing effects, with only one case related to both phases. The RDI was argued to depend on both types of intervention. In terms of interconnections, Fig. 4 shows the connected sub-criteria. The only two sub-criteria having only inbound and no outbound connections are ACP and ARP, indicating that these effects do not influence others.

2.3. AHP: past and present applications

The AHP has been applied widely in several sectors in the last three decades (Golden et al., 1989). The first references are related to Zahedi's (1986) work showing organizations deploying AHP predominantly in the manufacturing process. Contemporary studies by Apostolou and Hassell (1993)) investigates AHP within the accounting function and shows increasing usage overtime. The healthcare industry is another target for AHP applications, and Liberatore and Nydick (2008) reviewed over 50 studies relating AHP to decision-making in the medical and healthcare profession.

Despite these examples showing how AHP related literature is often specifically oriented towards some sector, existing reviews (Ishizaka & Labib, 2011; Sipahi & Timor, 2010) help to summarize the main areas of application of AHP: the authors show that AHP is widely applied in industries such as manufacturing, agriculture, environment, power and energy, transportation, construction, and healthcare. Moreover, AHP has also been applied diffusely to education, logistics, e-business, information technology (IT), research and development (R&D), telecommunications, finance and banking, urban management, defence and military, politics and government, marketing, tourism and leisure, sports, archaeology, auditing, and mining.

In all these fields and sectors, AHP has been applied to help solve a host of problems (Golden et al., 1989): (1) project selection and (2) location selection (Cheng & Li, 2005), (3) resource allocation (Braunschweig & Becker, 2004; Ramanathan & Ganesh, 1995), (4) risk management (Mustafa & Al-Bahar, 1991), (5) technology selection, (6) conflict management (Lam & Chin, 2005), (7) project evaluation, and (8) benchmarking (Dey, 2002).

Despite the existing high pressure on international organizations to optimize available resources and account for the selection of intervention sectors in several countries, we did not find evidence of AHP being applied to resource allocation in the field of DC.

In fact, although AHP has been applied to real-world cases, DC organizations tend to neglect the use of more complex MCDM methods such as AHP (Author et al., 2019b) and prefer more operational tools such as SPWR when planning and implementing development projects (FAO, 2006a; World Bank, 2018).

The AHP methodology helps DMs to apportion a decision into a hierarchical structure (Saaty, 1987, 2008). This decision structure comprises L {L1, L2, … Lx} levels that normally correspond to at least one global goal at L1 level, two or more criteria at L2 level, and two or more alternatives on the last Lx level. More than three levels can exist. The decision hierarchy or structure for our case study is presented in Fig. 3, and it can be used as an example. Each level includes F {F1.1, F2.1, …Fx.y} decision factors. In our study (Fig. 3), the decision has been structured into four levels containing: one overall goal on L1 (decision factor F1.1), three criteria on L2 (factors F2.1 to F2.3), eight sub-criteria on L3 (factors F3.1 to F3.8), and five alternatives on L4 (factors F4.1 to F4.5). The AHP method uses pairwise comparison matrixes (PCMs) to compare the relative importance of factors on one level against each criterion on the upper level of the decision structure. In case of multiple DMs, each DM must complete a pairwise comparison matrix for each level and for each factor at the mother-level (upper level in the decision structure). A PCM is a two-dimensional ar-

Table 1
Describing all the goals, criteria, sub-criteria, and alternatives in the decision tree shown in Fig. 3. Definitions and descriptions are generated from the participatory discussion held during meeting 1 'SPWR phase' or from the literature, wherever cited.

Acronym	Complete name	Description
Global goal		
DSA	*Durabilité du Secteur Agricole* or Sustainability of the agricultural system sustainability	The FAO definition for sustainable agricultural development is 'the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development … conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable.' (FAO, 1995)
Sub-goals or Criteria		
DEC	*Durabilité économique* or economic sustainability	Economic sustainability refers to practices that support long-term economic growth without negatively impacting environmental, social, and cultural aspects of the community.
DEN	*Durabilité environnementale* or environmental sustainability	Environmental sustainability is the management of our physical environment in a way that supports living within ecological limits, protects natural resources, and meets the needs of communities without compromising the ability of future generations to meet their own needs.
DES	*Durabilité sociale* or social sustainability.	Social sustainability encourages communities to promote social interaction and fosters community investment while respecting social diversity. It includes cultural sustainability, which is the idea that fostered practices honour traditional values, customs, spaces, and way of life.
Desirable effects or Sub-criteria		
RDI	*Réduire la dépendance de l'extérieur* or reducing external dependencies	Reducing external dependencies is an important goal because people feel frustrated by the incapacity of the local and national governance to valorize the huge potential of the area in terms of available resources and possibility to foster local well-being. The potential to gain self-sufficiency is experienced on a large scale as an urgent need when confronting the prospect of foreign markets rapidly entering the region. On a smaller scale, self-sufficiency is perceived by people as the possibility to profit from local resources that are perceived as abundant but inaccessible.
DP	*Diversifier la production* or diversifying agricultural production	Diversifying agricultural production is perceived as a chance to increase resiliency due to climate change, unpredictable agricultural seasons, unstable market prices, and unstable socio-political local conditions.
APC	*Augmenter le rendement des cultures* or improving crops yield	The increase in crop yield is perceived as the key desirable effect in agriculture.
RUAC	*Réduire l'utilisation des agrochimiques* or reducing agrochemicals use	The reduction in agrochemicals use is perceived as a means of improving the environment and health impact of agriculture. Moreover, it is considered to be the best approach to decrease production expenses (if other means are provided to increase the yield).
LE	*Lutter contre l'érosion des sols* or preventing soil erosion	Preventing soil erosion is perceived as a priority by the population living in such sloping regions. Considering that agriculture is traditionally implemented on hard slopes and that rainy seasons are quite aggressive in the entire region, the phenomenon of massive soil erosion is observed and is rapidly reducing agricultural productivity.
AFS	*Augmenter la fertilité des sols* or improving soil fertility	Improving soil fertility is perceived as a prerequisite for expanding yields and reducing the need for fertilizers. In fact, soil fertility is the key asset for agricultural production,

Table 1 (*Continued*)

Acronym	Complete name	Description
ACP	*Augmenter la conservabilité des produits agricoles* or improving the shelf life of agricultural products	Agricultural products are prone to seasonal price fluctuations due to the availability of products during a specific period in the year and proximity to the agricultural market in the region. The possibility to increase the shelf life of products is perceived as a huge potential for reducing production waste and increasing and stabilizing incomes.
ARP	*Augmenter la rentabilité des produits agricoles* or Improving rentability of agricultural products	Rentability of products in such a closed market context is the key triggering factor for improving well-being. Improved rentability is perceived as the sum of many factors such as the opportunity to sell during more profitable periods of the year, improve and differentiate product quality in order to satisfy the needs of the elite and more profitable markets in the region.
Interventions or Alternatives		
FTA	*Formation et appui Technique Agricole* or agricultural technical training	This is a training and technical demonstration intervention including capacity building for producers as well as local technicians and training on new techniques. The training is always accompanied by a basic supply of inputs and implementation of one or more centres for technical assistance and sale of inputs and tools.
ISA	*Introduction des Semences Ameliorées* (et connaissances) or introduction of improved seeds (and knowledge)	It is a triple intervention: distribution of improved seeds belonging to improved local varieties (no unsuitable and infertile hybrids), training for farmers interested in the conservation of agro-biodiversity and its valorization by improving local varieties and launching a local seed company.
TPA	*Transformation des Produits Agricoles* or processing of agricultural products	This is a composite intervention aimed at improving the performance of the target value chains. The intervention was described as a demonstration, within ad hoc demonstrative farms, of the profitability of agriculture through the introduction of profitable crops in functional rotation, integration of livestock and agriculture in order to value the existing synergies, creation of small decentralized processing units, artisanal but improved, and the establishment of local cells for maintaining structures and technical means.
ISBP	*Intervention de Structuration de la Base Productive* or intervention on farmers' organization building	This is a training intervention focused on structuring agricultural and agri-food associations and cooperatives, including economic support to meet the costs of formalization, post-creation animation to promote an associative spirit and good administrative functioning, and support for access to micro-credit or for the creation of local tontines.
AM	*Accès au marché* or access to markets	This is an action that supports market studies focused on target value chains and for building, according to the results of the studies, new structures well located for marketing (covered markets with storage space and means for facilitating the flow of foodstuffs). The action is complemented by the establishment of local cells for the maintenance of structures and technical means.

ray where decision factors are compared pairwise by attributing a score on a 1–9 scale (or reciprocal values 1/9 – 1) by asking the question: 'how many times F2.1 is more important than F2.2 in front of F1.1?' Priority vectors are then calculated for each PCM (local priority vectors) and aggregated into a priority matrix for each level. In the case of our study, we concluded with eight priority vectors at level 4, three priority vectors at level 3, and one priority vector at level 2. Single priority vectors are aggregated into matrixes at each level and these matrixes are then aggregated into a final priority vector that contains the relative weight of alternatives against the global goal. When the AHP is applied in group sessions, individual final priority vectors can be aggre-

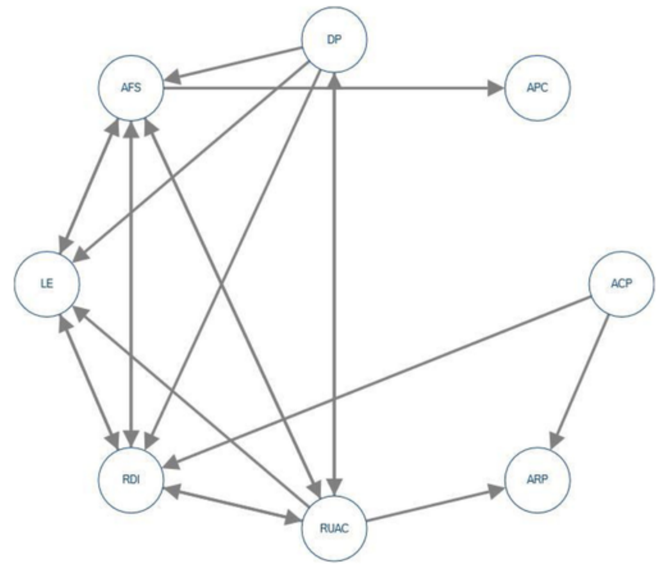

Fig. 4. Directed graph showing existing interconnection between subcriteria.

gated into a group priority matrix, and a group or consensus priority vector can be computed.

The AHP can be implemented in four simple consecutive steps:

1) Computing the vector of criteria weights
2) Computing the matrix of sub-criteria weights
3) Computing the matrix of option scores
4) Ranking the options

Each step will be described in detail hereafter. It is assumed that *m* evaluation criteria and *s* sub-criteria are considered, and *n* options are to be evaluated.

In order to compute the weights for different criteria (F2.1 to F2.3 in Fig. 3) against the overall goal, the AHP creates a pairwise comparison matrix A. Matrix A is a m × m real matrix (see Formula 2), where m is the number of evaluation criteria considered. Each entry a_{jk} of matrix A represents the importance of the j^{th} criterion relative to the k^{th} criterion. If $a_{jk} > 1$, then the j^{th} criterion is more important than the k^{th} criterion; similarly, if $a_{jk} < 1$, then the j^{th} criterion is less important than the k^{th} criterion. If two criteria have the same importance, then the entry a_{jk} is 1. The relative importance between the two criteria is measured according to a numerical scale from 1 to 9. The values in matrix A are pairwise consistent by construction because the entries a_{jk} and a_{kj} satisfy the following constraint:

$$a_{jk} * a_{kj} = 1 \tag{1}$$

Obviously, $a_{jj} = 1$ for all j.

$$A\,(m*m) = \begin{bmatrix} a_{11} & \cdots & a_{1k} \\ \vdots & \ddots & \vdots \\ a_{j1} & \cdots & a_{jk} \end{bmatrix} \tag{2}$$

Once matrix **A** is built, it is possible to derive from **A** the *normalized pairwise comparison matrix* $\mathbf{A}_{norm}$ (3) by making the sum of entries on each column equal to 1;

$$A_{norm} = \begin{bmatrix} \bar{a}_{11} & \cdots & \bar{a}_{1k} \\ \vdots & \ddots & \vdots \\ \bar{a}_{j1} & \cdots & \bar{a}_{jk} \end{bmatrix} \tag{3}$$

Each entry $\bar{a}_{jk}$ of matrix $\mathbf{A}_{norm}$ is computed as

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{j=1}^{m} a_{jk}} \tag{4}$$

Finally, the criteria weight vector W_c (an m-dimensional column vector) is built by computing the geometric mean of the entries on each row of A_{norm}, that is,

$$W_c = \begin{vmatrix} w_1 \\ \vdots \\ w_j \end{vmatrix}$$

W_c contains the weights of m criterion against the global goal and its entries are computed using the GMM with Formula (5).

$$w_j = \sqrt[m]{\bar{a}_{j1} * \bar{a}_{j2} * \ldots * \bar{a}_{jk}} \tag{5}$$

In order to compute the weights for different sub-criteria (F3.1 to F3.8 in Fig. 3), the AHP starts creating PCMs B1, B2, and B3 in order to compare the eight sub-criteria against each one of the criteria at the above level. Each matrix B is a *s* × *s* real matrix, where *s* is the number of evaluation sub-criteria considered. Formulas (1)–(5) are used again, as shown for weight computation for criteria, by replacing matrix A with matrixes B1, B2, and B3. In this case the aim is to obtain the three sub-criteria weight vectors w_1, w_2, and w_3, which are s-dimensional column vectors containing the relative weight of sub-criteria against each of the three criteria. These column vectors are built by averaging the entries on each row of $B1_{norm}$, $B2_{norm}$, and $B3_{norm}$. Finally, the three sub-criteria weight vectors are reunited in a *s* × *m* sub-criteria weight matrix W_s.

$\mathbf{W_s}$ is obtained as

$$W_s = \begin{vmatrix} w_1 & w_2 & w_3 \end{vmatrix} \tag{6}$$

Table 2
Showing the classification of sub-criteria according to some useful features for describing factor interconnectivity. Acronyms: RDI - Réduire la dépendance de l'extérieur or reducing external dependencies; DP - Diversifier la production or diversifying production; APC - Augmenter le rendement des cultures or improving crop yields; RUAC - Réduire l'utilisation des agrochimiques or reducing the use of agrochemicals; LE - Lutter contre l'érosion des sols or preventing soil erosion; AFS - Augmenter la fertilité des sols or improving soil fertility; ACP - Augmenter la conservabilité des produits agricoles or improving shelf life of agricultural products; ARP - Augmenter la rentabilité des produits agricoles or improving rentability of agricultural products.

	Max/min	Human capital related	Other policies related	Production related	Processing related	N° of inbound connections	N° of outbound connections	N° of total connections
ACP	MAX	Y	N	N	Y	0	2	2
AFS	MAX	Y	N	Y	N	4	4	8
APC	MAX	Y	N	Y	N	01	0	1
ARP	MAX	Y	N	N	Y	2	0	2
DP	MAX	Y	N	Y	N	1	4	5
LE	MAX	Y	N	Y	N	4	2	6
RDI	MIN	Y	Y	Y	Y	5	3	8
RUAC	MIN	Y	Y	Y	N	3	5	8

In order to compute the matrix containing the scores of options (from F4.1 to F4.5 in Fig. 3), a PCM Ox is first built for each of the *s* sub-criteria. This means that we first build PCMs O1 to O8. Each matrix Ox is a n × n real matrix, where n is the number of options evaluated.

The AHP then applies to each matrix Ox, which is the same two-step procedure described for PCMs A, B1, B2, and B3 and Formulas (1)–(5), that is, it divides each entry by the sum of entries in the same column and averages the entries on each row, thus obtaining the score vectors o_x, where $x = 1,\ldots,s$. Each of the eight vectors contains the scores of the evaluated options with respect to the s^{th} sub-criterion.

Finally, the score matrix $\mathbf{O_w}$ is obtained. It is a $n \times s$ real matrix where each entry o_{jk} represents the score of the n^{th} option (F4.1 to F4.5 in Fig. 3) with respect to the s^{th} sub-criterion.

$$O_w = \left[o_1 \ldots o_8\right] \tag{7}$$

namely, the s^{th} column of $\mathbf{O_w}$ corresponds to o_x vector.

Once the weight vector w_c, sub-criteria weight matrix W_s, and score matrix O_w have been computed, the AHP obtains a vector **v** of global scores by multiplying **O, Ws,** and $\mathbf{w_c}$, that is,

$$v = \left(O_w * W_s\right) * w_c \tag{8}$$

Where v is a n-dimensional column vector containing the aggregated (or global) weights of the n options against the global goal. In other words, the n^{th} entry v_n of **v** represents the global score assigned by the AHP to the n^{th} option.

If multiple DMs exist, the global priority vectors of alternatives against the global goal are aggregated using GMM in order to build the final group global priority vector.

As the final step, options ranking is accomplished by ordering the global scores in decreasing order, thus building the final ranking of the options.

Given that the choice of the priority vectors computation method and the aggregation mode can change the results of the analysis, we prefer to clearly state that our case does not concern a unique choice among exclusive alternatives, rather it refers to a distributive problem such as resource allocation. According to Saaty and Vargas (1993), the distributive mode of aggregation is recommended in distributive decision problems, and it implies normalization of weights as specified by the Formula (4).

Moreover, GMM (Formula (5)) was picked among the possible methods for computing local priorities because it is insensitive to low consistency rates in PCMs (Dijkstra, 2013). For aggregating individual local priorities into group global priority, the GMM was held as a method in order to avoid the rank reversal in global ranking (Stoklasa & Krejci, 2018).

In fact, we emphasize here the need for a computing method that grants both mathematical robustness related to reducing rank reversals and the possibility of accepting high local inconsistency degrees, which are typical of complex real contexts.

Given the participatory framework that characterizes the present work and the operational aim of the decision process, which constitutes the case study for our work, we treated inconsistency in two separate ways: during the PAHP phase, inconsistency of local priorities was only used in terms of highlighting the most inconsistent comparisons and to guide discussions on them. For the specific purpose of our work, the first phase did not have 'too inconsistent PCMs' and, therefore, there was no need for evaluating the PCMs' CR against a threshold. Conversely, during the desk-AHP phase, inconsistency analysis was run and used to extract only consistent decision makers whose priorities were used to allocate resources.

Concerning the inconsistency threshold adopted, it is widely documented in literature that the consistency ratio (CR) threshold for judging a PCM as consistent depends mainly on the matrix size, with higher thresholds when the number of alternatives in PCMs becomes higher (Wedley, 1993). In addition, it depends on the sample characteristics and the analysis (group and/or individual) type. For individual experts, the acceptable CRs are restricted to 0.10 or 0.15, while the CR consistency threshold for groups could be relaxed to 0.20 or 0.25 to allow for non-expert contributions (Ho, 2005). Building on these assumptions, we decided to use a threshold equal to 0.25 and to accept and use scarcely consistent PCMs, as they reflect the perceptions of experts in a complex context, whose opinion, even if scarcely consistent, is the only tool available for informing decisions.

The CRs of all the PCMs in the decision structure have been computed according to Saaty (1980). The author has proved that for a consistent reciprocal matrix, a consistency ratio (CR) can be calculated by comparing the consistency index (CI) of each PCM with an appropriate random consistency index (RI). While RIs are tabled values that vary according to the amount of comparison elements (Saaty, 1980), CI can be calculated on the basis of a consistency measure λ related to each row of a PCM. λ is obtained for each row as the matrix product between the priority vector of the PCM and each row of the PCM, divided by the weight (or priority value) of the same row. Therefore, CI, which is a global measure of consistency for each PCM, is computed for each PCM as a deviation from mean λ using the following formula

$$CI = \frac{\lambda_{mean} - n}{n - 1} \tag{9}$$

where λ_{mean} is computed by averaging the λ values of the PCM rows, and n is equal to the number of elements compared in the PCM.

CRs are computed by Formula (10) $CR = \frac{CI}{RI}$.

(10)

3. Results and discussion

3.1. PAHP for individual local priorities: criteria, sub-criteria ranking, and consensus building[6]

During the PAHP session, criteria and sub-criteria were analysed by pairwise comparison and AHP analysis was implemented using PriEsT software.

The PriEsT app calculates and shows local priority vectors and CRs for each PCM in the decision structure. Moreover, the software graphically shows the three most inconsistent comparisons for each PCM as a tool for eliciting discussions and for adjusting local preferences. This was done during two rounds of in-depth plenary discussion about local priorities and two individual work sessions. During each round, the participants modified their preferences according to the most inconsistent comparisons hinted at by the software, and the adjusted preferences were recorded. Local priority vectors were, therefore, computed and discussed again during each round, bringing improvements for each participant's consistency and consensus about the relative importance of the selected criteria/sub-criteria. It is important to highlight here that the PAHP phase focused on the identification of the most important criteria/sub-criteria with a participative approach. This indicates that the AHP methodology was mostly used in this phase as a discussion-eliciting tool, and that the consistency improvement process was judged satisfactorily when the consistency ratio (CR) improved by approximately 0.2, despite the final CR local value that remained above the 0.24 threshold in many cases.

As mentioned earlier, we were able to identify and discuss most frequent inconsistencies in order to improve global performance. Examin-

6 In this section, we use acronyms for goals, criteria, sub-criteria, and alternatives. Please refer to the captions of Tables 3–6 for explanation of acronyms.

ing the local priority vectors separately for the two levels of criteria and sub-criteria, we were able to identify where most frequent inconsistencies are generated. For comparing the criteria against the goal, inconsistencies were homogeneously distributed among the DMs and the criteria comparisons showing light prevalence of DEC_DES and DEN_DES inconsistent judgements. Examining the frequency of single criteria in inconsistent comparisons, we find that DES is the most frequent criteria in inconsistent choices.

In comparing the sub-criteria against the three criteria, the top-three inconsistent comparisons were RDI_APC, APC_RUAC, and RUAC_ARP, and even after the adjustment rounds, the APC, RUAC, RDI, and ARP sub-criteria remained the most frequent in inconsistent judgements.

The PAHP phase, after the two rounds of discussion on consistency improvement mentioned above, yielded individual aggregate priority vectors for the eight sub-criteria against the global goal. The results are shown in Table 3. Local priority vectors for criteria show high diversity among the DMs' opinion. In Fig. 5 and Table 4, the local priority vectors concerning first level comparison for the eleven DMs can be visualized. Only two DMs attribute equal weight to the three criteria. Notably, seven DMs among the eleven attributes greater importance to environmental sustainability, while only two DMs prioritize economic sustainability and one DM attributes equal weight to environmental and economic sustainability. In the opinion of six out of eleven DMs, social sustainability is the least important and never gets the first rank. Following Wedley (1993) thresholds, CRs witness acceptable consistency levels for only six DMs out of eleven (only six DMs show $CR < 0.24$).

Local priority vectors for sub-criteria show even higher diversity among the DMs reflecting different perspectives and perceptions regarding the relative importance of target desirable effects on the agricultural sector. The CRs show high variability and according to Wedley (1993), only five out of eleven DMs produced consistent judgements despite their indisputable expertise in rural development (only five DMs show $CR < 0.24$).

Inconsistencies identified during the PAHP phase were useful to elicit discussions. In general, inconsistencies related to the comparison of L2 criteria against the L1 global goal may be attributed to the intrinsic interconnection between the three dimensions of sustainability. Specifically, L2 vs. L1 comparison showed that DES caused difficulties in individual preference expression. This may be attributed to the definition and operationalization of the concept of social sustainability with respect to the most acknowledged concepts of economic and environmental sustainability.

Inconsistencies related to the comparison of L3 sub-criteria against each of the three L2 criteria may be generally attributed to the complexity of operational interventions in complex contexts and the intrinsic interconnections that practical interventions on agricultural development have. Specifically, L3 vs. L2 comparisons showed ARP, APC, RDI, and RUAC being the main source of inconsistent judgement. Among these sub-criteria, which we remind being desirable effects of interventions, we find the only two 'minimizing' effects and the two 'maximizing' effects with no outbound relations with other criteria, as shown in Fig. 4. Inconsistent judgements about the two 'minimizing' effects could be attributed to the difficulty in comparing the impact of minimizing factors in a set of maximizing factors. In other words, it means that these inconsistencies may be related to some form of inertia in DMs' reasoning. Inconsistent judgements about APC and ARP could be because these factors were perceived as dominated by the others in terms of being completely dependent on others, and this in turn determines inconsistencies when evaluating the relative importance of these two sub-criteria in respect of other factors. It is important to underline that inconsistent DMs were fundamental for our participatory implementation of AHP because of their role in indicating the most difficult comparisons and, therefore, boosting the discussion meant to build consensus among the participants. For this reason, we find it useful to report individual local priority vectors with CRs above the threshold in Tables 3–5.

3.2. AHP for group global priority: resource allocation on alternatives

The group global priority vector for the five alternatives was computed using R and Excel software. R was used to reproduce AHP analysis for individual global priorities. The results were compared with those derived from the PAHP phase generated by the PriEsT app in order to triangulate the results and to have consolidated priority matrixes for each level of the decision hierarchy and for global priorities. The two procedures, following the same GGM aggregation methodology, produced matching results in terms of priority vectors and CRs. The priority matrixes produced by R software for each level and DM were aggregated using GMM on an Excel spreadsheet. The results are presented in Table 5.

On the one hand, Table 5 shows the individual global priority vectors for the whole team because, as already mentioned, inconsistent DMs were valuable for the scope of the PAHP application, that is, eliciting discussion and building consensus.

According to the eleven DMs group, the group's global priority vector shows the ranking of alternatives (and resource allocation on the interventions) as follows:

1 Technical training on cropping techniques (FTA – Intervention de formation technique agricole): 35 %
2 Supply of improved seeds and training on improved seed production (ISA - Introduction de semences améliorées): 23 %
3 Farmers' organization building (ISBP – Intervention de structuration de la base productive): 17 %
4 Agricultural products processing (ITPA – Introduction de la transformation des produits agricole): 14 %

Table 3
Aggregated local priority vectors of sub-criteria against the global goal for eleven DMs. Acronyms: RDI - Réduire la dépendance de l'extérieur or reducing external dependencies; DP - Diversifier la production or diversifying production; APC - Augmenter le rendement des cultures or improving crop yields; RUAC - Réduire l'utilisation des agrochimiques or reducing the use of agrochemicals; LE - Lutter contre l'érosion des sols or preventing soil erosion; AFS - Augmenter la fertilité des sols or improving soil fertility; ACP - Augmenter la conservabilité des produits agricoles or improving shelf life of agricultural products; ARP - Augmenter la rentabilité des produits agricoles or improving rentability of agricultural products.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
RDI	0.12	0.12	0.05	0.05	0.14	0.16	0.03	0.04	0.12	0.12	0.06
DP	0.14	0.09	0.09	0.17	0.30	0.31	0.08	0.18	0.12	0.14	0.06
APC	0.13	0.28	0.12	0.14	0.12	0.17	0.10	0.21	0.08	0.14	0.18
RUAC	0.13	0.16	0.06	0.07	0.12	0.14	0.16	0.07	0.10	0.20	0.05
LE	0.13	0.07	0.48	0.13	0.07	0.09	0.13	0.15	0.08	0.13	0.05
AFS	0.13	0.12	0.07	0.15	0.15	0.06	0.23	0.09	0.12	0.12	0.23
ACP	0.08	0.06	0.06	0.13	0.06	0.04	0.06	0.12	0.21	0.09	0.04
ARP	0.14	0.10	0.07	0.16	0.04	0.03	0.20	0.14	0.18	0.08	0.32
CR	0.18	0.42	0.68	0.08	0.51	0.39	0.16	0.33	0.14	0.21	0.30

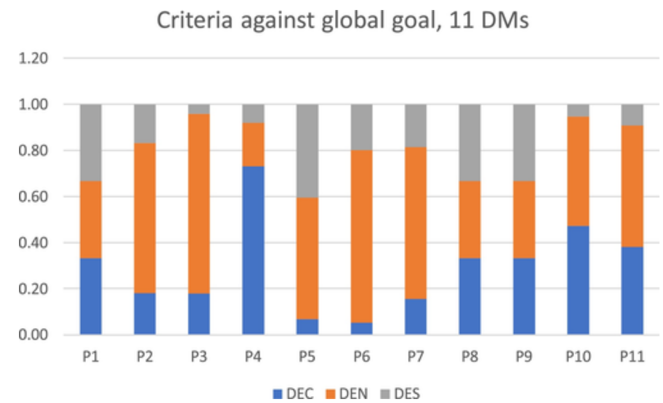

Fig. 5. Graph showing the priority vectors for the eleven DMs for level 1 (criteria against goal).

5 Access to market (AM – Accès au marché): 11 %

On the other hand, in order to build a resource allocation pattern on solid methodological basis, we ran the mentioned consistency test and retained only the consistent DMs, whose aggregated CR is below the 0.24 threshold, in order to compute the resource allocation pattern. Table 6 shows the results. Comparing Tables 5 and 6, it is clear that rank reversal occurs only for the alternatives ranked 2nd and 3rd (ISA and ISBP), and the rank reversal effect in terms of changing weighting for resource allocation is limited to +/- 5 % for both factors. The final weights of alternatives determine the following resource allocation pattern:

1 Technical training on cropping techniques (FTA – Intervention de formation technique agricole): 40 %
2 Farmers' organization building (ISBP – Intervention de structuration de la base productive): 20 %
3 Improved seed supply and training on improved seed production (ISA - Introduction de semences améliorées): 18 %
4 Processing of agricultural products (ITPA – Introduction de la transformation des produits agricole): 12 %
5 Access to market (AM – Accès au marché): 10 %

4. Conclusion and research perspectives

The ARDST project constituted the framework for the implementation of a mixed methods evaluation aimed at decision-making. The whole evaluation and the decision path have been animated through participatory methodologies that informed an improved consensus and a shared decision about both the factors guiding the choice and suitable priority interventions in the agricultural sector of Goma Diocese (GD). During the complete decision path, the case study presented here is a perfect setting for a two-step AHP implementation, namely for experimenting PAHP and producing new insights both in terms of methodological implementation and operational results.

From a methodological point of view, our AHP implementation in group decision-making shows all the criticality found in the existing academic debate on robustness of this methodology (Krejčí & Ishizaka, 2018; Kułakowski, 2018; Pan, Lu, Liu, & Deng, 2014; Russo & Camanho, 2015; Tran, 2013). Nonetheless, AHP was found to turn subjectivity and inconsistency into valuable assets and elicit discussion to improve consensus within the working team. The implementation of PAHP was useful both to structure experts' contributions and to improve DMs' ability to perform multi-criteria weighting and priority allocation. In other words, we were able to use inconsistent pairwise comparisons in order to foster participation and to train DMs to perform holistic judgements. A holistic perception is an important skill when dealing with the complexity of sustainable agricultural development because when incomparable things must be compared this is the only human ability that allows to support choices (Hsieh, 2007; Larrick, 2008). Considering the high level of data inconsistency produced by the application of AHP in our case study, we experienced how strict transitivity, often called linear transitivity, must be considered an ideal outcome of preference expression, exactly as proposed by the first theorist of AHP (Saaty & Vargas, 1984). Several other authors (Nurmi, 2014; Wedley, 1993) state that in real-life situations it is misleading to associate complete and transitive preference relations with rationality and robustness of the technique, especially if it is assumed that AHP and other techniques, such as pairwise ranking, are meant to aid the decision and not to substitute the decision maker.

Nurmi (2014) reports that *'It is generally agreed that intransitivities can occur, especially when the number of items being compared under a multi-criteria framework gets to be greater than five. It is also gener-*

Table 4
Local Priority Vectors for eleven DMs comparing criteria against the goal (level 1 comparison). Acronyms: DEC - Durabilité économique or economic sustainability; DEN - Durabilité environnementale or environmental sustainability; DES - Durabilité sociale or social sustainability.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
X DEC	0.33	0.18	0.18	0.73	0.07	0.05	0.16	0.44	0.33	0.47	0.38
X DEN	0.33	0.65	0.78	0.19	0.53	0.75	0.66	0.39	0.33	0.47	0.53
X DES	0.33	0.17	0.04	0.08	0.40	0.20	0.19	0.17	0.33	0.05	0.09
CR	*0.43*	*0.31*	*0.48*	*0.06*	*0.16*	*0.70*	*0.24*	*0.02*	*0.00*	*0.00*	*0.12*

Table 5
Eleven DMs' individual priority vectors and aggregated group priority vector for the alternatives against the goal. Acronyms: FTA - Formation et appui Technique Agricole or technical agricultural training; ISA - Introduction des Semences Ameliorées (et connaissances) or introduction of improved seeds (and knowledge); TPA - Transformation des Produits Agricoles or processing of agricultural products; ISBP - Intervention de Structuration de la Base Productive or intervention on farmers' organizations building; AM - Accès au marché or access to market.

Rank	Alternatives (interventions)	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	Group Global priority vector
1	**FTA**	0.42	0.22	0.42	0.40	0.32	0.38	0.38	0.39	0.33	0.23	0.31	**0.35**
2	**ISA**	0.12	0.18	0.25	0.17	0.16	0.22	0.25	0.29	0.36	0.23	0.26	**0.23**
3	**ISBP**	0.21	0.31	0.16	0.18	0.22	0.13	0.22	0.12	0.08	0.21	0.12	**0.17**
4	**ITPA**	0.14	0.17	0.10	0.14	0.16	0.14	0.09	0.15	0.15	0.14	0.10	**0.14**
5	**AM**	0.10	0.13	0.07	0.10	0.14	0.12	0.07	0.05	0.08	0.19	0.21	**0.11**
Sum		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
CR		0.12	0.35	0.50	0.08	0.76	0.37	0.09	0.29	0.26	0.25	0.28	

Table 6
Three ‘consistent’ DMs’ individual priority vectors and aggregated group priority vector for the alternatives against the global goal (resource allocation vectors). Acronyms: FTA - Formation et appui Technique Agricole or technical agricultural training; ISA - Introduction des Semences Ameliorées (et connaissances) or introducing improved seeds (and knowledge); TPA - Transformation des Produits Agricoles or processing of agricultural products; ISBP - Intervention de Structuration de la Base Productive or intervention on farmers' organization building ; AM - Accès au marché or access to market.

Ranking	Alternatives (interventions)	P1	P4	P7	Group Global priority vector
1.00	**FTA**	0.42	0.40	0.38	0.40
2.00	**ISBP**	0.21	0.18	0.22	0.20
3.00	**ISA**	0.12	0.17	0.25	0.18
4.00	**ITPA**	0.14	0.14	0.09	0.12
5.00	**AM**	0.10	0.10	0.07	0.10
Sum		1.00	1.00	1.00	1.00
CR		0.12	0.08	0.09	

ally agreed that, if intransitivities are found, they should be analysed and changed, if deemed appropriate. That is, there is no inherent rule that says a set of comparisons should not contain any intransitivities, but they should be made explicit’ (Gass, 1998, pp. 616–624).

In other words, DMs may be good reasons for having intransitive individual preference relations and incomplete preferences. These good reasons were pointed out by the application of PAHP and valorized in terms of team building and in-depth comprehension of different perspectives.

In fact, from an operational point of view, the PAHP methodology is suited for training the project team in MCDM methodologies, for eliciting discussions and for identifying a shared resource allocation pattern that matches the existing international guidelines for agricultural development in the region (IFAD, 2015; FAO, 2017; IFAD, 2015).

Moreover, participants in the decision process appreciated the use of PAHP methodology because it provides the opportunity to structure their own participation and self-improvement work. This has two-fold implications: first, assessing how the proposed methodology was able to overcome the possible bias recorded for the participatory group methodologies; second, spreading participation and the culture of evaluation.

First, asking the participants to work individually on PCMs, and the fact that PCMs drive participants to focus separately on the different levels of the decision structure, helps to reduce the impact of respondent-induced bias, exactly as these biases are managed and reduced at different degrees in the interactive, nominal, and Delphi groups (Sutton & Arnold, 2013). In our experience, the values established by the participatory approach overcome the negative impact of the lack of anonymity during the process, both in terms of the resulting data quality and consensus building.

Second, in our experience, the participatory approach to evaluation and decision-making we used, denotes the choice of data collection and treatment methodologies in which plurality of disciplines and stakeholders were actively sought and equally considered. Working with a constructivist and transformative approach to evaluation, and focusing on decision-making, participation implies the physical contribution of a plurality of disciplines, and the use of a procedure that grants participants equal contribution potential and the opportunity to improve each participant’s ability to better contribute in further decision-making processes.

Participation also implies uncovering biases that become a shared framework for the decision process.

According to Fals-Borda and Rahman (1991), participation is a real and endogenous experience of and for the common people, as it reduces the differences between both experts and communities and mental and manual labour. O’Neill (1989) identified that participation is real when participants can determine their outcomes, and this becomes relevant in the field of DC and the discussion on evaluation.

Concerning the comparisons of L3 vs. L2 vs. L1 factors in the decision tree (Fig. 3), the PAHP path was useful in improving team consensus and identifying the most important factors underpinning the choice of forecasted interventions. These factors (criteria and sub-criteria) are important to build a new solid project proposal that incorporates both the ambition of drafting a shared proposal and focusing on the most deeply felt desirable effects being sought. In fact, in the framework of a project proposal, the choice of proposed interventions is normally the result of an ex-ante evaluation. More precisely, the relative importance of the arguments underlying the choice is subjective and is rarely investigated with advanced MCDMs such as AHP. The reasons behind the choice are often stated by referring to international guidelines issued by developmental organizations such as the FAO, World Bank or others. Nonetheless, even if these references completely cover the statements, it is difficult to deny the 1981 statement made by Shumway (1981, p. 171) declaring, *‘… any ex-ante evaluation procedures are inherently subjective. The only difference is where subjectivity enters and how it is processed. Consequently, the legitimate role of subjectivity in ex-ante evaluation needs to be recognized clearly and respected.’* Subjectivity has to be valorized during the decision-making process.

During our research, we were able to use the most frequent inconsistencies in PCMs in order to elicit the discussion and adjust local preferences. Thus, subjectivity and inconsistent subjective judgements were pointed out and approached as resources for improving both the entire decision process and the participants' ability to ‘take action’ in project cycles by becoming actors of an evaluation culture. Our experience, and namely the work carried out by comparing L3, L2, and L1 factors in the decision tree (Fig. 3), shows that PAHP can foster the valorization of different opinions in group decision-making and, therefore, strengthens the existing idea that use of PAHP allows diverse subjective and objective factors to be considered in the decision process, as evidenced by other authors (Aznar et al., 2011; Russo and Camanho, 2015). In other words, PAHP has been found to be useful in structuring and giving pace to the participation of experts, allowing for building synergies between research methodologies and practical decisions.

From the resource allocation perspective, our study confirms once more (Ramanathan & Ganesh, 1995; Cheng & Li, 2005) that AHP can be used as a resource allocation tool and provides first insights about the possibility to adapt it in the field of DC. Despite the existing high pressure on international organizations to obtain the best out of their limited resources and to account for the selection of work axes in several countries, few authors investigate the effect of structuring participatory decision processes in the field of DC. If an evaluative culture must be spread along the results chain in DC, the use of participatory MCDM, such as the proposed PAHP, must become the standard in all the phases of the policy-to-project cycle. For this reason, even if some simplified forms of MCDM tools are currently appropriate (DFID, 2002; FAO, 2006a, 2006b; IFAD, 2000; UNESCO, 2008; World Bank, 2018), our experience suggests that PAHP deserve to become a relevant operational tool in the field of DC in order to spread the frequently summoned evaluation culture.

5. Lessons learned

If the transition towards more sustainable agricultural development implies the shift towards renewed approaches to the planning of policies and specific interventions (IPES-Food, 2017), approaching development with the lens of socio-ecological systems framework (Ostrom, 2009) forces us to implement new methodologies for community planning and decision aiding in a participatory situation. In such a context, where the degree of sharing and local acceptance of proposed interventions are important for achieving the expected results, PAHP should be used to inform more shared decisions about intervention.

On the one hand, the present experience perceives the need to continue operational research on MCDM tools that are appropriate for both higher policy and ground-level interventions. Such type of research should be kept operational in order to not lose contact with reality and to implement 'live' training to DC practitioners. On the other hand, the registered levels of inconsistency among the preferences expressed by the DMs show that the creation of a hierarchical structure of an operational decision in a complex context is indeed a subjective action that is absolutely prone to overlapping of composing factors which, in turn, renders complete consistency of comparison utopian. Training international development practitioners in using their holistic judgement is often neglected and this could profit from the use of methodologies such as PAHP. The high appreciation level participants expressed during the experience enables us to affirm that further research could profitably focus on the impact of using PAHP on the ability of a DM team to remain consistent when evaluating alternatives and criteria in complex contexts.

Contributions

Professor Guido Sali supervised the planning and the implementation of the whole research, here comprised the writing of this paper. Dr. Pietro De Marinis implemented the participatory data collection and analysis, the desk data processing and the writing of the paper.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.evalprogplan.2020.101793.

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