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RESEARCH ARTICLE

Forest Stewardship Council (FSC) pesticide policy and integrated pest management in certified tropical plantations

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Abstract The Forest Stewardship Council (FSC) was the first non-governmental organization composed of multi-stakeholders to ensure the social, environmental, and economic sustainability of forest resources. FSC prohibits certain chemicals and active ingredients in certified forest plantations. A company seeking certification must discontinue use of products so listed and many face problems to comply with these constraints. The aim of this study was to assess the impacts of certification on pest management from the perspective of Brazilian private forestry sector. Ninety-three percent of Brazilian FSC-certified forest companies rated leaf-cutting ants as "very important" pests. Chemical control was the most important management technique used and considered very important by 82 % of respondents. The main chemical used to control leaf-cutting ants, sulfluramid, is in the derogation process and was classified as very important by 96.5 % of the certified companies. Certified companies were generally satisfied in relation to FSC certification and the integrated management of forest pests, but 27.6 % agreed that the prohibitions of pesticides for leaf-cutting ant and termite control could be considered as a non-tariff barrier on high-productivity Brazilian forest plantations. FSC forest certification has encouraged the implementation of more sustainable techniques and decisions in pest management in forest plantations in Brazil. The prohibition on pesticides like sulfluramid and the use of alternatives without the same efficiency will result in pest mismanagement, production losses, and higher costs. This work has shown that the application of global rules for sustainable forest management needs to adapt to each local reality.

Keywords Certification · Derogation · Forest entomology · IPM · Pesticides · Sulfluramid

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Introduction

From the late 1970s, deforestation and forest degradation have received increasing international attention. This has brought a greater focus on deforestation in developing countries, leading to boycotts of products of uncertain origin by forest environmental movements (Basso et al. 2011; Overdevest and Rickenbach 2006). The difficulties in distinguishing products from sustainable or unsustainable origins led to the emergence of forest certification programs (Bell and Hindmoor 2012). The Forest Stewardship Council (FSC) was created to address issues of sustainability and international trade in the face of economic globalization, and growing environmental concerns, including recognition of the rights of indigenous peoples (Klooster 2010). This was largely in response to the lack of regulation by intergovernmental bodies on the sustainability of forest activities (Bell and Hindmoor 2012).

The FSC began operating in 1993 as the first non-governmental organization composed of multi-stakeholders to attempt to ensure social, economic, and environmental sustainability of forest resources (Hackett 2013). The scheme is based on standards established for the international trade of sustainably managed forests and is arguably one of the most rigorous forest certification systems in the world (Hackett 2013). Under this scheme, a forestry company needs to follow 10 principles and 56 criteria to gain the FSC's stamp of approval (FSC 2014). By adopting policies of social and environmental responsibility, the company can differentiate itself from competitors through its social and environmental practices and gain access to premium international markets (Robinson 2012).

The FSC certified area in Brazil corresponds to approximately 7.3 million hectare. Forest plantations represent approximately 8 % of the certified area in the world and about 61 % of that in Brazil (FSC 2013; ABRAF 2013). Among the major pests of Brazilian forest plantations, there is a group that stands out over any other, the leaf-cutting ants of the genera *Atta* and *Acromyrmex* (Della Lucia et al. 2014; Zanetti et al. 2014).

Leaf-cutting ants exhibit a number of features that make the management and control techniques for these insects very different from other insect pests. These characteristics include social behavior, foraging activities, cultivation of fungi, high levels of hygiene of individuals and colonies, and high structural complexity of the colonies (Della Lucia et al. 2014). These factors, and also the large number of ant species and the attractiveness of non-native tree species to them, make it even more difficult to manage this pest. This has been known for a long time, as quoted in the famous phrase of the naturalist Auguste de Saint-Hilaire, "Either Brazil annihilates the leaf-cutting ants or the leaf-cutting ants will annihilate Brazil" (Della Lucia et al. 2014). A single colony of *Atta* sp. per hectare can reduce wood production by up to 0.13 m^3 h^{-1} (Souza et al. 2011). Losses caused by leaf-cutting ants can reach billions of dollars worldwide (Montoya-Lerma et al. 2012), and the costs of controlling these insects can vary between 30 to 75 % of the total forest management costs of plantations (Alipio 1989; Vilela 1986).

Chemical control is the most commonly method used by forest companies to control leaf-cutting ants in plantations (Zanetti et al. 2014), since it is the only method available that reliably produces satisfactory results in controlling this pest (Della Lucia et al. 2014; Montoya-Lerma et al. 2012). The most widely used insecticides for the control of leaf-cutting ants are sulfluramid, fipronil, deltamethrin, and fenitrothion (Zanetti et al. 2014).

In the FSC's "Principles and Criteria," a series of 10 standards includes the FSC pesticide policy, which has three key elements: (a) identification and prevention of use of "highly hazardous" pesticides, (b) promotion of "non-chemical" techniques for pest management as an integrated strategy, and (c) proper use of pesticides (FSC-POL-30-001 (2005) EN). The list of chemicals prohibited from use in certified areas was last updated in 2015 (FSC-STD-30-001a EN, 2015). If a listed product is needed, an application for derogation to support continued use on certified forests must be submitted (FSC 2007). In the derogation process, the need for a specific active ingredient for controlling a species of insect, weed, or disease must be proved (FSC 2012). The pesticide that is applying for derogation must be the only sustainable and technically feasible technique to control a peculiar pest that is causing forest health or productivity problems. After the derogation approval, conditions are determined for the use of the highly hazardous pesticides. The derogation lasts 5 years, and during this time, companies have to seek alternatives to that pesticide (FSC 2012).

Deltamethrin, fipronil, fenitrothion, and sulfluramid, widely used for leaf-cutting ants and root termite control in Brazilian forestry, are now prohibited and in the FSC derogation process (except fenithrotion) (Zanuncio et al. 2016). Fipronil and sulfluramid are considered highly hazardous pesticides because of their acute toxicity to mammals and birds. Deltamethrin and fenithrotion were also listed for this and because they are considered endocrine-disrupting chemicals and may exhibit acute toxicity to aquatic organisms (FSC 2015a; FSC 2015b). The FSC is thus prohibiting all registered and effective pesticides that, at present, represent the only viable technique for the control of leaf-cutting ants (Britto et al. 2016; Zanuncio et al. 2016). Poorly implemented control or total lack of control of leaf-cutting ants in Brazilian forest plantations can drastically affect the productivity and profitability of any forest plantation business, especially in the early years (Cantarelli et al. 2008; Matrangolo et al. 2010; Reis Filho et al. 2011).

Forestry companies in Brazil and in other countries, such as Australia and South Africa, have had difficulty in meeting the requirements of the FSC pesticide policy (Carnegie et al. 2005; Govender 2002). The biggest problem for the legitimacy of the FSC is in these countries in the southern hemisphere due to the complexity of the forests, the high cost of certification, and their lack of market access (Schepers 2010).

Impacts of certification on forest management may vary among regions due to management regimes and trends in land ownership (Rametsteiner and Simula 2003). Companies following the principles of FSC certification have shown benefits to forest management practices in response to the changes they may have made (Klooster 2010), and these impacts on forest management have been intensively studied (Araujo et al. 2009). The impact of forest certification on companies in the USA (Moore et al. 2012), Argentina, Chile (Cubbage et al. 2010), Brazil (Araujo et al. 2009), and other countries (Auld et al. 2008) and the costs of certification on forest production (Cubbage et al. 2009; Van Deusen et al. 2010) have been studied. Problems with forest certification in relation to weed management (Rolando et al. 2011) and the prohibition of genetically modified plants (Strauss et al. 2001b) has been also reported, but the impact of FSC certification on integrated pest management (IPM) has been rarely discussed (Carnegie et al. 2005; Govender 2002). Environmental and financial costs and benefits affect the adoption of forest certification systems by companies (Cubbage et al. 2009). Direct costs are linked to the requirements of the certification process and indirect costs to the restrictions on forest management options and excessive demands, as in the establishment of plantations and the use of pesticides (Van Deusen et al. 2010).

The main objective of this study was to assess the impacts forest certification by FSC on the practices and adoption of integrated pest management by the Brazilian private forestry sector. The outcome of this research may assist forest companies to determine whether or not to adopt/maintain forest certification and also assist in discussions with FSC on the application and evolution of their system. The research addressed three key questions: (1) whether integrated pest management practices in forest companies had change in response to forest certification, (2) whether forest companies are satisfied with the changes implemented in pest management programs in response to certification, and (3) whether certified companies find it difficult to comply with the standards imposed by the FSC while maintaining control of highly damaging insect pests.

Materials and methods

Impacts of forest certification on companies can be evaluated from certification reports, interviews, and questionnaires or by using a combination of these techniques (Moore et al. 2012). Questionnaires were sent via e-mail to all organizations with FSC-certified forest plantations in Brazil as at August 2013 ($n = 54$). Eligible companies were sourced from the certification system website (http://info.fsc.org/), which listed all certified forest plantations within Brazil and the names of the forest owner or manager of each. Only private organizations (industrial or non-industrial) were included as no national forests are certified. Certification bodies and auditors were not included in the survey as the knowledge of changes in pest management strategies after the adoption of certification resides with the company.

A draft questionnaire was initially prepared and reviewed by academics and researchers from various forestry agencies (academic staff at the Federal University of Viçosa with extensive experience in integrated management of forest pests and forest certification, PhD students in Entomology and Forestry Sciences with experience in these areas, and researchers from the Forest Science and Research Institute—IPEF). The questionnaire was approved by the Federal University of Viçosa Ethics Committee on Human Research (CEP) and recognized by the Brazilian National Committee for Ethics in Research (CONEP) (CAAE 20,163,313.8.0000.5153).

The final questionnaire (Appendix 1) comprised 25 questions. The questionnaire was adapted from others that assessed the impact of certification as a whole (Araujo et al. 2009; Cubbage et al. 2010; Moore et al. 2012). Questions on the importance of groups of forest pests, pest control techniques, and on chemical insecticides in the derogation process were done used Likert scale (1–5); this scale was also used to assess possible advantages and disadvantages of certification in relation to integrated pest management and to verify the satisfaction of companies with certification (related to pest management). Lists of changes associated with the implementation of FSC certification in integrated pest management addressing environmental, social, and economic aspects were made.

A pre-survey e-mail was sent to potential respondents, reporting our intention to carry out this research with their organization and also outlining the questionnaire, which was then attached to a letter in a subsequent e-mail sent following a positive reply. Respondents were instructed to fill out the questionnaire, save the file, and reply to the e-mail attaching the completed file. Organizations that did not respond to the first e-mail received another e-mail 11 days later, the remaining non-respondents a third letter e-mail after a further 2 weeks, and a final e-mail letter 2 weeks after this to any remaining non-respondents. Another attempt to invite participation of non-respondents was made by telephone 1 month after the last e-mail had been sent.

Data analysis

Once complete, the survey responses were tabulated and the data were presented as descriptive statistics; arithmetic means were used for numerically open answers (e.g., costs of IPM) and frequencies for questions that used the Likert scale.

Participants evaluated their expectation and satisfaction in relation to the influence of FSC on pest management on a Likert scale of 1–5 points. Analysis of expectations and satisfaction was performed using an IPA diagram (importance-performance analysis) (Martilla and James 1977). These types of analyses can assist in identifying the benefits received by companies and allow an evaluation of the performance of the certification system. To build this matrix, respondents expressed their expectation for each benefit of certification for their companies (on the scale "not important at all" to "very important," 1–5 point Likert scale) and then rated the performance of this benefit after the certification of forest plantations (on the scale "not achieved" to "fully achieved," 1–5 point Likert scale). This is represented on a two-axis graph, where the meeting point is the overall average of the responses, a practice known as importance-performance analysis (Araujo et al. 2009; Overdevest and Rickenbach 2006). The plotted points represent the average importance and performance for a possible benefit. If a survey item appears in quadrant A, it means that companies believe that this item was important but were not satisfied with its performance for certification, while appearing in quadrant B indicates that this item was important and companies were satisfied with its performance. Items in quadrant C mean that companies considered them as of low importance and low performance, while those in quadrant D were rated as having low importance but where companies were satisfied with performance following certification.

Results

Twenty-nine forestry companies, out of a total of 54 certified by the FSC in Brazil in 2013, responded to the survey (2 companies refused to answer the survey). Companies from at least two states in each of the five Brazilian geopolitical regions were represented in the sample, with a total coverage of approximately 1.3 million hectare or about 30 % of the area of certified forest plantations in Brazil.

Plantation area, certification, and cultivated species

Of the companies sampled, 62.1 % reported having FSC certified plantations considered small (less than 25,000 ha), 20.7 % very large plantations (greater than 100,000 ha), 10.3 % large plantations (between 50,000 and 100,000 ha), and 6.9 % average plantations (between 25,000 and 50,000 ha). The respondents planted a range of hardwood and softwood species, with approximately 38 % cultivating more than one species (Table 1).

The companies included in the survey had received FSC forest certification between 1996 and 2012. Of these, 20.7 % had obtained one additional certification in addition to their FSC certification and 17.2 % more than two other forest certifications. ISO 9001 certification was the most common among these additional forest certifications with 24.1 % of respondents, followed by ISO 14001 (20.7 %), Brazilian Programme of Forest Certification—CERFLOR (under the umbrella of the Programme for the Endorsement of Forest Certification (PEFC); 17.2 %), and Occupational Health and Safety Assessments Series (OHSAS; 6.9 %).

Table 1 Percentage of tree species planted by respondent forest companies certified by FSC in Brazil

Species	Percentage
Eucalyptus spp.	69.0 %
Pinus spp.	55.2 %
Acacia spp.	10.3 %
Araucaria angustifolia	10.3 %
Tectona grandis	6.9 %
Other species	3.5 %

Importance of forest pests, control techniques, and active ingredients in derogation

The respondents indicated that out of a range of forest pests, leaf-cutting ants were rated very important and "important" by approximately 93 and 3.5 % of respondents, respectively (Fig. 1). On the other hand, all the other groups of forest pests were ranked as very important by less than 17.2 % of the respondents (as in the case of sap-sucking insects).

Total importance rating (i.e., very important + important) for defoliating caterpillars was 44 %, sap-sucking insects 40 %, defoliating beetles 37.5 %, root termites 32 %, mites 28 %, gall insects 25 %, and woodborers 21 %. Heartwood termites had the lowest degree of importance (12.5 %).

Chemical control was the most important pest management technique used by FSC-certified Brazilian forestry companies and was considered very important by 82 % of companies (Fig. 2). Companies also considered biological control (71.4 %), tree resistance (54 %), cultural control (37.5 %), and mechanical control (34.5 %) as important (very important + important). Behavioral control techniques (e.g., use of hormones and pheromones) were the least important (8.4 %).

Among chemicals that were in a derogation process, sulfluramid was classified as very important by 96.5 % of the companies certified by the FSC (Fig. 3), followed by fipronil, with total importance of 70.4 % and deltamethrin 50 %. Fenitrothion was considered less important (25 %).

Most companies developed research in partnerships with research institutes (65.5 %) to search for alternative chemicals for those in derogation. Among the leading institutes were EMBRAPA (Brazilian Agricultural Research Corporation), FUNCEMA (National Fund for Control of Wood Wasp), PROTEF (Forest Protection Program of the Forest Science and Research Institute), and the PCCF (Cooperative Program of Forest Certification) being the most cited. Their research with these institutes focus on the search for substitutes for chemicals in derogation, alternative methods of pest control, and the development of biological control. Research developed in partnership with Brazilian universities (37.9 %) was the second most popular type of research. Only 17.2 % of companies said that they carried their own research programs. No surveyed company conducted research in partnership with NGOs.

Changes in integrated pest management and staff

Twenty one of the respondent companies said that they hired and/or reallocated employees of pest monitoring and management to meet the requirements of FSC pesticide policy. The

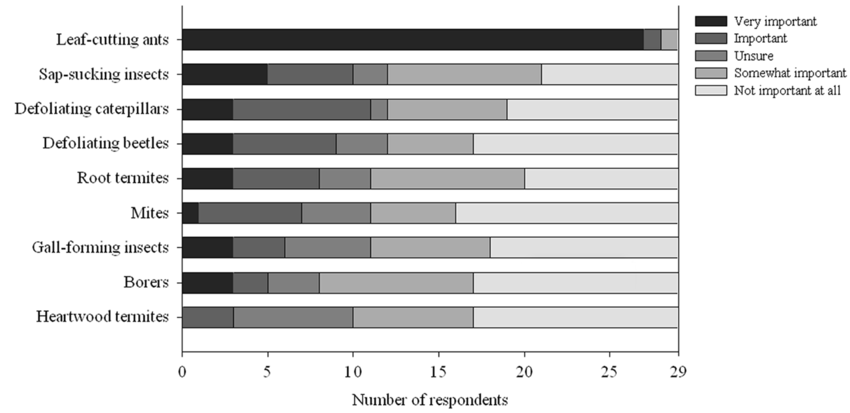


Fig. 1 Importance of forest pests according to FSC-certified companies in Brazil that completed the survey

average number of employees hired/reallocated by respondent companies was 7.2, ranging from 1 to 40. The need for pest monitoring was the big responsibility for these extra staff, with an average of 5.1 workers needed for this purpose. Pest control was responsible for the hiring/reallocation of 2.4 workers and environmental and wildlife areas, public relations, and other (e.g., forest balance and FSC), 0.7, 0.3, and 0.1 workers, respectively. The single company that hired and/or reallocated 40 employees implemented monitoring of leaf-cutting ants, which was largely responsible for the increase in its staff. Another company hired three full-time employees for forest protection (a forest engineer and two technicians) and four part-time employees.

Approximately 80 % of companies responded that staff working in integrated pest management received some types of specific training to suit the requirements of the FSC pesticide policy. The average number of employees who received training for pest management in relation to FSC was 24.3, ranging from 1 to 100.

When asked if an integrated pest management plan was in place before they acquire FSC certification status, a total of 62.1 % (*n* = 18) responded negatively.

Companies were also asked about what changes were adopted in integrated pest management practices to comply with FSC standards (Table 2). These changes could have included social and legal changes in IPM (Table 3) and economics and implementation of system changes in IPM (Table 4).

Costs and impacts to integrated pest management as a result of certification

Fifty-eight percent of companies (*n* = 17) identified that there were additional costs associated with IPM due to FSC forest certification, but they shared few details or estimates of these costs.

The average expenditure of companies on chemical control of forest insect pests was US$ 29.50/ha/year (*n* = 7) compared to US$ 0.46/ha/year (*n* = 3) for biological control. One company said that costs of chemicals that complied with the FSC policy were higher, because they are more expensive. Monitoring had an average cost of US$ 2.14/ha/year (*n* = 13), and spending on employee training in relation to certification was US$0.62/ha/year (*n* = 7). Actions to comply with derogation, with an average cost of US$ 0.88/ha/year (*n* = 5), was the cost most cited among those classified as "other." One company reported costs generated by changes in pest management of US$ 2.26/ha/year).

The degree of satisfaction of companies in relation to the FSC and integrated pest management showed that 55.2 % (*n* = 16) classified it as worthwhile compared to 27.6 % (*n* = 8) that were uncertain as to their degree of satisfaction (Fig. 4a).

A total of 44.8 % (*n* = 13) indicated satisfaction with the cost/benefit of the FSC with regard to IPM, while 34.5 %

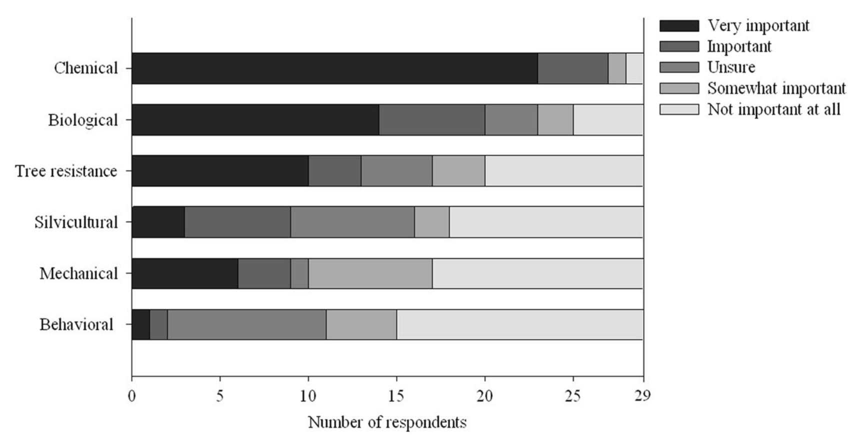


Fig. 2 Importance of control techniques used in integrated management of forest pests, according to the companies certified by the FSC in Brazil included in the survey

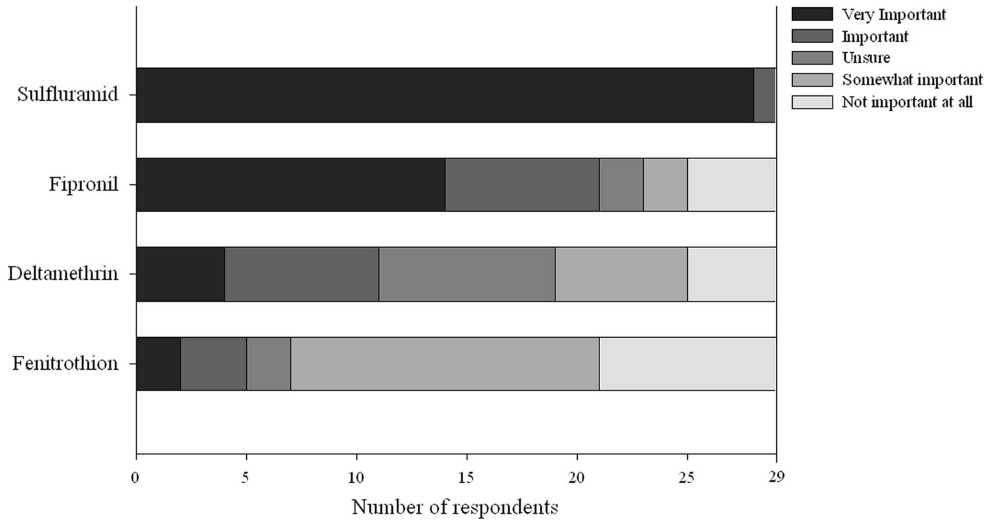


Fig. 3 Importance of the active ingredients used for chemical control in the integrated management of forest pests, according to companies certified by the FSC in Brazil included in the survey

(n = 10) said they were unsure. On the other hand, 13.8 % (n = 4) reported that they were unsatisfied (Fig. 4b).

Forestry companies were generally satisfied in relation to the FSC and the integrated management of forest pests, but 27.6 % (n = 8) fully agreed that the prohibition of active ingredients for control of leaf-cutting ants and termites was an imposition of a non-tariff barrier on the high productivity of Brazilian forest plantations; 37.9 % (n = 11) partially agreed with this statement with 17.2 % (n = 5) totally disagreeing (Fig. 4c). A total of 44.8 % of companies said they would probably maintain FSC certification even without a new derogation of deltamethrin, fenithrothion, fipronil, and sulfluramid and in the absence of feasible alternatives (Fig. 4d).

Table 2 Percentage of respondents that made changes in integrated pest management to meet the requirements of the FSC standards and most common changes described by them on each item

IPM changes	Percentage	Most common changes
Chemical security and storage	86.2 %	Construction of storage locations, adequacy of existing deposits, use of personal protective equipment, creation of policies and procedures, specific training
Monitoring	75.9 %	Creation of monitoring programs for key pests, adoption of systematic monitoring, greater control of pests outbreaks and associated pesticide use, pre- and post-planting monitoring, monitoring done by non-pest management-related staff (e.g., security personnel, forestry staff)
Pesticide reduction goals	72.4 %	Creation of reduction goals with the FSC; local application of pesticides, instead of whole plantation area; greater monitoring of the amount of insecticides used
Investments in research/partnerships	62.1 %	Search for new active ingredients, partnerships with universities and research institutes, cooperation with other forest companies
Activity log	62.1 %	Creation of computerized management control and information systems, annual reports of chemical use
Identification of pest species	51.7 %	Better identification through inventory and monitoring, laboratory analysis, partnerships with researchers
Calculations of economic injury level (EIL)	44.8 %	Customization and strategic planning, trials in plantation areas to determine the EIL
Biological control	37.9 %	Investments in research on natural enemies of sucking pests, wood-wasp biocontrol, replacement of chemical control
Regeneration and wildlife surveys	37.9 %	Monitoring of fauna and flora, forest inventory, creation of new policies and procedures
Endangered species protection	37.9 %	Use of MLP (mini-port lures) for leaf-cutting ant control, areas of native forest, forest zoning
Adoption of other insecticide formulations	34.5 %	–
Non-target species protection	34.5 %	–
Calculations of growth and yield	24.1 %	Creation of continuous forest inventory
Biological diversity planning	20.7 %	Search for more clones for planting
Cultural control	13.8 %	Plantations in mosaic formations, using the greatest diversity of species and clones
Log storage	10.3 %	Changes in silvicultural practices

Table 3 Percentage of respondents that made changes in the legal and social aspects of integrated pest management to meet the requirements of the FSC standards and most common changes described by them on each item

IPM changes	Percentage	Most common changes
Social impact analysis	58.6 %	Creation of mechanisms for measuring social impact by forestry operations related to IPM, before and after it takes place, in communities and nearby properties; meetings with surrounding communities
Stakeholder consultation	58.6 %	Communication plan with neighboring communities before insecticide applications, consultations with research centers on the use of sulfluramid, public consultation and distribution of informational brochures about the products used, public consultations as a result of the derogation
Public availability of the data of pest control and management	55.2 %	Summary of pest control available for stakeholders
Compliance with environmental laws	44.8 %	Adaptations to the new forest code, city, state, and federal laws; compliance with standards and greater monitoring of third-party employees
Guarantee of rights and labor practices	37.9 %	Monitoring of third-party employees
Use of insecticides registered by MAPA (Ministry of Agriculture, Livestock and Food Supply)	34.5 %	Reduction of chemical options for the sector, search for products that meet the demands of the FSC
Offer workshops	13.8 %	Greater number of workshops offered

The lack of viable alternatives to prohibited chemicals or those in derogation was considered by 75.9 % of respondents as a very important consideration and among the possible highest costs of FSC certification on the integrated management of forest pests (Fig. 5), followed by the prohibition of the use of fertilizers (62.1 %), prohibition (and derogation) of insecticides registered for use by the Ministry of Agriculture, Livestock and Food Supply—MAPA (58.6 %), and the maintenance of records of the control and monitoring of pests (44.8 %). The prohibition of the use of genetically modified organisms was considered a less important cost (24.1 %).

General satisfaction

Between the possible benefits of certification to the integrated pest management showed that respondent companies considered 12 items important and are happy with their performance (Fig. 6, quadrant B). On the other hand, companies considered important but were not satisfied with the performance of items (13) smaller amount of pesticides used (environmental) and (17) learning on forest integrated pest management (Fig. 6, quadrant A). Ten items appeared on quadrant C (Fig. 6), with low importance and performance. Items (8) "green" marketing (economic) and (16) larger areas of native forests close to plantations (environmental) were included in quadrant D (Fig. 6), indicating that companies care less about these items in relation to pest management but recognize and are satisfied with their performance.

General comments by certified companies

Approximately 65.5 % of the respondents expressed their opinions or made suggestions for improving pest management regulation under FSC. The most notable criticism, which included 63 % of respondents (n = 12), related to the criteria adopted by the FSC for the prohibition of certain pesticides. Many of the responding companies affirmed that these criteria should take into account the mode of application of insecticides. Two illustrative comments were "The proper use and safety involved in the application should be considered as mitigating in prohibition evaluation" and "Consider the mode

Table 4 Percentage of respondents that made changes in economics and system implementation of integrated pest management to meet the requirements of the FSC standards and most common changes described by them on each item

IPM changes	Percentage	Most common changes
Creation/application of specific procedures	79.3 %	Procedures on how to monitor and control pests, creation of a detailed operational guide of pest control, procedures on how to apply each pesticide, standardization of procedures
Monitoring/internal audit	75.9 %	Improving the internal and external audits, with greater monitoring of integrated pest management, reducing operational costs; internal and external FSC audits
Minimize control costs	48.3 %	Increasing monitoring of pests, rational use of insecticide baits, systematization to reduce control costs
Entomological research	34.5 %	Partnerships with research centers and universities
Economical analysis	27.6 %	Conducting annual comparative analysis of costs

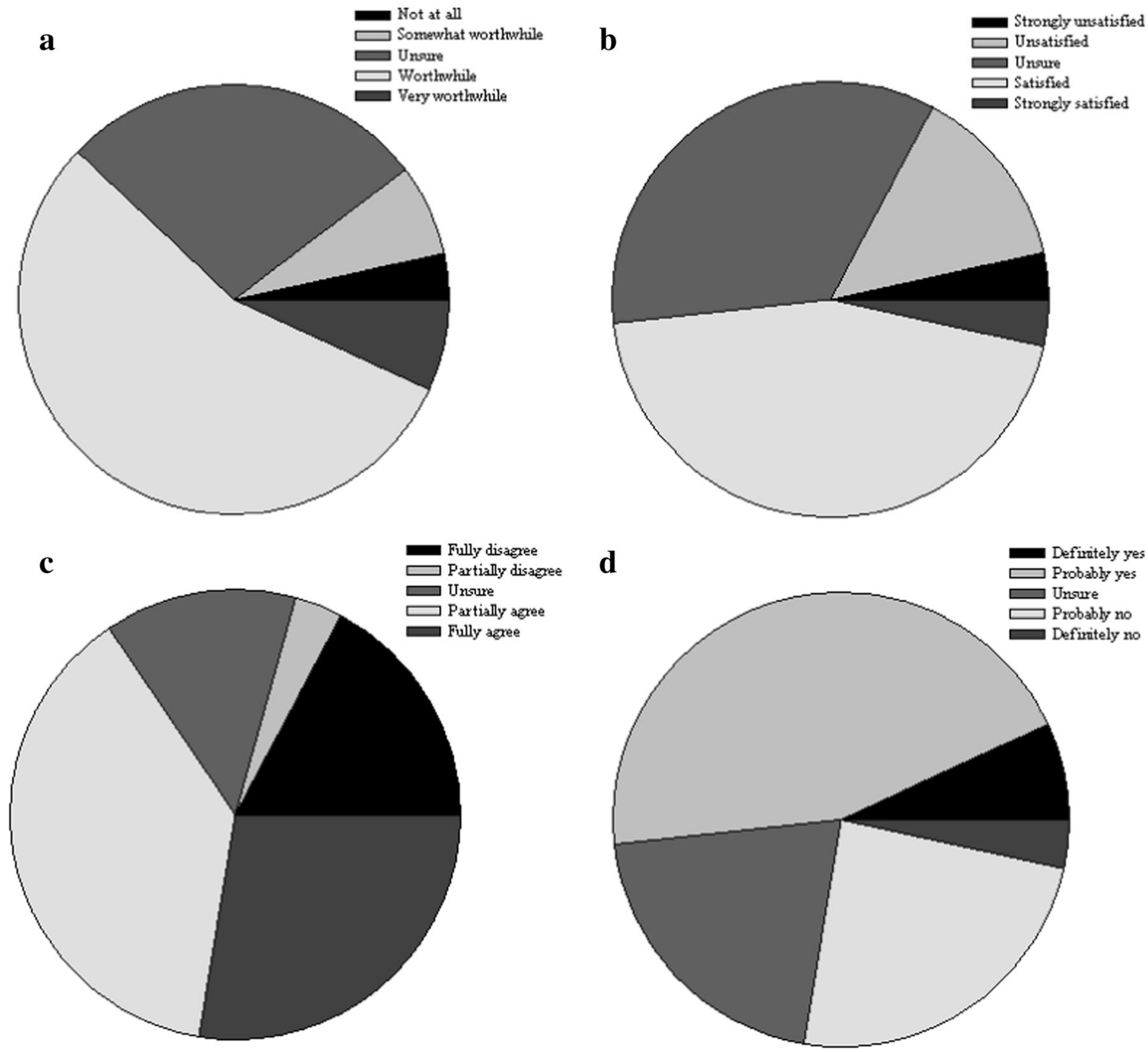
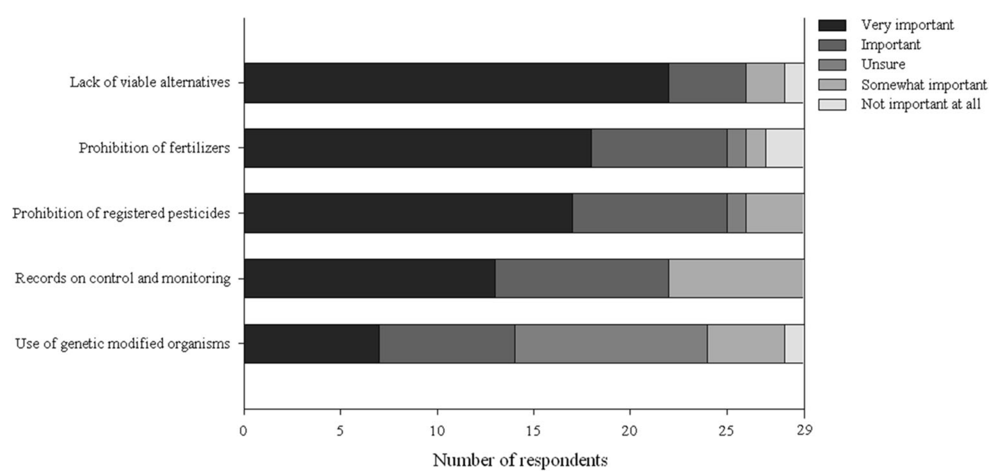


Fig. 4 **a** Degree of satisfaction of respondents representing the Brazilian forestry companies with FSC certification and the integrated management of forest pests. **b** Satisfaction with cost/benefit relationship of FSC certification and the integrated management of forest pests in the opinion of Brazilian forestry companies. **c** Do your company agree that the prohibitions on leaf-cutting ant pesticides would be an imposition of a non-tariff barrier to the Brazilian high productivity? **d** In case of a permanent prohibition on chemicals in derogation (deltamethrin, fenithrothion, fipronil, and sulfluramid), would your company keep FSC certification?

Fig. 5 The importance of some possible costs of FSC forest certification to integrated pest management in the opinion of respondent Brazilian-certified companies



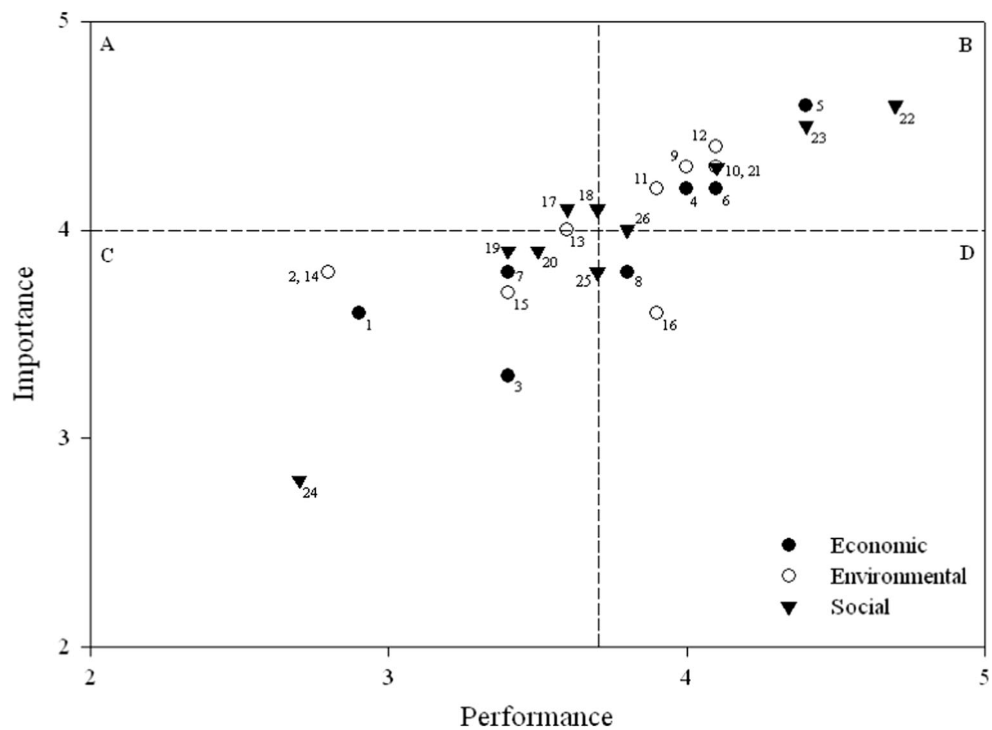


Fig. 6 Analysis of importance and performance of the possible benefits of FSC forest certification for integrated pest management of Brazilian forestry companies, (1) smaller losses in production; (2) lower control costs; (3) competition with other companies; (4) recognition and credibility; (5) greater commitment to the management; (6) better planning; (7) capture new markets; (8) green marketing; (9) model of good forestry; (10) improvements in management practices; (11) improvement on forest protection; (12) better monitoring, planning, and execution of actions of pest management; (13) smaller amount of pesticides used; (14) more use of non-chemical techniques; (15) smaller risk for non-target species; (16) larger areas of native forests close to plantations; (17) learning on forest-integrated pest management; (18) better public trust; (19) more IPM research; (20) credibility with regulatory agencies; (21) better organization of activities; (22) improved training and safety of applicators; (23) improve the quality of life of employees; (24) increase in the number of employees with the pest management; (25) less conflicts with neighbor communities; and (26) better relationship with stakeholders

of application, dose, concentration, and frequency of the use of pesticides." Some companies argued that FSC pesticide policy does not match the national legislation on pesticides. They made comments such as "they should consider the regulatory norms for registration of chemical products in each country, positively considering countries where there is a structured and rigorous process for analysis and registration of active principles" and "consider the existing norms for approval and release of these products by national agencies, since this process is extremely slow, judicious, and technical in Brazil. Some companies believed that the pesticide policy should take into account bioecological and geographical differences, so as to "make changes in the guidelines to be followed by national and even regional levels, as many pest problems and demands do not apply to countries or regions as a whole. The diversity of pests in the same country is very high, and potential pests in a given region may have the same significance as in another but do not require the same type of management control due to weather and environmental conditions of each region."

About 32 % (n = 6) of the respondents made suggestions related to availability of chemicals for the control of forest pests. One company stated "... clearly the policy of the FSC is not very collaborative, limited to a prohibitive character and without offering alternatives." Companies expressed the need of time extension for the search of alternatives to the active principles in derogation. Some also suggested reconsideration of the use of the genetically modified organisms (GMOs).

Discussion

Importance of forest pests, control techniques, and active ingredients in derogation

As expected, leaf-cutting ants were considered the most important forest pests, almost unanimously, far ahead of the second most important, the sap-sucking insects (e.g., *Thaumastocoris peregrinus*), regardless of the forest species planted, because leaf-cutting ants can defoliate endemic Brazilian and exotic trees (Montoya-Lerma et al. 2012; Nickele et al. 2009; Zanetti et al. 2014).

The chemicals in derogation for control of leaf-cutting ants are formulated as either dry powder, for fogging, or predominantly as granular baits, the latter mainly made with sulfluramid. Because of this, sulfluramid was considered the most important chemical in derogation for virtually all respondent companies. Sulfluramid is a compound in the fluoroafilatic sulfonamid group and is less toxic than its predecessor, dodecachlor. It is slow acting and of low persistence in the environment. It is rated in the Brazilian Ministry of Agriculture hazard classification as IV or "slightly toxic" (MAPA 2014) and by the World Health Organization as class III or "slightly dangerous" (WHO 2004). According to the FSC pesticide policy, sulfluramid was prohibited for its potential to bioaccumulate and toxicity to mammals and birds (FSC 2007). These processes can be considered less important when insecticide baits are used, because these are insoluble in water, immovable in the soil, and the formulation and mode of application prevent drift and leaching. Furthermore, the baits contain low concentrations of the active ingredient and have a reduced time of exposure to non-target species because they are applied near the nest and are quickly collected and consumed by ants. The main way in which pesticides can reach a body of water is leaching through the soil or drift from aerial applications (Al Heidary et al. 2014; Jensen and Olesen 2014; Payraudeau and Gregoire 2012; Yu et al. 2014).

This raises a question: what is the risk of sulfluramid leaching and reaching water bodies and/or bioaccumulating to a toxic level? The movement, ecotoxicity, and bioaccumulation of sulfluramid in forest plantations have been poorly studied, and the real risk of sulfluramid applied in these environments to the Brazilian biota needs to be evaluated in independent studies. Moreover, sulfluramid should not permanently be considered as the only available option for leaf-cutting ant control in Brazil, but its prohibition by FSC should not be enforced while there are no other methods that have the same efficiency. Prohibition in this case only serves to damage Brazilian forestry companies and their productivity and may even derail the integrated pest management of these insects, something that criterion 10.7 in the principles and criteria of the FSC claims to promote as an essential part of the management plan of a certified company (FSC 2002). As seen in this study, Brazilian companies have advanced considerably in relation to this goal, and research has been carried out to find viable substitutes for sulfluramid. However, the deadlines for derogation, the prohibition policy, and the lack of a collaborative policy by FSC appear to be an obstacle to good forest pest management in Brazil.

In addition, FSC causes confusion by contradicting itself. The sulfluramid is included in the highly hazardous pesticide list of 2007 for its potential to bioaccumulate (FSC 2007). In the last list, in 2015 (FSC 2015a), sulfluramid is not considered a bioaccumulating substance but as toxic to mammals and birds. This change occurred despite the bioaccumulation criteria being maintained (FSC 2007; FSC 2015b), so the reasons for the change are still not clear. The same happened with deltamethrin, fipronil, and fenithrotion, which are no longer considered bioaccumulators and are now in other criteria, which they were not in the previous list.

Changes in integrated pest management and staff

Among the main changes made by Brazilian companies in the integrated management of forest pests following FSC certification, increased security and storage of chemicals stood out, followed by increased monitoring and use of pesticide reduction targets. Better and more transparent forest management is the main motivating mechanism for forest certification of Brazilian companies (Araujo et al. 2009). A survey of US forest companies showed that the main changes caused by FSC certification were in environmental and forest management contexts (Moore et al. 2012). In certified Argentine and Chilean companies, the most important changes in forest management were related to more careful use of chemicals (Cubbage et al. 2010). Changes, such as the construction of shelters for storing pesticides, may seem simple at first glance but are of great importance for human and environmental safeties. Shelters prevent pesticides from coming into contact with soil and water, decrease the amount of obsolete pesticides (Dvorská et al. 2012), and prevent contact with non-target animals. Poisoning by pesticides is a major form of suicide in rural areas in some regions of the world (Mohamed et al. 2009), and in Brazil, 5075 cases of poisoning by agricultural pesticides were registered in 2011, with suicide attempts accounting for approximately 18 % of these cases (SINITOX 2011). An enclosed shelter helps prevent this social problem and prevents unnecessary exposure of workers and environment to pesticides.

Pest monitoring in Brazilian forest companies, mainly for leaf-cutting ants, reduces both the environmental impact caused by the indiscriminate use of pesticides and the costs of control, in addition to facilitating decision-making on whether to control or not. Monitoring can also generate other important information, such as data on the population dynamics of these pests and their impact on forest productivity, helping to define economic damage threshold levels for these pests (Souza et al. 2011; Zanetti et al. 2000a; Zanetti et al. 2000b). These are some of the reasons that FSC-certified forest companies have increased their interest in sampling and monitoring of leaf-cutting ants and in seeking alternative forms of control (Della Lucia et al. 2014). Certified companies are also adopting targets for reduced pesticide usage. This is desirable, but if poorly executed can result in adverse effects such as increased pest infestation and increased compensatory use of pesticides in the future.

Changes of social aspects of integrated forest pest management due to FSC certification were less common, with few companies claiming to have implemented them. This may be due to the fact that companies were adequately covered in this regard before certification, or due to compliance with state and/or federal laws, such as the restricted use of pesticides registered by MAPA and guaranteed labor rights.

The major changes to pest management included greater environmental security and lower risk caused by pesticides (e.g., through the use of pesticide shelters, monitoring, and specific procedures) and reductions in the amount of pesticides applied in plantations (e.g., reduction targets for insecticides and monitoring). While some FSC policies are negatively impacting integrated pest management in certified forest companies, positive changes can also be observed in improved environmental and social qualities in pest management.

Costs and impacts to integrated pest management as a result of certification

Most certified companies reported additional costs of integrated pest management associated with FSC certification, and that part of these increased costs was due to the increased need for employee training and in usage of products in accordance with FSC policies. In a survey of FSC-certified companies (plantations and native forests) in Chile, Brazil, the USA, and Canada, total expenditures associated with certification were around US$ 0.905/ha (Cubbage et al. 2009), less than half of the US$ 2.26/ha (n = 1) spent on changes in pest management due to FSC reported here and similar to the US$ 0.62/ha spent on actions related to requests for derogation of the chemicals mentioned above. In case of a permanent prohibition on these chemicals and in the absence of viable alternatives (which is the current scenario for Brazilian forestry), these costs could rise exponentially (e.g., the cost of controlling leaf-cutting ants could reach 75 % of the total cost of forest management) or even disrupt production in forest plantations certified by FSC. Companies with smaller plantations have higher relative costs generated by certification than bigger ones (Cubbage et al. 2009), and the same must be true in relation to pest management costs.

It may be advisable for the FSC to encourage increased use of sampling techniques and economic injury levels because these lead to a more rational use of insecticides, rather than outright prohibition of some of these chemicals, as alternatives to replace those chemicals in derogation are not currently available (Della Lucia et al. 2014). In addition, the FSC prohibits certain promising alternative techniques to control pests, such as the use of GMOs. Opportunities related to GMO eucalyptus, for example, are stalled due to the fact that most producers of this species are under FSC certification (Wingfield et al. 2013). This prohibition is negative for pest management and prevents certified companies participating in field research on the quality and biosafety of GMOs (Strauss et al. 2001a). The lack of viable alternatives permitted by FSC was the most important cost to certified companies mainly because of these prohibitions and also the perceived lack of a collaborative approach by FSC to these policies.

General satisfaction

A little more than half of respondents considered themselves dissatisfied or uncertain, perhaps because of the problems discussed above in relation to chemical prohibition and the lack of viable alternatives, especially for the control of leaf-cutting ants. Furthermore, over half of the companies agreed that the prohibition on these chemicals is a way of imposing a non-tariff barrier on the Brazilian forestry and that the lack of viable alternatives will increase production costs with greater expenditures and potential declines in productivity. This opinion is not new, since for almost a decade, developing countries have linked certification as a form of barrier to trade and expressed these concerns to the Committee on Trade and Environment of the World Trade Organization (WTO) and to the Conference on Trade and Development of the United Nations (Gulbrandsen 2005; Pattberg 2006). The WTO only accepts voluntary and non-discriminatory environmental certifications. In this regard, the FSC's prohibition of the only viable ways to control a pest that is restricted to certain regions could be seen as discriminatory. This aspect of certification needs to be investigated because in international standards, often some stakeholders are advantaged while others are disadvantaged. For example, early adopters of certification help to shape it to suit their technical and operational requirements, leaving the higher costs of change to those that certify later (Mattli and Büthe 2003). In the case of forestry, countries that have developed certification have shaped it to fit a totally different ecobiological reality to that of forest plantations in tropical areas. Reflecting this, many of the rules and prohibitions of FSC do not distinguish between local differences.

Despite apparent dissatisfaction with the prohibition on pesticides used to control leaf-cutting ants, more than half of the companies surveyed said that they would maintain FSC certification even if alternatives were not found after the prohibition of these chemicals. This shows that despite negative effects in relation to pest management, FSC forest certification has aspects (e.g., improvements in integrated pest management and in security of storage and use of pesticides) that bring greater overall benefits than the costs of chemical prohibition. The FSC has apparently failed to achieve one of its stated objectives (stop tropical forest deforestation) but has been successful in improving and implementing sustainable forest management (Rotherham 2011). It also can be said that it has assisted in promoting the adoption of integrated management of forest pests in Brazilian plantations.

Over a quarter of responding organizations indicated they would not maintain FSC certification in the scenario proposed above. In the USA and Canada, FSC-certified companies were more reluctant to maintain certification than companies certified by the Sustainable Forestry Initiative (SFI) that is affiliated with the PEFC program (Moore et al. 2012). The companies that responded that they would not maintain FSC certification would probably migrate to, or maintain, their existing PEFC certification (in the case of companies that have both certifications), a less restrictive system in relation to pesticide usage. Today, the differences between the FSC and PEFC are becoming smaller, and both aim towards similar goals, but supporters of the FSC tend to undermine the rival program (Moore et al. 2012; Rotherham 2011). The regulation of chemical pesticides and GMOs is perhaps one of the few differences between the two stamps (Moore et al. 2012). The PEFC was created in response to the rigid demands made by FSC (Auld et al. 2008), and these demands may also cause a future exchange of certification scheme by forestry companies. Why then would Brazilian FSC-certified forestry companies not migrate into a program that has fewer restrictions on pest management? The answer to this question may reside in the fact that FSC stamped products have strong appeal in the market, in addition to the strong export market focus of the forestry sector in Brazil. Unlike the situation in the USA and Canada, Brazilian companies consider international consumers very important when deciding to certify (Araujo et al. 2009).

Conclusion

This study provides an empirical contribution of the costs, benefits, and degree of satisfaction of forest companies on the impact of FSC certification on integrated pest management in Brazilian forest plantations. The FSC forest certification has increased the implementation of more sustainable techniques and actions in integrated pest management in Brazilian plantations, particularly by improving pest management and the security of storage and use of chemicals. In addition, there is now increased interest by companies in regard to pest sampling, monitoring, and evaluation of economic injury level and in stimulating the search for sustainable alternatives for use in pest management.

The continued maintenance of FSC forest certification by Brazilian companies may depend on whether the prohibition on the chemicals used to control leaf-cutting ants has long-term negative consequences on the management of these pests or not and if the negative consequences (or costs) outweigh the benefits. These benefits include an increased market share or premium prices for wood and wood products, something that Brazilian FSC-certified companies have not yet been able to achieve.

Application of oversimplified solutions, such as the prohibition of chemicals such as sulfluramid and the use of alternatives without the same efficacy for the management of leaf-cutting ants, will result in mismanagement of these pests and associated production losses and higher costs. This study demonstrates that the application of global standards for sustainable forest management may require adaptation to local realities. Data from the FSC used to prohibit sulfluramid are based on laboratory tests and almost no testing in Brazilian tropical forest plantations. Field studies are necessary to verify the actual environmental risk from the use of this chemical and to reduce uncertainty about its continued use. New insecticides that meet FSC requirements should be developed, but deadlines for derogation should be extended or the prohibition suspended, at least for sulfluramid, until a new viable product is developed and commercially available for the control of leaf-cutting ants.

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