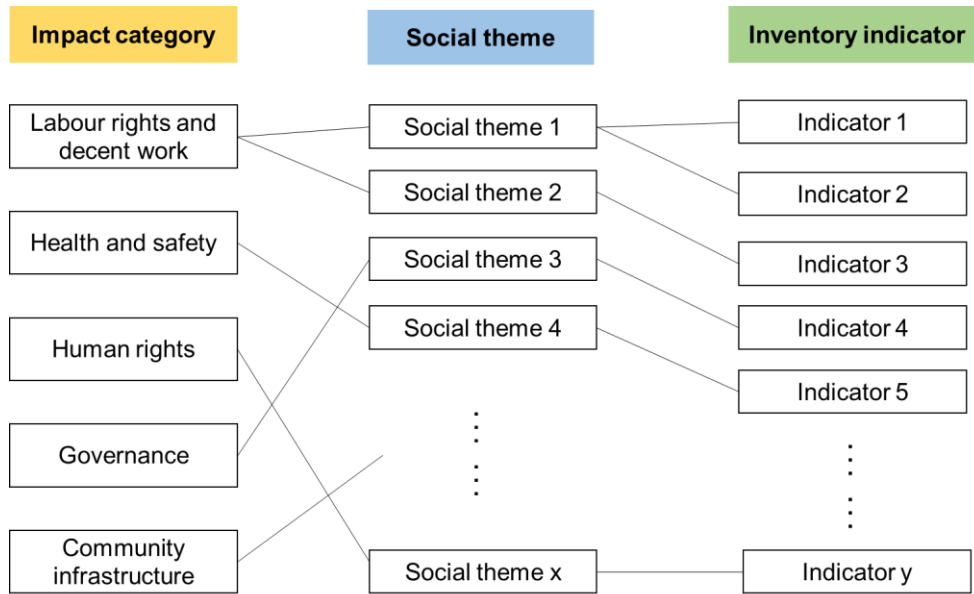
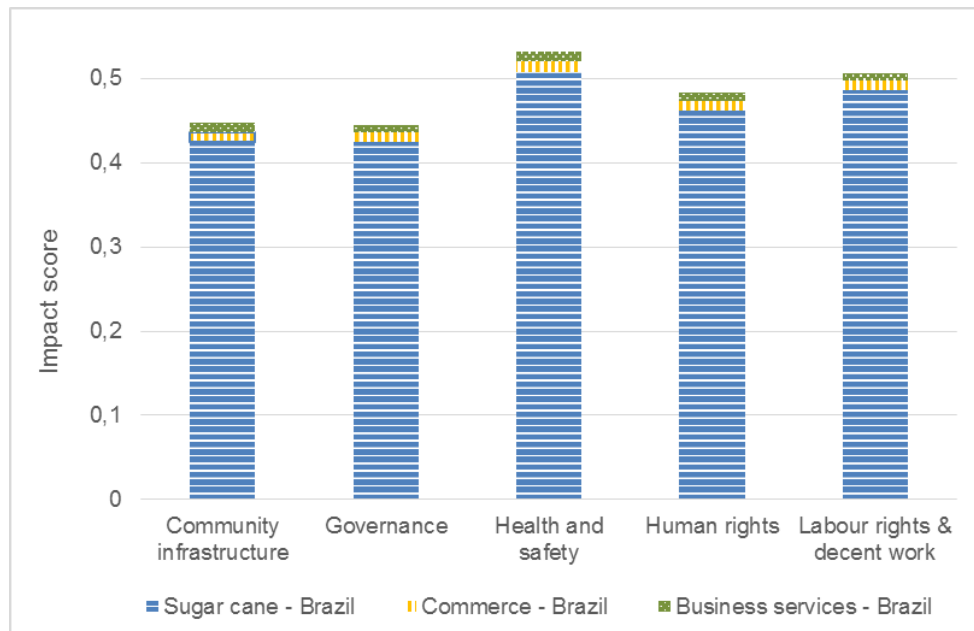


**Fig. 1** Assessment framework of Social Hotspots Database for a country-sector<sup>a</sup>



<sup>a</sup> Adapted from the UNEP/SETAC S-LCA guidelines (2009)

**Fig. 2** Aggregated Impact Scores of three country-sectors by impact category



**Fig. 3** Social themes identified most frequently with their coding frequencies

No.	Social Theme	Impact Category	No. of related samples	Coding Frequency (times)
1	Occupational health and safety	Health and safety	17	52
2	Local employment	Labour rights and decent work	19	35
3	Fair salary	Labour rights and decent work	14	31
4	Social benefits and social security	Labour rights and decent work	15	31
5	Access to material resources	Community infrastructure	10	19
6	Delocalization and migration	Labour rights and decent work	11	15
7	Forced labor	Labour rights and decent work	8	14
8	Contribution to economic development	Labour rights and decent work	10	14
9	Public commitment to sustainability issues	Governance	5	13
10	Equal opportunity and discrimination	Human rights	8	13
11	Safe and healthy living conditions	Health and safety	7	11
12	Freedom of association and collective bargaining	Labour rights and decent work	4	10

Identified as social hotspots in SHDB as well  
 Included but not identified as social hotspots in SHDB  
 Not included in SHDB

**Fig. 4** Comparison of social impacts of manual and mechanical sugarcane harvesting by social theme

Social theme	Manual harvesting	Mechanical harvesting
Health and safety		
Local employment		
Fair salary		
Access to material resources		
Delocalization and migration		
Public commitment of sustainability issues		
Safe and healthy living conditions		
Equal opportunity and discrimination		

Worse performance  
 Better performance

**Table 1** Impact categories and related social themes included in Social Hotspots Database

<b>Impact categories</b>	<b>Social themes</b>
Labour rights and decent work	<ul style="list-style-type: none"> <li>- Child labour</li> <li>- Forced labour</li> <li>- Excessive working time</li> <li>- Wage assessment</li> <li>- Poverty</li> <li>- Migrant labour</li> <li>- Freedom of association</li> <li>- Unemployment</li> <li>- Labour laws</li> </ul>
Health and safety	<ul style="list-style-type: none"> <li>- Injuries and fatalities</li> <li>- Toxics and hazards</li> </ul>
Human rights	<ul style="list-style-type: none"> <li>- Indigenous rights</li> <li>- High conflicts</li> <li>- Gender equity</li> <li>- Human health issues</li> </ul>
Governance	<ul style="list-style-type: none"> <li>- Legal systems</li> <li>- Corruptions</li> </ul>
Community infrastructure	<ul style="list-style-type: none"> <li>- Hospital beds</li> <li>- Drinking water</li> <li>- Sanitation</li> <li>- Children out of school</li> <li>- Smallholder vs. commercial farms</li> </ul>

**Table 2** Categories adopted in content analysis

<b>Impact categories</b>	<b>Coding themes</b>
Labour rights and decent work	<ul style="list-style-type: none"> <li>- Child labour</li> <li>- Forced labour</li> <li>- Working hours</li> <li>- Fair Salary</li> <li>- Freedom of association and collective bargaining</li> <li>- Social benefits and social security</li> <li>- Delocalization and migration</li> <li>- Local employment</li> <li>- Contribution to economic development</li> </ul>
Health and safety	<ul style="list-style-type: none"> <li>- Occupational health and safety</li> <li>- Safe and healthy living conditions</li> </ul>
Human rights	<ul style="list-style-type: none"> <li>- Equal opportunities and discrimination</li> <li>- Cultural heritage*</li> <li>- Respect of indigenous rights</li> <li>- Secure living conditions</li> <li>- Respect of intellectual property rights*</li> </ul>
Governance	<ul style="list-style-type: none"> <li>- Public commitments to sustainability issues*</li> <li>- Prevention and mitigation of armed conflicts*</li> <li>- Technology development*</li> <li>- Corruption</li> <li>- Promoting social responsibility*</li> </ul>
Community infrastructure	<ul style="list-style-type: none"> <li>- Access to material resources</li> <li>- Access to immaterial resources</li> <li>- Community engagement*</li> <li>- Fair competition</li> <li>- Supplier relationships*</li> </ul>

\*Social themes additional to those in Social Hotspot Database, based on recommendations from the UNEP/SETAC Guidelines (UNEP/SETAC 2009).

**Table 3** Country-sectors included after applying cut-off criterion of 1% and their shares of worker hours

<b>Country-Specific-Sector</b>	<b>Share out of total worker hours (%)</b>
Sugarcane, sugar beet (Brazil)	85%
Commerce (Brazil)	2.2%
Business services (Brazil)	1.9%
Bovine cattle, sheep and goats, horses (Brazil)	1.2%
Animal products (Brazil)	1.2%

**Table 4** Social Hotspots Index (SHI) of Country-Sectors in each impact category

	Community Infrastructure	Governance	Health and safety	Human rights	Labour Rights and Decent Work
Sugar cane, sugar beet (Brazil)	0.36	0.33	0.50	0.40	0.45
Commerce (Brazil)	0.39	0.33	0.50	0.39	0.40
Business services (Brazil)	0.39	0.33	0.50	0.34	0.29

**Table 5** Indicators with high and very high risk levels in sugarcane sector in Brazil in Social Hotspots Database

Social theme	Impact Category	Risk level	Indicators
Access to Hospital Beds	Community infrastructure	High risk	- Risk that there are too few hospital beds to support population
Smallholder v. Commercial Farms	Community infrastructure	High risk	- Characterization of large land holdings
Legal system	Governance	Very high risk	- Characterization of CIRI Independent Judiciary
		High risk	- Characterization of BTI Rule of Law
Occupational Injuries & Deaths	Health and safety	Very high risk	- Risk of fatal injury by sector
		High risk	- Risk of non-fatal injuries by sector
Occupational Toxics & Hazards	Health and safety	High risk	- Risk of loss of life by airborne particulates in occupation - Risk of loss of life years by asthma due to airborne particulates in occupation - Risk of loss of life years by chronic obstructive pulmonary disease due to airborne particulates in occupation - Risk of loss of life years by mesothelioma due to occupation - Risk of loss of life years by silicosis due to airborne particulates in occupation
Human Health (Communicable Diseases)	Human rights	Very high risk	- Risk of HIV - Risk of malaria
		High risk	- Risk of Dengue Fever - Risk of Leprosy - Risk of Tuberculosis
Indigenous Rights	Human rights	Very high risk	- Risk that indigenous people are negatively impacted at sector level
Gender Equity	Human rights	High risk	- Characterization of GGG - Characterization of GII
High Conflict Zones	Human rights	High risk	- Characterization of Heidelberg Barometer <sup>a</sup> - Overall Risk for High Conflict-increased if risk exists at sector level
Human Health (Non-communicable Diseases) and other health risks	Human rights	High risk	- Risk of dying from Malignant neoplasms - Risk of Obesity (BMI = 30 kg/m <sup>2</sup> ), Aged 15+, Females
Child Labour	Labour rights and decent work	Very high risk	- Risk of Child Labour in sector, Female - Risk of Child Labour in sector, Male - Risk of Child Labour in sector, Total
Forced Labour	Labour rights and decent work	Very high risk	- Risk of Forced Labour by Sector
		High risk	- Risk of Forced Labour in Country according to Qualitative Sources
Wage Assessment	Labour rights and decent work	Very high risk	- Risk of Sector Ave Wage being lower than Country's Minimum Wage - Risk of Sector Ave Wage being lower than Country's Non-poverty Guideline
Freedom of Association, Collective Bargaining, and Right to Strike	Labour rights and decent work	High risk	- Risk that a country lacks or does not enforce Freedom of Association rights
Labour Laws	Governance	High risk	- Risk that Country does not ratify ILO conventions by Sector
Migrant Workers	Labour rights and decent work	High risk	- Risk that a country has not ratified international conventions or set up policies for immigrants <sup>b</sup>

<sup>a</sup>The Heidelberg Barometer has three sub-indicators, counted separately here: i) number of conflicts; ii) maximum intensity of conflicts; and iii) change in conflicts.

<sup>b</sup> Risk that a country has not ratified international conventions or set up policies for immigrants has four sub-indicators, counted separately here: i) policy regarding the integration of non-citizens; ii) ratification of ILO convention No. 97 on migration for Employment 1949; iii) ratification of ILO convention No. 143 on migrant workers 1975; and iv) ratification of international convention on the protection of rights of migrant workers and their families, NY 18 Dec 1990.

**Table 6** Social hotspots identified by Social Hotspots Database (SHDB) and the numbers of indicators with high and very high risk levels

No.	Social themes	Impact category	High risk	Very high risk	Sum	Content analysis (Y-Yes; N-No)
1	Occupational Toxics & Hazards	Health and safety	5	0	5	Y
2	Human Health - Communicable Diseases	Human rights	3	2	5	N
3	High Conflict Zones	Human rights	4	0	4	N
4	Migrant Workers	Labour rights and decent work	4	0	4	Y
5	Child Labour	Labour rights and decent work	0	3	3	N
6	Legal System	Governance	1	1	2	N
7	Occupational Injuries & Deaths	Health and safety	1	1	2	Y
8	Gender Equity	Human rights	2	0	2	Y
9	Human Health - Non-communicable Diseases and other health risks	Human rights	2	0	2	Y
10	Forced Labour	Labour rights and decent work	1	1	2	Y
11	Wage Assessment	Labour rights and decent work	0	2	2	Y
12	Smallholder v. Commercial Farms	Community infrastructure	1	0	1	Y
13	Indigenous Rights	Human rights	0	1	1	N
14	Freedom of Association, Collective Bargaining, and Right to Strike	Labour rights and decent work	1	0	1	Y
15	Labor Laws	Governance	1	0	1	N

**Table 7** Inventories of social hotspots identified in content analysis

Social theme	Inventory
Health and safety	a) Sugarcane workers agree that they are exposed to high health risks due to agrochemicals use (Lehtonen 2010); b) Heavy workload: Cutting cane is a repetitive task, and workers often have to work under high temperature. Wounds caused by exhaustion, fatigue, spinal diseases, and high psychological stress are reported. Injuries and death records due to exhaustion are reported too (Junior et al. 2012; Luz et al. 2012; Priuli et al. 2014; Rocha et al. 2010); c) Pre-harvest burning is reported to be related to the increase of respiratory diseases, cardiovascular diseases, cancer and renal dysfunction (Santos et al. 2015); d) Requirements for protection equipment are considered well-regulated and implemented (Hermele 2011a; Rocha et al. 2010).
Local employment	a) Increasing mechanization rate of sugarcane harvesting is causing job loss, especially for low-schooling and unskilled workers (Guilhoto et al. 2002; Smeets et al. 2008; Macedo 2007; Moraes 2007; Moraes et al. 2015; Walter et al. 2011; Hall et al. 2009; Lehtonen 2010; ELLA 2012; Duarte et al. 2013; Viana and Perez 2013); b) Governments and the industry association have established training programs for the replaced workers (Amaral 2011); c) Demand for skilled labour as drivers, mechanics and technicians have increased (Duarte et al. 2013; Moraes 2007).
Fair salary	a) Sugarcane cutters were paid by productivity, and this payment method may lead to exhaustion due to heavy workload (Smeets et al. 2008; Martinelli and Filoso 2008; Walter et al. 2011; Hermele 2011a; Xavier et al. 2011; Luz et al. 2012; Duarte et al. 2013); b) Payment of workers in sugarcane industry in Brazil is documented to be well above minimum wages - two to three times of the minimum wage at the harvesting season (Smeets et al. 2008; Goldemberg et al. 2008; Walter et al. 2011; Rocha et al. 2010; Hermele 2011a); c) Income of workers in the Centre-South of Brazil is reported to be higher than the North-Northeast region (Macedo 2007).
Social benefits and social security	a) The number of formal workers has increased over the past decade. Sugarcane sector has a high rate of formal workers, reaching more than 80%. The Centre-South region provided more formal jobs than the North-Northeast region (Smeets et al. 2008; Macedo 2007; Moraes 2007; Martinelli and Filoso 2008; Walter et al. 2011; Moraes 2011; Viana and Perez 2013); b) Social benefits provided by sugarcane companies varied from one to another, but most of the companies are reported to comply with the regulations (Macedo 2007; Goldemberg et al. 2008; Walter et al. 2011; Hall et al. 2009).
Access to material resources	a) The area of sugarcane cultivation has increased considerably (Chaddad 2010; Xavier et al. 2011); b) Large producers occupy approximately 75% of the land, and the number of smallholder farmers has been declining (Goldemberg et al. 2008; Smeets et al. 2008); c) Agro-ecological zoning regulation has protected rainforest, wetland and “cerrado” (tropical savanna ecoregion of Brazil) (Chaddad 2010); d) Most of the companies provide accommodations for non-local workers, but poor housing and transportation conditions have been reported for migrant workers (Walter et al. 2011; Rocha et al. 2010); e) Most of the companies provide school, nursery centers and day care for workers and their children (Smeets et al. 2008; Walter et al. 2011).
Delocalization and migration	A large number of sugarcane workers are migrant workers from the North-Northeast to the Centre-South of Brazil to work at the harvesting seasons. They are mostly young male with low schooling, who are reported to have few job opportunities in their original regions. Poor living conditions are reported for these migrant workers (Macedo 2007; Moraes 2008; Moraes et al. 2015; Walter et al. 2011; Hall et al. 2009; Lehtonen 2010; Hermele 2011a; Junior et al. 2012; Duarte et al. 2013).
Forced labour	Cases of slavery labour are found in the literature (Smeets et al. 2008; Walter et al. 2011; Lehtonen 2010; Hermele 2011a; McGrath 2013).



(Table 7 - continued)

Public commitment of sustainability issues	Brazilian Sugarcane Industry Association (UNICA) has been actively engaged with government and international organizations to shape regulations, such as establishing the agreements of Green Protocol and National Commitment to Improve Working Conditions for Sugarcane Workers. UNICA has also proactively encouraged and helped members to improve their sustainability practices through sustainability reporting and certification following the frameworks of BONSUCRO, Global Bioenergy Partnership (GBEP) and Global Reporting Initiative (GRI). UNICA is one of the first agro-industry unions worldwide who has published GRI reports (Chaddad 2010; Hermele 2011b; Viana and Perez 2013; UNICA 2010; Moraes et al. 2015).
Contribution to economic developments	Sugarcane industry contributes significantly to the income of agro-business in Brazil and provides job opportunities at a relatively low cost. The municipalities with sugarcane production are reported to have better socio-economic indicators than municipalities without sugarcane production (Macedo 2007; Goldemberg et al. 2008; Walter et al. 2011; Chaddad 2010; Martinelli et al. 2011; Duarte et al. 2013; Machado et al. 2016).
Freedom of association and collective bargaining	Regulations and legal systems in Brazil ensure that workers have the rights for freedom of association and collective bargaining. Some authors have reported the active engagement of labour unions, while others found evidences of violations of labour regulations among migrant workers (Hermele 2011a; Macedo 2007; Martinelli and Filoso 2008; Moraes 2007).
Safe and healthy living conditions	Sugarcane pre-harvest burning emits a number of air pollutants. Particularly, the associated particulate matter emissions are reported to result in increasing health risks related to respiratory diseases in communities close to sugarcane plantations (Arbex et al. 2000; Arbex et al. 2007; Martinelli and Filoso 2008; Uriarte et al. 2009; ELLA 2012; Duarte et al. 2013).
Equal opportunity and discrimination	a) Very few females work as sugarcane cutters due to heavy workload. Cases have been reported that women are required to be sterilized to obtain the job (Hermele 2011a; Junior et al., 2012; Moraes et al. 2015; Smeets et al. 2008); b) With the increasing rate of mechanization, workers with low schooling are the most vulnerable population to lose their jobs; meanwhile, the number of female workers is expected to increase (Chaddad 2010; Duarte et al. 2013; Goldemberg et al. 2008; Moraes et al. 2015).