Using an analytic hierarchy process approach to prioritize public policies addressing family farming in Brazil

Maria Angélica Petrini[a,*]
mapetrini@gmail.com
maria.petrini@feagri.unicamp.br

Jansle Vieira Rocha[a]
jansle.rocha@feagri.unicamp.br

J. Christopher Brown[b]
jcbrown2@ku.edu

Rafael Carlos Bispo[a]
rafael.bispo@feagri.unicamp.br

[a]School of Agricultural Engineering, University of Campinas, Av. Cândido Rondon, 501, Campinas, SP, 13083-875, Brazil

[b]Department of Geography and Atmospheric Science, University of Kansas, Lawrence, KS 66045, United States

Corresponding author.

Abstract

In Brazil, some see intensive, large-scale production of sugarcane-based ethanol, based on a model of capital and land concentration, as a threat to the survival of family farming. Family farmers are increasingly under pressure to sell or rent land to mills where sugarcane monoculture is expanding. In this context, the government is working to formulate or change public policies in order to support farmer livelihoods in sugarcane growing regions. The present study is based on research conducted in the municipality of Ipiranga de Goiás, Goiás State, Brazil. It employs the analytic hierarchy process (AHP) method, with participation of stakeholders at federal, state and municipal levels, to support public policy decision-making addressing family farming. The stakeholders prioritize environmental and economic benefits as the most important criteria requiring the attention of policy makers. Also, stakeholders agree that diversification of production is the most appropriate alternative for strengthening family farming. The AHP approach can be the starting point in the formulation of public policies. The approach helps ensure transparency, and it purposefully includes family farmer points of view. Policies derived from this process, therefore, may have a higher likelihood of being supported and accepted by farmers.

Keywords: Analytic hierarchy process, Decision-making, Multiple stakeholders, Family farming, Sugarcane.

Highlights

- We assess policy priorities of family farmers in an area of sugarcane expansion.
- We use the analytic hierarchy process with participation of multiple stakeholders.
- A case study presents a practical application of the method.
- Public policies addressing family farming should focus on diversification of production.
- Sensitivity analysis demonstrates robustness of results.

1. Introduction

Agriculture in general, and family farming in particular, are among the most essential activities in the world. In addition to producing food, family farming is linked to food and nutrition security, preservation of agro-biodiversity, and sustainable use of natural resources. In Brazil, however, family farming has taken a secondary and subordinate role to large-scale agribusiness, which has been favored by agricultural policies designed to modernize and ensure its reproduction (Wanderley, 1995). Moreover, infrastructure and rural credit programs have favored cash crop production over food crops (Novo et al., 2010; Carvalho and Marin, 2011).

This situation began to change with the creation of Pronaf in 1996 - The National Program for Strengthening Family Farming. This program signaled public concern about family farming for the first time. Until then, policies exclusively supported large-scale agribusiness, which was considered the only viable form of production in the modernization of Brazilian agriculture (Sachs, 2001). Policy makers viewed family farming as an important generator of employment and income. As part of a larger package of rural development initiatives, Pronaf was originally structured into 4 parts: articulation of public policies for rural areas; installation and improvement of infrastructure and services; financing for family farming production; and family farmer education and training. From the beginning, the government chose the financing element – Pronaf credit – as the main instrument to promote sustainable development of family farming; the high cost and scarcity of credit for farmers was viewed as a major roadblock to family farm development (Aquino, 2009). Pronaf's rural credit provides

loans with low interest rates to cover annual costs or long-term investment in family farming.

Law 11,326/2006 provided a legal definition for family farming in Brazil. This made it possible for (1) family farming-related activity to be included in official government statistics, (2) secured the legal grounds for public policies specifically addressing this sector, and (3) recognized family farmers as political actors and direct beneficiaries of public policy. According to that law, the family farmer is the one that meets all the following criteria: does not exceed the maximum area of landholding for the municipality or county where the farm is located[1]; predominantly uses labor of his/her own family within the economic activities of his/her establishment; has a family income predominantly from economic activities tied to the establishment itself; manages his/her establishment with his/her family. Though Pronaf helped make the family farmer a focus of policy, other issues have remained. The Brazilian government still has not developed a census properly characterizing the specific and diversified livelihood strategies of this social group to help track progress in the sector; agricultural censuses still focus only on production data (Neves, 1995). Family farming and family farmers also remain relatively invisible in studies and discussions about bioenergy and decision-making in development. Family farmers are often viewed instrumentally, as mere producers, rather than as rural actors with their own distinct voices and views about rural development (Rossi and Hinrichs, 2011).

Brazil is seen as a major world player in the production of biofuels (mainly in the form of sugarcane), backed by strong rhetoric and discourse about the positive role of biofuels in promoting sustainability. Many researchers and policy analysts believe that biofuels could offer an opportunity for agricultural and rural development. Some initiatives have emerged as an attempt to integrate family farming systems into sugarcane ethanol production (Wilkinson and Herrera, 2010; Agostinho and Ortega, 2012; Maroun and La Rovere, 2014). Small-scale production and cooperative efforts could contribute to economic stability and improve livelihoods, if farmers maintain control of their crops and land (Dauvergne and Neville, 2010). Others have argued that sugarcane production potentially reduces global greenhouse gas emissions, creates jobs,

[1] In Brazil, the limit is 4 *módulos fiscais* (literally, tax modules), and this unit of measure attempts to represent the minimum area required for a farm to be economically viable. The size of the tax module varies from 5 to 110 ha, depending on the municipality, and the size is set by the National Institute for Colonization and Agrarian Reform - Incra. In Goiás, a tax module varies between 7 and 80 ha. In Ipiranga de Goiás, the tax module is 20 ha (Landau et al., 2012).

and increases income. Moreover, the availability of underutilized land, abundant water, and other favorable climatic conditions allow for the growth of both food and fuel crops, without promoting deforestation (Wilkinson and Herrera, 2010; Novo et al., 2012). However, after the initial euphoria defending so-called "sustainable" ethanol from sugarcane in the international biofuels debate, fundamental questions arose concerning negative environmental, social, and economic impacts of biofuel production. In Brazil, sugarcane ethanol is being intensively produced at a large scale, increasing corporate control of production and distribution, resulting in capital and land concentration in such a way that it is unclear whether the sector can benefit family farmers. In addition, others are concerned that sugarcane production has led to competition with food production and negative land use change impacts, such as loss of biodiversity and deforestation (Dauvergne and Neville, 2010; Novo et al., 2010; Maroun and La Rovere, 2014). Brown et al. (2014) addressed the difficulty of tracking shifts in agricultural area dedicated to food versus fuel production in Brazil. Regional hot spots were identified where major shifts toward or away from staple crop may be occurring, but without empirical studies at finer scales, it is difficult to determine to what degree food production is being replaced by sugar cane.

The increase of federal government support to biofuels in the early 2000's resulted in considerable land use changes in central Brazil, with the expansion of intensive sugarcane-monoculture, which led to pressures on family farmers for selling/renting land to the sugar mills. Renting land is an attractive low-risk option for farmers, compared with other land use options. The sugarcane industry also incentivizes renting via long-term contracts and the opportunity for monthly payments for the land lease. This new scenario could cause significant impacts on family farming production, including a decrease in food production and extinction of local food markets, landscape change, and an overdependence on income from the sugar mills; farmers might even quit agriculture altogether. Moreover, rural extension and technical assistance services could lose their importance in supporting family farmers, who find themselves stripped of their status as food producers, inserted in the middle of a sea of mill-cultivated sugarcane.

The government, therefore, needs to formulate or modify public policies in sugarcane producing regions to support farm livelihoods and income. Research on family farmer interactions with the sugar mills concerning land use, sustainability, and income, among other issues, can help form the basis for policy-making. For example,

Frate and Brannstrom (2015), using the Q method, explored tensions between agrarian reform settlements – specifically with respect to food security and safety and sugarcane mills. The authors revealed patterns of views among diverse key actors, views that complicate the notion that tensions fall along dichotomous small-scale versus agribusiness-oriented interests.

Many observers are calling for more direct participation by family farmers in development and policy-making processes to achieve agricultural development that truly values family farming. It is believed that better social and environmental outcomes are achieved when local development programs are discussed and negotiated among all stakeholders involved in the process, with the municipality or a group of municipalities as the territorial unit, in which family farmers are key actors (Sachs, 2001). It is often the problem, however, that small farmers lack the power and political channels to participate in political debates and influence public policies in the first place (Guanziroli et al., 2013). One aspect of the Pronaf program, however, provided space for the creation of Municipal Councils for Sustainable Rural Development (CMDRS). The councils have the potential to bring farmers into the political arena, because they provide an appropriate space for farmers to express their interests within a democratic decision-making body. The councils have control over municipal-level, public resources and allocations, and they serve to adjust federal and states policies to municipal needs.

In this context, it becomes necessary to determine objectively what are the policy priorities of family farmers in areas affected by the expansion of sugar cane. Knowing these priorities is an essential step policy makers must take to arrive at policies that have a high likelihood of being accepted by farmers, implemented, and then assessed for whether they achieved intended social and environmental outcomes. The analytic hierarchy process (hereafter AHP) is a well-established methodology that deals with multi-criteria decision-making and allows for the participation of multiple stakeholders. Using the AHP, policy makers are able to incorporate important human dimensions of decision-making, by quantifying and deriving measurements for subjective as well as group preferences. AHP works as a link between the field of debates and the field of practical actions by public managers. It is a tool that can help policy makers take people's desires, expectations, and wishes and translate them into beneficial public policies. This article presents an application of the AHP in a study of family farming in the municipality of Ipiranga de Goiás, in Goiás State, Brazil, an area of intense sugar cane expansion.

2. The analytic hierarchy process

In human decision-making, a variety of subjective and objective criteria are taken into consideration. In fact, making a choice is rarely an objective action, and it usually involves a certain degree of inconsistency. Policy makers are under increased pressure to make decisions in a transparent and responsible way. In this context, the AHP is an approach that combines both objective and subjective criteria in decision-making, in a manner that is easy for lay people to understand. On one hand, AHP requires the use of computers to perform mathematical calculations. On the other hand, it provides a relatively simple approach for users to express preferences for complex problems (Itami et al., 2001). Additionally, Garfi et al. (2011) highlight the multi-faceted aspect of AHP, considering it an appropriate tool for human development projects aiming to improve living standards in developing countries; the AHP is simple, flexible, and transparent to participants, and it focuses on the needs of beneficiaries.

Originally developed by Thomas Saaty in the 1970's, the AHP is one of the most widely used methods of multi-criteria decision-making. It is a useful tool based on mathematical and psychological fundamentals to analyze complex decisions, many times involving multiple stakeholders and multiple alternatives, using a hierarchical structure that facilitates rigorous definition of priorities and preferences in decision-making processes (Saaty, 1991). The AHP can deal with both quantitative and qualitative attributes. It can be applied with a limited number of individuals or groups, as long as they are knowledgeable about the problem at hand, which is different from statistical methods that require ideal sample size for data collection. Furthermore, this approach can also be used in decision-making procedures where perceptions of individuals, groups, or both, are under consideration (Duke and Aull-Hyde, 2002; Kukrety et al., 2013).

According to Saaty (1990), the practical application of the AHP involves three basic steps. The first step is to structure the problem as a hierarchy. From top to bottom, the elements may include the overall goal to be achieved, criteria and sub criteria that contribute to the goal, and alternatives that are to be evaluated with respect to criteria in the level above. Garfì and Ferrer-Martì (2011) presented a comprehensive list of criteria and evaluation indicators as a guideline in multi-criteria analysis for an effective assessment of water and sanitation projects in developing countries, detailing technical,

environmental, social and economic aspects. Choosing the appropriate criteria and possible subcriteria is the main challenge when working with multi-criteria decision-making; they are specific to each site and context, so the selection of the elements should be discussed by all decision-makers and involved stakeholders, reflecting their concerns and preferences (Garfì and Ferrer-Martì, 2011).

In the second step, we carry out pairwise comparison judgments among the elements at one level of the hierarchy in terms of the next higher level. Qualitative (verbal) comparisons are converted into quantitative values by using a numerical scale of integers ranging from 1 to 9. This scale was validated for effectiveness, not only in many applications by a number of people, but also through theoretical comparisons with a large number of other scales (Saaty, 1990). The fundamental scale of values to represent the intensities of judgments is shown in Table 1.

Table 1. The fundamental scale.

Source: Saaty (1990).

Intensity of importance	Definition (verbal scale)	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals	If activity ***i*** has one of the above numbers assigned to it when compared with activity ***j***, then ***j*** has the reciprocal value when compared with ***i***	

Each one of the comparison matrices assumes the form:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \dots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}$$

where a_{ij} represents the pairwise comparison rating for attribute i and attribute j. Given the reciprocal property of the matrix, if $a_{ij} = x$, then $a_{ji} = 1/x$ where $x \neq 0$. Only $n(n-1)/2$ actual pairwise comparisons are needed for an $n \times n$ comparison matrix (Saaty, 1991).

The scores obtained from individual preference are used to synthesize local priorities of each element of the hierarchy by using the eigenvalue method. The vector of priorities is the principal eigenvector of the matrix. It gives the relative priority of the element measured in a ratio scale (Saaty, 1990). In addition, the AHP also allows decision makers to maintain control over the inconsistent comparisons that may occur due to inherent human nature (Kukrety et al., 2013).

The consistency ratio (CR) is calculated based on properties of reciprocal matrices. Saaty (1991) proved that the largest eigenvalue, λ_{max}, of a reciprocal matrix is always greater than or equal to n (number of rows or columns). If there are no inconsistencies in pairwise comparisons, then $\lambda_{max} = n$. The more consistent the comparisons are the closer to n are the λ_{max} values. The quantity $\lambda_{max} - n$ measures the degree of inconsistency within the $n \times n$ matrix. The consistency index (CI), that measures the inconsistencies of pairwise comparisons, is given by equation $CI = (\lambda_{max}-n)/(n-1)$. The CR measures the coherence of the pairwise comparisons. It is defined by CR = CI/RI, where RI is the average consistency index of the randomly generated comparisons. Values of $CR \leq 0.1$ are considered as acceptable. Otherwise, higher values of CR mean an undesirable level of inconsistency, and participants should revise their pairwise comparison judgments.

Finally, in the third step, the pairwise comparison judgments are used to develop overall priorities for ranking the alternatives. The overall priority values are calculated from the top of the hierarchy by multiplying the local priority of an element by the priority value of the level just above it. The sum of the overall priorities at each level is equal to one. As a result, the overall priority value of the elements at a level shows the proportionate contribution to the overall preference of the individual or the stakeholder group (Kukrety et al., 2013).

AHP has found its widest applications in multi-criteria decision-making, in planning and resource allocation, and in conflict resolution (Saaty and Vargas, 2001). It has been applied in various research topics including public participation in decision-making processes in public administration, environmental management, sustainability and energy issues, and agricultural policies. Duke and Aull-Hyde (2002) used the AHP

to identify public preferences for the environmental, agricultural, growth control, and open space attributes of farmland in Delaware/USA. Oddershede et al. (2007) presented a decision model based on community preferences to determine activities that would best contribute to rural development in Chile. Xu et al. (2012) applied AHP to understand what Chinese peasants want to achieve by participating in the "Grain for Green" program and what their priorities are with respect to planting selected types of trees. Chávez et al. (2012) used AHP to rank alternative farming activities to tobacco for crop diversification in Argentina. Kurka (2013) employed the AHP method to assess different bioenergy alternatives concerning their regional sustainability in Scotland. Kukrety et al. (2013) incorporated stakeholder perceptions about the most suitable restoration planning and management option in India by using the AHP.

Furthermore, the AHP can be used in conjunction with Geographic Information Systems (GIS), configuring a decision support tool for allocation of land (Eastman et al., 1995). Itami et al. (2001) combined the AHP and GIS for assessing biophysical capability for horticultural crops in rural catchments in Australia. Barros et al. (2007) used variables derived from remote sensing data and the AHP method to delimitate favorable areas to the coffee crop agroecosystem in 4 municipalities of Minas Gerais State, Brazil. Akinci et al. (2013) identified suitable lands for agricultural use in Turkey applying the AHP to determine the weights of the parameters, which were used to create the agricultural land suitability map.

3. Case study: promoting public policies toward family farming

3.1. Study area

This research was conducted in Ipiranga de Goiás municipality, Goiás State, Brazil (Fig, 1). The municipality is located in the region with the highest concentration of family farmers in Goiás State; in addition, rapid sugarcane expansion has occurred there over the past decade that may impact family farming activities. According to the latest 2006 agricultural census, small, family-owned and operated farms comprised 92.5% of all agricultural establishments, and sugarcane occupied 34.5% of all agricultural area in Ipiranga de Goiás. Sugarcane fields are cultivated by the Cooper-Rubi ethanol and sugar mill located to the west, just outside Ipiranga de Goiás (Fig. 1), in the neighboring municipality of Rubiataba. There are other two mills within a radius

of 30 km from Ipiranga de Goiás, however all of the sugarcane activity in the study area is tied to Cooper-Rubi.

Ipiranga de Goiás was founded in 2001; its territory was originally a part of the municipality of Ceres. Although its political autonomy is recent, Ipiranga de Goiás's historical legacy extends to creation of the first National Agricultural Colony of Goiás in 1941, which originally distributed lots between 26 and 32 ha in size (Castilho, 2012).

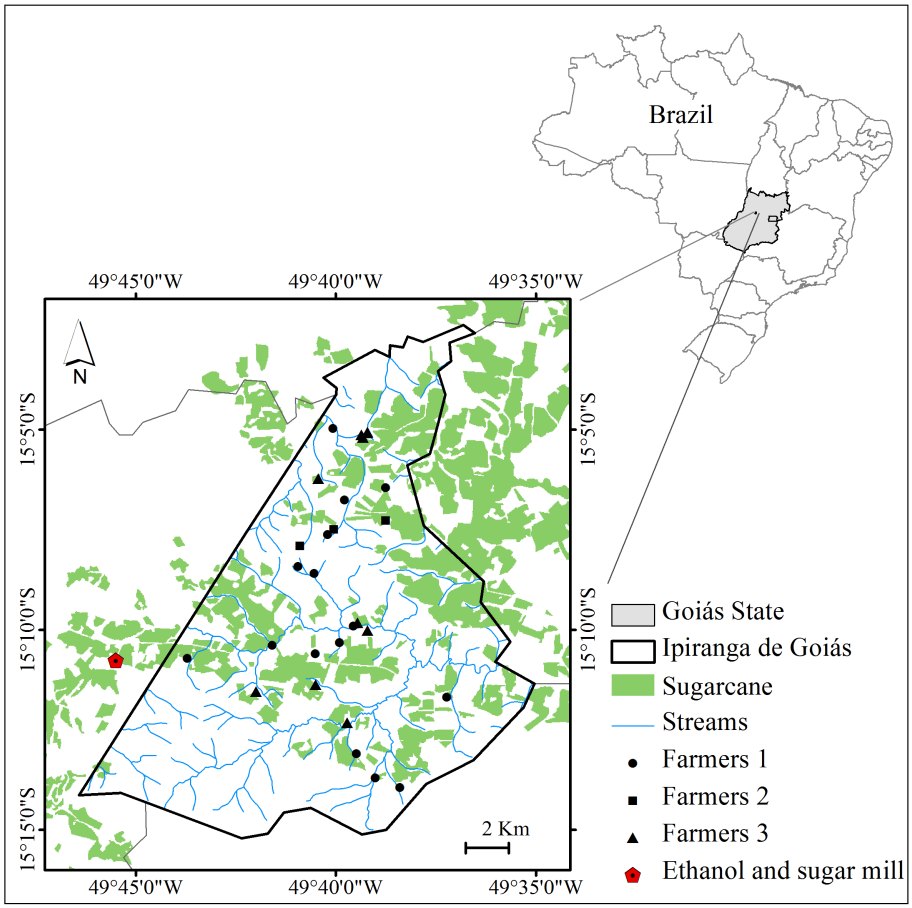

Fig. 1. Ipiranga de Goiás, Goiás State, Brazil. Sugarcane mask is from the Canasat Project (Rudorff et al., 2010). Farmers 1, Farmers 2, and Farmers 3 form the family farmers stakeholder group and are defined in Table 3 and Section 4.

3.2. AHP hierarchy

The AHP decision hierarchy built for the present study was based on literature reviews (Ellis, 1998; Ananda and Herath, 2003; Schneider, 2007; Chávez et al., 2012; Xu et al., 2012; Kukrety et al., 2013; Kurka, 2013; Kurka and Blackwood, 2013) as well as information gathered during preliminary fieldwork in October 2013. This fieldwork was fundamental to the engagement of stakeholders in the study and to the selection of criteria and decision attributes, considering there are no well-established guidelines for

this type of AHP application, similar to that presented by Garfì and Ferrer-Martì (2011) for water and sanitation projects.

At that time, we interviewed the Municipal Secretary of Agriculture, a local agent of Emater - the Goiás State Enterprise for Technical Assistance and Rural Extension, 3 family farmers indicated by them, and the Administrative and Financial Manager of the Cooper-Rubi ethanol and sugar mill. The choice of these stakeholders was due to their political, social and economic relevance in Ipiranga de Goiás. Each interview lasted approximately 2 h and 30 min, at their work offices and at farm homes. We applied a questionnaire with closed-ended questions about social and economic aspects of agriculture in Ipiranga de Goiás, and also open-ended questions focusing on the importance of the sugarcane to the region and positive and negative consequences of the recent sugarcane expansion. Field notes from interviews allowed us to understand how farmers and government have responded to the pressure from sugarcane expansion and to what extent public policies have affected the farmers in the municipality, giving us the basis to create the AHP hierarchy. Then, in a post-fieldwork exercise, we built the AHP hierarchy shown in Fig. 2.

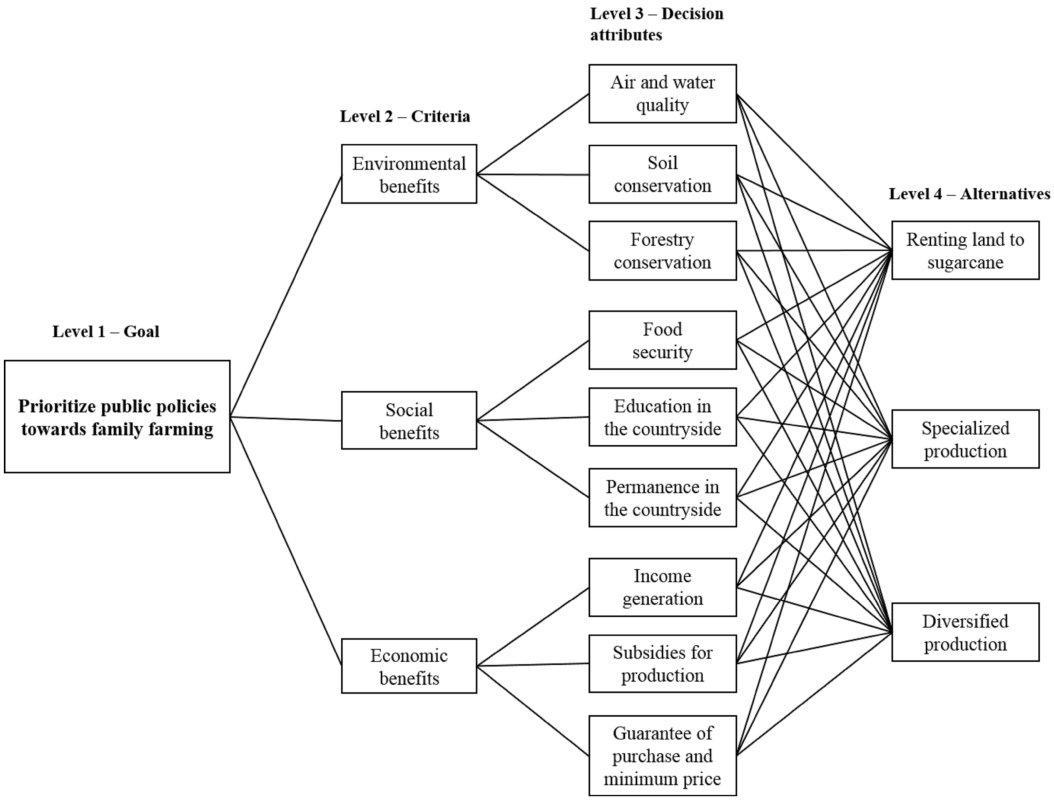

Fig. 2. Four levels of hierarchical structure used in this case study.

We have 4 levels and limited numbers of elements for a number of reasons, based on an understanding of human cognition and past research by other authors. To avoid confusion with a large number of comparisons, which significantly increases uncertainty of the process, it is recommended that the number of elements in a category should not exceed 10 (Kukrety et al., 2013; Delgado-Galván et al., 2014). The top level of the hierarchy represents the goal, which defines priorities for public policies addressing family farming. The second level refers to criteria dealing with the environmental, social and economic benefits to be achieved with implementation of public policies. They are the three pillars, environmental, social and economic factors, which sustainable rural development policies should integrate simultaneously. The third level of the hierarchy consists of nine decision attributes: air and water quality, soil conservation and forestry conservation under environmental benefits; food security, education in the countryside and permanence in the countryside under social benefits; income generation, subsidies for production and guarantee of purchase and minimum price under economic benefits. The definition of these decision attributes was directly related to what we learned during the preliminary interviews. Those interviews helped us identify areas of concern that policy makers should address in policies to meet the demands of family farmers.

Regarding the environmental criteria, field notes indicated that there is a need to improve environmental quality in Ipiranga de Goiás. Numerous environmental problems were mentioned as major concerns among family farmers and representatives of government: deforestation, soil erosion, air pollution caused by sugarcane straw burning practices and vinasse stench, decreasing water availability due to irrigated cultivation of sugarcane, and water pollution by pesticides. These concerns are unsurprising, given that there is no environmental agency in the municipality, and, consequently, no environmental monitoring. Considering the criteria under social benefits, the main concerns relate to reduction of food production in the municipality itself and rural out-migration. For that, there are few successful initiatives implemented that could be expanded. One is focused on “Community Farming” (a state/municipal partnership encouraging farmers to cultivate mainly rice and vegetables, sharing harvests among themselves), and another is the “Rural Housing Program” to build or renovate houses in the countryside. In addition, Emater drew attention to the lack of technical courses to improve farmers' professional skills. With respect to economic benefits, the stakeholders interviewed mentioned the lack of economic incentives and

mechanisms to encourage family farming production, which leads the farmers to rent their lands to sugarcane mills because they cannot be competitive, even though most farmers have accessed Pronaf to obtain rural credit. A brief description of each decision attribute is shown in Table 2.

Finally, the fourth and bottom level of the hierarchy consists of the alternatives, in terms of agricultural activities that might be more adequate for the success of the public policies. The alternatives represent options for family farming activities facing the pressure from sugarcane expansion: rent land to sugarcane mills, which is already underway; specialized production, when the family farmer has income from only one type of agricultural activity; and diversified production, in which the family farmer grows various products for market.

Table 2. Description of criteria and decision attributes selected for this case study.

Criteria	Decision attributes	Refers to:
Environmental benefits	Air and water quality	Promotion and/or maintenance of air and water quality levels as well as water resources availability
	Soil conservation	Control and prevention of soil erosion and soil contamination by pesticides
	Forestry conservation	Protection of vegetation, preventing deforestation, visual impacts on landscape and impacts on biodiversity
Social benefits	Food security	Arable land available for food production and conditions of access to good quality and variety of food products
	Education in the countryside	Offering of technical courses that improve the professional qualifications of the family
	Permanence in the countryside	Conditions to maintain living and working in the countryside, avoiding rural out-migration
Economic benefits	Income generation	Income generation in the countryside through direct income transfers
	Subsidies for production	Mechanisms to reduce purchase costs of agricultural inputs
	Guarantee of purchase and minimum price	Mechanisms to guarantee the outflow of agricultural production and the maintenance of the market price of the products

3.3. Stakeholders

Rua (2009) defines stakeholders, in general, as political actors whose interests may be affected, positively or negatively, by the direction taken by a specific public policy. Political actors can be individuals, groups or organizations, with particular characteristics. They can be further distinguished as public actors (politicians and bureaucrats), private actors (companies, businessmen) or workers.

Six stakeholder groups associated with the problem and defined in the preliminary fieldwork were involved in this study case, totaling 33 participants (Table 3): at the federal level, an agent of Conab (National Food Supply Agency); at the state level, an agent of Emater (Goiás State Enterprise for Technical Assistance and Rural Extension); and at the municipal level, an employee (administrative and financial manager) of the ethanol and sugar mill Cooper-Rubi, the president of the cooperative Cooperagro (Regional Agriculture and Cattle Ranching Cooperative of Rubiataba), the Municipal Secretary of Agriculture, and family farmers. We identified the family farmers interviewed through initial contacts with Emater and Secretary of Agriculture and through snowball sampling. The farmers were classified into three groups according to their position in relation to the sugarcane industry: those who have never rented land to sugarcane producers (15); those who rented land to sugarcane producers at least once in the past (3); and those who were renting land to sugarcane producers at the time of interview (10), a total of 28 farmers.[2]

Table 3. Stakeholder participants.

Stakeholder groups	Level	Explanation	Respondents
Conab (National Food Supply Agency)	Federal	Conab is affiliated with the Ministry of Agriculture, Livestock and Food Supply, responsible for contributing to the regularity of food supply and guaranteeing income to rural producers, participating in the formulation and execution of agricultural and supply policies.	Superintendent for the Support of Family Farming
Emater (Goiás State Enterprise for Technical Assistance and Rural Extension)	State	In general terms, Emater is the State agency for planning, coordinating and executing plans, programs and projects of technical assistance, agricultural extension, research and sustainable rural development, giving priority to family farming in Goiás.	Local agent

[2] Family farmers in most cases involved both the male and female heads of household and children as a group, thus judgments represent family choices. For the other government officials and industry representatives, the representative from CONAB was a woman, and the rest were men.

Cooper-Rubi (Ethanol and Sugar Mill of Rubiataba)	Municipal	Founded in 1987, with subsidies from Proálcool[3]. This mill has been responsible for the expansion of sugarcane production in Rubiataba and surroundings. Cooper-Rubi produces all the sugarcane that it processes, cultivated in 22,000 ha, of which less than 1,000 are its property; it has land leasing contracts in Rubiataba and 8 other neighboring municipalities, including Ipiranga de Goiás.	Administrative and Financial Manager
Cooperagro (Regional Agriculture and Cattle Ranching Cooperative of Rubiataba)	Municipal	This cooperative was created in 1971. Currently, there are approximately 2,000 rural properties affiliated to Cooperagro, within a radius of 40 km of Rubiataba. There are 85 milk producers from Ipiranga de Goiás.	President
Secretary of Agriculture	Municipal	The Municipal Secretary of Agriculture is a political position, chosen by the mayor and his party, usually for a 4 year-term when municipal elections occur. The current mandate is 2013-2016.	Municipal Secretary
Family farmers	Municipal	According to the law 11,326/2006, the family farmer is the one that meets these criteria: does not exceed the maximum area of landholding for the municipality (80 ha in Ipiranga de Goiás); predominantly uses family labor within the economic activities of his/her establishment; has a family income predominantly originated by economic activities tied to the establishment itself; manages his/her establishment with his/her family.	Family farmers were classified into three groups: 15 farmers who have never rented land to sugarcane producers (named Farmers 1); 3 farmers who rented land to sugarcane producers at least once in the past (Farmers 2); and 10 farmers who were renting land to sugarcane producers at the time of interview (Farmers 3).

3.4. Pairwise comparisons

The AHP pairwise comparison surveys were carried out during fieldwork, June and July, 2014, in Brasília-DF (Conab's office), and in Ipiranga de Goiás and Rubiataba, a neighboring municipality where the ethanol and sugar mill and the cooperative are located. Representatives of Conab, Emater, Cooper-Rubi, Cooperagro and Secretary of Agriculture were interviewed at their work offices. Family farmers

[3] The first oil crisis in 1973 led the Brazilian government to take further initiatives, not only to lower the historical high dependence on imported fossil fuels, but also to "save" the sugarcane industry. Then, The National Alcohol Program – Proálcool was created in order to improve the production of sugarcane ethanol as a substitute for gasoline, through increases of subsidies to the industry and investment in research and development to generate new technologies (Novo et al., 2010).

were interviewed at their homes. Each participant was asked to indicate the relative preference of one element over the other, considering the point of view of the public or private enterprise they were representing, while the family farmers were asked to use personal judgment based on their own perceptions and experiences to express their relative preferences. Most individuals took approximately one hour and 30 min to complete the pairwise comparisons process.

Starting with the second level of the hierarchy (Fig. 2), we asked: regarding the implementation of public policies toward family farming, which benefit do you think should be given more importance? How much more? In order to facilitate participant judgments, we used cards with pairs of elements and a graded color scale that visually guided the participant during the comparison process. We displayed cards with the first pair of criteria and the participants were instructed to choose one criterion and the intensity of importance of such criterion over the other, moving the marker through the scale, from light yellow (equal importance) to dark red (extreme importance). Fig. 3 shows an example of a pairwise comparison between the criteria environmental benefits and social benefits, in which environmental had strong importance over social. Three combinations of pairs of criteria were possible in this level. Next, considering the third level of the hierarchy, we asked: regarding the environmental benefits that public policies should provide, which is more important? How much more? This question was repeated with the other two criteria – social and economic benefits – to compare participant decisions regarding the respective attributes. Three combinations of pairs of decision attributes were possible under each criterion, totaling 9 comparisons. With respect to the forth level of the hierarchy, we asked: which of these agricultural activity options do you think is most appropriate for achieving air and water quality? How much more? This question was repeated with the other eight decision attributes. For each decision attribute, three combinations of pairs of alternatives were possible, totaling 27 comparisons. Thus, a total of 39 pairwise comparisons were made across all the hierarchy levels, following the same procedure with cards and scale as shown in the example from Fig. 3.

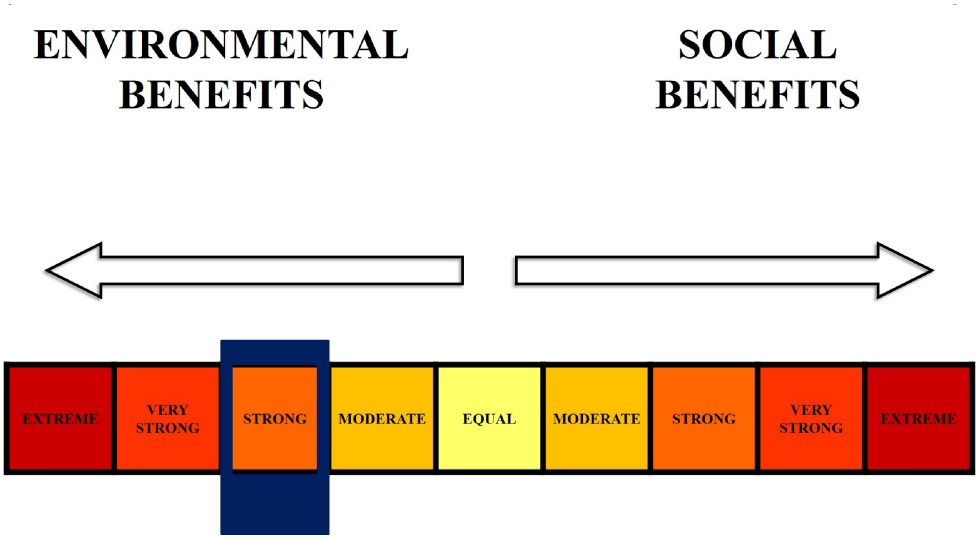

Fig. 3. Example of pairwise comparison considering the second level of the hierarchy.

All the participants used a verbal scale to make qualitative comparisons, which were converted into quantitative values by using Saaty's fundamental scale (see Table 1). Using a laptop computer during the fieldwork, the judgments obtained from the pairwise comparisons were entered into the AHP Excel Template, developed by Goepel, 2013, in order to find the local priorities. The consistency ratio (CR) equal or below 0.1 was checked for all judgments. In case of a stakeholder group, such as the family farmers, a consensus decision approach was used. The individual judgments for each group of family farmers were aggregated by calculating the geometric mean (Saaty and Vargas, 2001; Goepel, 2013) of all decision matrices. Furthermore, the AHP Excel Template has an output field showing the consensus index for more than one participant/decision maker. This is calculated based on the row geometric mean method results of all inputs using Shannon alpha and beta entropy (Goepel, 2013). Global priorities were calculated in post-fieldwork by inputting data from the AHP Excel Template to the AHP Online System also developed by Goepel <http://bpmsg.com/academic/ahp.php>, a web based AHP solution that can manage complete AHP projects and group sessions. We downloaded the data in csv format (comma separated values) for further processing as well as sensitivity analyses in a Microsoft Excel spreadsheet.

Along with the AHP questionnaire, we applied another questionnaire composed of closed- and open-ended questions for each family farmer in order to build a

socioeconomic profile and gather farmer opinions about the sugarcane industry and activities in the region.

Before proceeding with the interviews, informed consent was obtained from each participant, according to procedures approved by the University of Campinas Ethics in Research Committee.

4. AHP results and discussion

Table 4 and Fig. 4 presents the consolidated priorities for each criterion by stakeholder group and the consistency ratio (CR) of the comparisons. The acceptable threshold of 0.1 or less was checked, and the results confirm that the judgments made by the participants are quite consistent. Participants in the family farmer groups presented high consensus in their judgments. The consensus index ranges from 0% (no consensus between participants) to 100% (full consensus between participants). Each group of farmers is reported from here as follows: Farmers 1 - 15 farmers who have never rented land to sugarcane producers; Farmers 2 - 3 farmers who rented land to sugarcane producers at least once in the past; Farmers 3 - 10 farmers who were renting land to sugarcane producers at the time of interview.

Table 4. Global priorities for criteria.

Stakeholders	Environmental benefits	Social benefits	Economic benefits	CR	Group consensus
Conab	0.091	0.455	0.455	0.00	-
Emater	0.455	0.091	0.455	0.00	-
Sec. agriculture	0.637	0.105	0.258	0.04	-
Mill	0.143	0.429	0.429	0.00	-
Cooperative	0.637	0.105	0.258	0.04	-
Farmers 1	0.448	0.303	0.248	0.00	74.5%
Farmers 2	0.177	0.193	0.630	0.01	81.2%
Farmers 3	0.320	0.201	0.480	0.00	76.0%

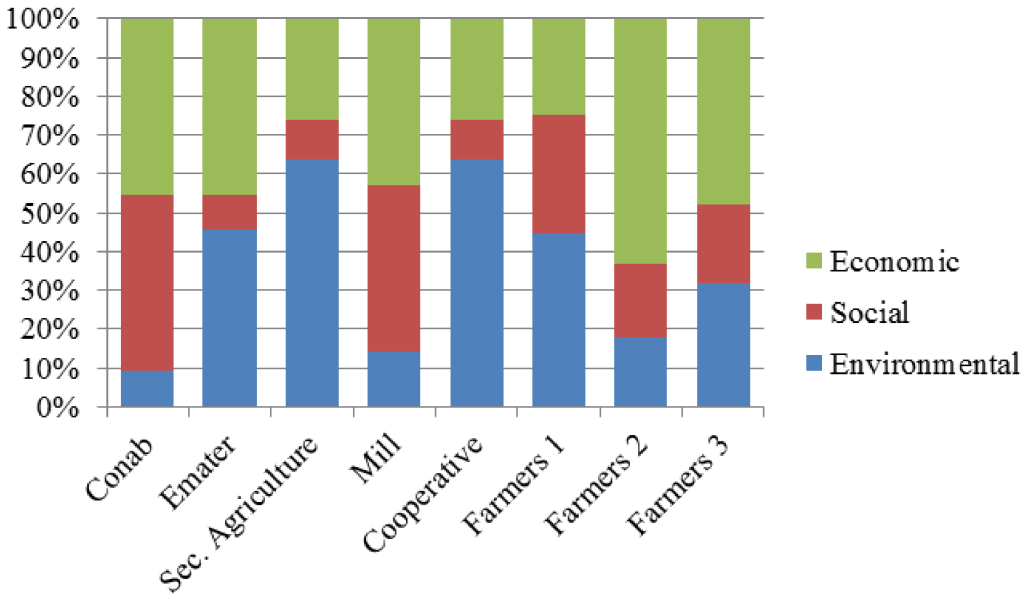

Fig. 4. Global priorities for criteria.

Environmental benefits are the most important criteria for the Secretary of Agriculture (63.7%), Cooperative (63.7%), Farmers 1 (44.8%) and Emater (45.5%) groups. The Farmers 2 and 3 groups preferred economic benefits (63% and 48%, respectively) over environmental and social. When farmers were asked about the advantages and disadvantages of the presence of sugarcane in the region, only 38% from Farmers 2 and 3 mentioned environmental impacts among others disadvantages, while 60% from Farmers 1 perceived environmental impacts, and these differences were reflected on the AHP ranking of criteria.

The ethanol and sugar mill group prioritized both economic and social benefits (42.9%) concerning public policies addressing family farming. The mill group did not recognize the need for environmental policies as did others stakeholders. During interviews, the stakeholders (Farmers, Emater, Secretary of Agriculture, and Cooperative) complained about environmental problems caused by the mill's activities. The impacts cited were: deforestation, use of pesticides, reduction of headwaters, decline in soil quality and water availability, air pollution due to straw burning, stench of vinasse, and loss of biodiversity. The Conab group also prioritized both economic and social benefits (45.5%). This is in accordance with its mission; the agency is responsible for managing agricultural and supply policies, to ensure basic needs of the population, preserving and encouraging market mechanisms.

Table 5 and Fig. 5 shows the global priorities for decision attributes according to each stakeholder group. "Air and water quality" had the highest weights among the attributes, and it is the most important attribute for 4 different stakeholder groups: Emater (34%), Secretary of Agriculture (40.6%), Cooperative (46.5%) and Farmers 1 (27%). In turn, Farmers 2 gave preferences for "subsidies for production" (29.4%) and "guarantee of purchase and minimum price" (23.2%). Farmers 3 expressed preferences in reverse, i.e. ranking "guarantee of purchase and minimum price" (22.4%) first and "subsidies for production" (18.9%) second, but both under the economic criterion. These farmers said that renting their land to the mill to grow sugarcane is not the best option, because they lose autonomy over their own land. At the same time, however, they recognize that at least part of their monthly income is guaranteed when they rent it for sugarcane production. They would prefer to work in the field, raising food crops or dairy cattle, if they could afford to or if some policy guaranteed the value of their own production. For the ethanol and sugar mill group, attributes under economic and social benefits are most important, emphasizing "subsidies for production" (31.5%). Only Conab prioritized a decision attribute under social benefits ("food security" with 22.1%) concerning public policies toward family farming. However, the importance among "income generation" (21.2%), "guarantee of purchase and minimum price" (21.2%) and "permanence in the countryside" (19.8%) is fairly similar.

Table 5. Global priorities for decision attributes.

Stakeholders	AWQ	SOI	FOR	FSC	EDU	PER	INC	SUB	GMP	CR	Group consensus
Conab	0.030	0.030	0.030	0.221	0.035	0.198	0.212	0.030	0.212	0.00	-
Emater	0.340	0.054	0.061	0.010	0.058	0.023	0.041	0.207	0.207	0.00	-
Sec. agriculture	0.406	0.165	0.067	0.063	0.021	0.021	0.029	0.105	0.124	0.01	-
Mill	0.015	0.091	0.037	0.143	0.143	0.143	0.025	0.315	0.089	0.03	-
Cooperative	0.465	0.120	0.052	0.029	0.068	0.008	0.019	0.168	0.072	0.02	-
Farmers 1	0.270	0.116	0.062	0.076	0.111	0.116	0.036	0.100	0.113	0.00	77.7%
Farmers 2	0.080	0.055	0.042	0.032	0.068	0.093	0.104	0.294	0.232	0.00	74.0%
Farmers 3	0.152	0.086	0.082	0.042	0.091	0.067	0.067	0.189	0.224	0.00	73.6%

AWQ air and water quality; SOI - soil conservation; FOR - forestry conservation; FSC - food security; EDU - education in the countryside; PER - permanence in the countryside; INC - income generation; SUB - subsidies for production; GMP - guarantee of purchase and minimum price.

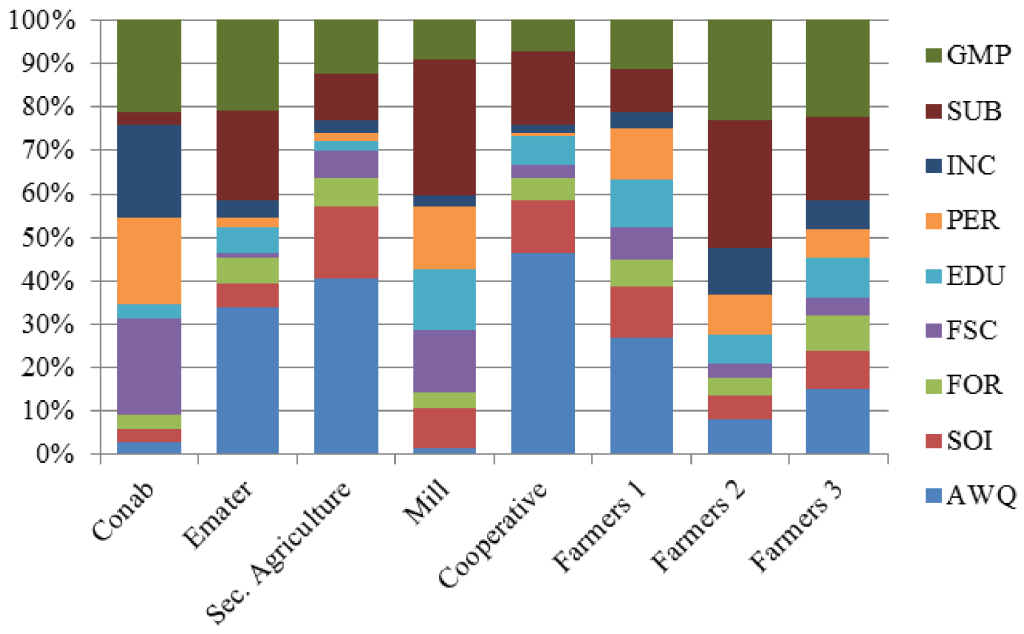

Fig. 5. Global priorities for decision attributes.

AWQ air and water quality; SOI - soil conservation; FOR - forestry conservation; FSC - food security; EDU - education in the countryside; PER - permanence in the countryside; INC - income generation; SUB - subsidies for production; GMP - guarantee of purchase and minimum price.

The alternatives were ranked as shown in Table 6 and Fig. 6. The results point out that "diversified production" notably outperformed the other two alternatives, followed by "specialized production" and "rent land to sugarcane" as the last choice, a preference shared even by the mill group. The results are consistent with what is found in the literature on rural livelihoods. The capability to diversify income sources improves livelihood security, hence the elimination of constraints and expansion of opportunities for diversification are desirable policy objectives (Ellis, 1998). Support for diversification makes sense because it is seen as an inherent characteristic of family farmers, who have historically had multiple occupations and multiple forms of income, while specialization of production, created and stimulated by agricultural modernization, makes the farmers dependent, vulnerable and subordinate (Schneider, 2007).

Among all stakeholder groups, those related to the governmental sphere gave the lowest weights to the alternative "rent land to sugarcane": Conab (5.8%), Emater (7.5%) and Municipal Secretary of Agriculture (7.1%). Participants in this group believe that

family farmers should focus their land resource on production on food, not sugarcane. Interview data reveal that successful government programs, such as the Family Agriculture Food Acquisition Program (PAA in its Portuguese abbreviation) coordinated by Conab, are nowhere to be found in Ipiranga de Goiás municipality, although 82% of all farmers expressed interest in obtaining access to this type of public policy program.

Table 6. Consolidated weights of alternatives.

Stakeholders	Rent land to sugarcane	Specialized production	Diversified production	Group consensus
Conab	0.058	0.165	0.776	-
Emater	0.075	0.392	0.533	-
Sec. Agriculture	0.071	0.278	0.651	-
Mill	0.143	0.143	0.714	-
Cooperative	0.104	0.127	0.769	-
Farmers 1	0.081	0.345	0.574	91.9%
Farmers 2	0.102	0.321	0.577	96.6%
Farmers 3	0.135	0.226	0.639	91.4%

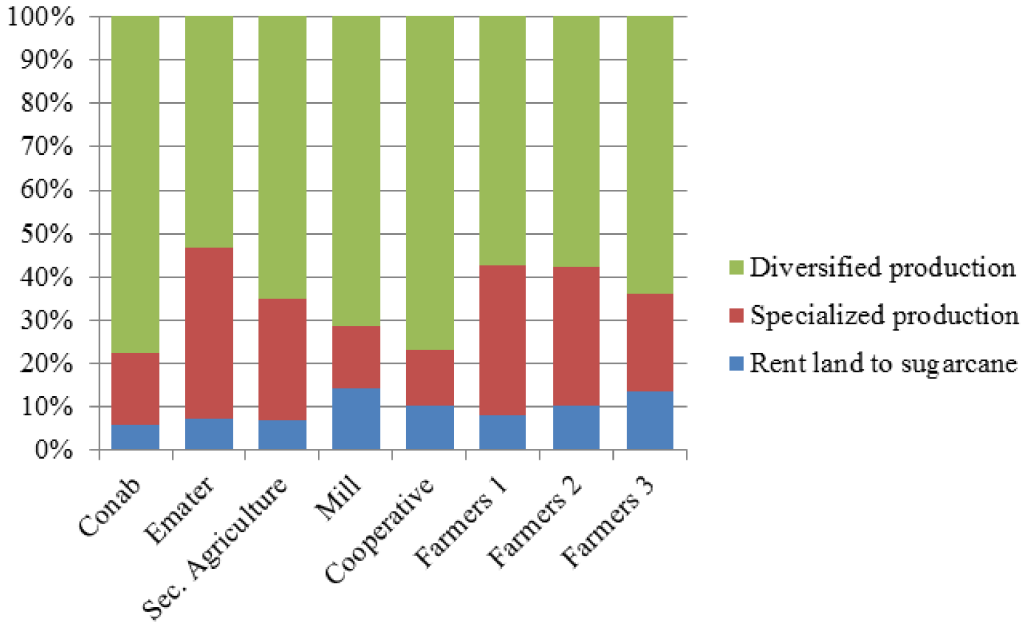

Fig. 6. Consolidated weights of alternatives.

4.1. Sensitivity Analysis

Analyses were conducted to verify the robustness of results. It is important to determine whether they are affected or not by hypothetical changes in the weights of criteria and decision attributes. If we found that a small change in weights affected

results, then they would have little utility for the formation of relevant policies (Xu et al., 2012). Sensitivity analysis takes into account three variables: the local weight of the criteria (economic, social, and environmental) or decision attributes; the weight each alternative received in relation to the criteria or attribute considered; and the global priority of the alternatives, or the final ranking of the alternatives considering all the criteria and attributes. In this study, the sensitivity analysis was done for each criteria and attribute for each stakeholder. In general, results were insensitive to any variation in the weights of the criteria or attributes. The "diversified production" alternative, which received the greatest global priority from all the stakeholders (see Table 6), was insensitive to any hypothetical change in weights. An exception is found in some of the results from Emater, where a change in weights of some criteria and attributes would make the "specialized production" alternative a more important policy direction. In no way, however, would changes in the weights of criteria and attributes result in the "rent land to sugarcane" alternative being any more than last in stakeholder preferences. In practical terms, this means that policy makers can feel assured that no hypothetical changes in weights of the criteria and attributes would lead to any different results.

Twelve graphs were generated to analyze the sensitivity of each criteria and attribute of the AHP hierarchy, for each one of the 8 stakeholder groups, totaling 96 graphs. Some examples can be found in supplemental materials.

5. Conclusions

Though there were differences among stakeholder groups regarding the priorities of criteria and decision attributes, we discovered that environmental and economic benefits should be the most important drivers of public policies in Ipiranga de Goiás municipality. Furthermore, all stakeholders agreed on the priority of “diversified production” as the most appropriate choice to promote public policies addressing family farming. These findings are corroborated by previous studies about the importance of diversification to raise the living standards of rural households.

This study is a first attempt to use the AHP for prioritizing public policies geared toward family farming in Brazil. The methodology is effective and can be applied in a number of different areas of application. In addition, the method is easy and simple to apply, and consistency tests can identify inconsistent judgments, leading to reliable

results. Having support material during the pairwise comparisons (the cards, the visual scale, etc.) proved useful in making the paired comparisons easier to understand among participants, especially the farmers.

Care should be taken, however, when building the hierarchical model, since the formulation of hierarchies and selection of criteria involve a certain level of subjectivity. It is possible for policy makers to derive different hierarchies for similar decision problems and consequently arrive at different solutions. Moreover, we should note that it is a mistake to consider this hierarchy as a model that fits all contexts and empirical situations. Decision makers interested in using this tool must first determine the characteristics and dynamics of family farming in a certain locale or region, and only after that adapt or build an appropriate hierarchy.

The AHP approach can be the starting point in the formulation of public policies, ensuring transparency and including family farmer viewpoints in the decision-making process, since they are the ones who will benefit from the implementation and consequences of the decisions made.

Acknowledgments

Fieldwork was funded by Feagri/Proap/Capes and Unicamp/Faepex (under grant nº 519.292 - 0556/14). We thank all participants in the interviews for making this study possible. The first author would also like to thank Capes (Coordination for the Improvement of Higher Education Personnel) for its financial support. Brown recognizes grant support from NSF-BCS-GSS 1227160.

References

Agostinho F. and Ortega E., Integrated food, energy and environmental services production as an alternative for small rural properties in Brazil, *Energy* **37**, 201 2, 103–114.

Akıncı H., Özalp A.Y. and Turgut B., Agricultural land use suitability analysis using GIS and AHP technique, *Comp. Electron. Agric*. **97**, 2013, 71 –82.

Ananda J. and Herath G., The use of analytic hierarchy process to incorporate stakeholder preferences into regional forest planning, *For. Policy Econ*. **5**, 2003, 13–26.

Aquino R., Avanços e Limites da Política de Crédito do Pronaf no Brasil (1 996–2008): Uma Reflexão Crítica. SOBER 2009, 2009, Anais da SOBER; Porto Alegre.

Barros M.A., Moreira M.A. and Rudorff B.F.T., Processo analítico hierárquico na identificação de áreas favoráveis ao agroecossistema cafeeiro em escala municipal, *Pesquisa Agropecuária Brasileira* **42** (12), 2007, 1769–1777.

Brown J.C., Rausch L. and Luz V.G., Toward a spatial understanding of staple food and nonstaple food production in Brazil, *Prof. Geogr*. **66** (2), 2014, 249–259.

Carvalho S.P. and Marin J.O.B., Agricultura familiar e agroindústria canavieira: impasses sociais, *Rev. Econ. Sociol. Rural* **49** (3), 2011 , 681–707.

Castilho D., A Colônia Agrícola Nacional de Goiás (CANG) e a formação de Ceres-GO — Brasil, *Élisée, Rev. Geo. UEG* Goiânia **1** (1), 2012, 117–139.

Chávez M.D., Berentsen P.B.M. and Oude Lansink A.G.J.M., Assessment of criteria and farming activities for tobacco diversification using the analytical hierarchical process (AHP) technique, *Agric. Syst*. **111** , 2012, 53–62.

Dauvergne P. and Neville K.J., Forests, food, and fuel in the tropics: the uneven social and ecological consequences of the emerging political economy of biofuels, *J. Peasant Stud*. **37** (4), 2010, 631–660.

Delgado-Galván X., Izquierdo J., Benítez J. and Pérez-García R., Joint stakeholder decision-making on the management of the Silao-Romita aquifer using AHP, *Environ. Model. Softw*. **51** , 2014, 310–322.

Duke J.M. and Aull-Hyde R., Identifying public preferences for land preservation using the analytic hierarchy process, *Ecol. Econ.* **42**, 2002, 131–145.

Eastman R., Jin W., Kyem P.A.K. and Toledano J., Raster procedures for multi-criteria/multi-objective decisions, *Photogramm. Eng. Remote Sens*. **61** (5), 1995, 539–547.

Ellis F., Household strategies and rural livelihood diversification, *J. Dev. Stud*. **35** (1), 1998, 1–38, http://dx.doi.org/10.1080/00220389808422553.

Frate C.A. and Brannstrom C., Will Brazil's ethanol ambitions undermine its agrarian reform goals? A study of social perspectives using Q-method, *J. Rural Stud*. **38**, 2015, 89–98.

Garfì M. and Ferrer-Martì L., Decision-making criteria and indicators for water and sanitation projects in developing countries, *Water Sci. Technol*. **64** (1), 2011 , 83–101 .

Garfì M., Ferrer-Martí L., Bonoli A. and Tondelli S., Multi-criteria analysis for improving strategic environmental assessment of water programmes. A case study in semi-arid region of Brazil, *J. Environ. Manag*. **92**, 2011, 665–675.

Goepel K.D., Implementing the analytic hierarchy process as a standard method for multicriteria decision making in corporate enterprises—a new AHP excel template with multiple inputs, *Proceedings of the International Symposium on the Analytic Hierarchy Process* 201 3.

Guanziroli C., Buainain A. and Sabbato A., Family farming in Brazil: evolution between the 1 996 and 2006 agricultural censuses, *J. Peasant Stud.* **40** (50), 2013, 817–843.

Kurka T., Application of the analytic hierarchy process to evaluate the regional sustainability of bioenergy developments, *Energy* **62**, 2013, 393–402.

Kurka T. and Blackwood D., Participatory selection of sustainability criteria and indicators for bioenergy developments, *Renew. Sustain. Energy Rev*. **24**, 2013, 92–102.

Kukrety S., Jose S. and Alavalapati J.R.R., Exploring stakeholders' perceptions with analytic hierarchy process—a case study of red sanders (*Pterocarpus santalinus L.*) restoration in India, *Restor. Ecol*. **21** (6), 2013, 777–784.

Itami R.M., Maclaren G. and Hirst K., Integrating the AHP with geographic information systems for assessing resource conditions in rural catchments in Australia. Pages 269–287, In: Schmoldt D.L., Kangas J., Mendoza G.A. and Pesonen M., (Eds.), *The Analytic Hierarchy Process in Natural Resource and Environmental Decision Making*, 2001 , Kluwer Academic Publishers; Dordrecht, The Netherlands.

Landau E.C., Cruz R.K., Hirsch A., Pimenta F.M. and Guimarães D.P., Variação geográfica do tamanho dos módulos fiscais no Brasil, *Embrapa Milho e Sorgo Documentos* **146**, 2012.

Maroun M.R. and La Rovere E.L., Ethanol and food production by family smallholdings in rural Brazil: economic and socio-environmental analysis of micro distilleries in the State of Rio Grande do Sul, *Biomass and Bioenergy* **63**, 2014, 140–155.

Neves D.P., Agricultura familiar: questões metodológicas, *Revista da Associação Brasileira de Reforma Agrária* **25** (2/3), 1995, 21–36.

Novo A., Jansen K., Slingerland M. and Giller K., Biofuel, dairy production and beef in Brazil: competing claims on land use in São Paulo state, *J. Peasant Stud*. **37** (4), 2010, 769–792.

Novo A., Jansen K. and Slingerland M., The sugarcane-biofuel expansion and dairy farmers'' responses in Brazil, *J. Rural Stud*. **28**, 2012, 640–649.

Oddershede A., Arias A. and Cancino H., Rural development decision support using the analytic hierarchy process, *Math. Comput. Model*. **46**, 2007, 1107–1114.

Rossi A.M. and Hinrichs C.C., Hope and skepticism: farmer and local community views on the socio-economic benefits of agricultural bioenergy, *Biomass and Bioenergy* **35**, 2011, 1418–1428.

Rua M.G., Políticas Públicas, 2009, Departamento de Ciências da Administração/UFSC, CAPES: UAB; Brasília.

Rudorff B.F.T., Aguiar D.A., Silva W.F., Sugawara L.M., Adami M. and Moreira M.A., Studies on the rapid expansion of sugarcane for ethanol production in São Paulo state (Brazil) using landsat data, *Remote Sens*. **2**, 2010, 1057–1076, http://dx.doi.org/10.3390/rs2041 057.

Saaty T.L., How to make a decision: the analytic hierarchy process, *Eur. J. Oper. Res*. **48**, 1990, 9–26.

Saaty T.L., *Método de Análise Hierárquica*, 1991 , McGraw-Hill, Makron; São Paulo.

Saaty T.L. and Vargas L.G., *Models, Methods, Concepts & Applications of the Analytic Hierarchy Process*, 2001, Kluwer Academic Publishers; Dordrecht, The Netherlands.

Sachs I., Brasil rural: da redescoberta à invenção, *Estudos Avançados* **15** (43), 2001 , 75–82.

Schneider S., A importância da pluriatividade para as políticas públicas no Brasil, *Revista de Política Agrícola* **3**, 2007, 15–34.

Xu W., Khoshroo N., Bjornlund H. and Yin Y., Effects of grain for green reforestation program on rural sustainability in China: an AHP approach to peasant consensus of public land use policies, *Stoch. Environ. Res. Risk Assess*. 2012, http://dx.doi.org/10.1007/s00477-01 2-0592-y.

Wanderley M.N.B., A agricultura familiar no Brasil: um espaço em construção, *Revista da Associação Brasileira de Reforma Agrária* **25** (2/3), 1995, 37–68.

Wilkinson J. and Herrera S., Biofuels in Brazil: debates and impacts, *J. Peasants Stud*. **37** (4), 2010, 749–768.

Supplemental material

We produced three sensitivity analysis graphs of each of the three criteria and nine decision attributes of the AHP hierarchy for each one of the eight stakeholder groups, totaling 96 graphs. We present here two examples of sensitivity analysis graphs, one that shows insensitity and another that shows sensitivity.

First, we take the Farmers 3 group (farmers who were renting land to sugarcane producers at the time of interview) and the economic criterion as an example. Fig. 1 shows how alternatives were prioritized relative to each other with respect to the economic criterion. The vertical line in the graphs marks the local priority given to the economic criterion from the Farmers 3 interviews. The weight is 0.480. The global priorities of alternatives can be read on the y-axis at the point that they intersect the vertical line marking the priority given to the economic criterion (0.639 for diversified production; 0.226 for specialized production; and 0.135 for rent land to sugarcane). We can see that diversified production is the most desirable alternative and that it remains that way regardless of the weight given to the economic criterion, given that no line representing the alternatives intersects with another. In other words, the final ranking of alternatives is *insensitive* to any changes in the weight respondents gave to the economic criterion. Moreover, we notice that the preference gap between diversified production and other two alternatives is significant, whereas the distance between specialized production and rent land to sugarcane is not large.

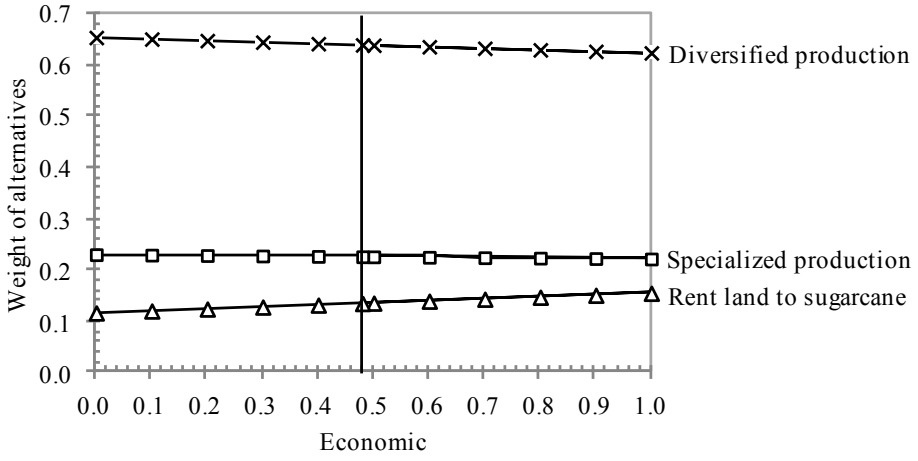

Figure 1. Sensitivity analysis of the economic criterion of the Farmers 3 group.

The majority of results showed a pattern similar to that shown in Fig. 1, for all stakeholders. The only exception was considering the Emater group. Its results were sensitive to changes in weights given to the environmental and economic criteria, and to the following attributes: air and water quality, food security, education, permanence in the countryside, income generation, subsidies for production and guarantee of purchase and minimum price. Fig. 2 illustrates these sensitive results from the Emater group. The weight given to the economic criterion from Emater respondents was 0.455, indicated by the intersection of the vertical line with the x-axis. The global priority of each alternative is indicated by the intersection of the alternative line with the vertical line marking the economic criterion weight (0.533 for diversified production; 0.392 for specialized production; and 0.075 for rent land to sugarcane). The dashed line shows where the weight for the economic criterion would have to be to begin to have a switch in the final priority ranking of the alternatives. In short, the sensitivity analysis allows for identifying unstable results. Instability is more of a concern the closer any alternative line intersection is to the vertical line marking the weight on the x-axis.

In this example, the priority for diversified production tends to decrease and specialized production tends to increase when economic weight increases, up to 0.8 (dashed line), at which point the alternative of specialized production would become the top option for any public policy aimed toward addressing economic benefits.

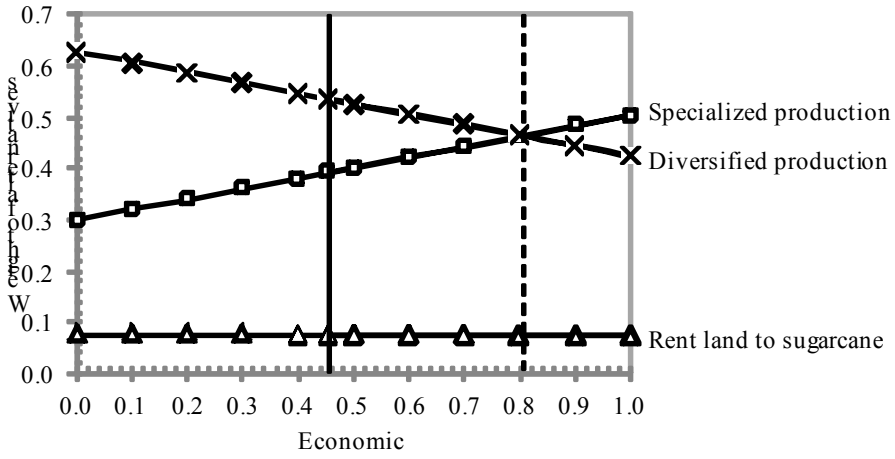

Figure 2. Sensitivity analysis of the economic criterion of Emater.