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Mineral production clusters evaluation through the sustainability matrix

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SÉRIE ESTUDOS E DOCUMENTOS

ISSN 0103-6319 ISBN 978-85-61121-43-3

SED - 75

Mineral production clusters evaluation through the sustainability matrix

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CETEM/MCT

2008

SÉRIE ESTUDOS E DOCUMENTOS

A Série Estudos e Documentos publica trabalhos na área mínero-metalúrgica. Tem como objetivo principal difundir os resultados das investigações técnico-científicas decorrentes dos projetos desenvolvidos no CETEM.

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Peiter, Carlos Cesar.
Mineral production clusters evaluation through the sustainability matrix / Carlos C. Peiter, Roberto C. Villas Boas. __ Rio de Janeiro: CETEM/MCT, 2008.

36p.:il

1. Produção mineral. 2. Cluster. I. Centro de Tecnologia Mineral. II. Villas Boas, Roberto Cerrini. III. Título. IV. Série.

CDD – 338.1

SUMÁRIO

RESUMO

São designadas como arranjos produtivos locais ou *clusters*, tal como definido por M. Porter, as aglomerações de numerosas empresas e instituições públicas em determinadas regiões geográficas ligadas por interesses e/ou cadeias produtivas comuns e complementares. O Brasil elaborou e vem implementando uma política pública para incentivar e desenvolver os arranjos produtivos, ou APLs, muito difundidos em alguns setores da economia interna , e dentre os setores escolhidos se encontra o setor de produção mineral.

A matriz de sustentabilidade, tal como descrita neste artigo, é uma ferramenta simples para elaborar diagnóstico qualitativo dos arranjos produtivos de base mineral com a finalidade de avaliar os aspectos importantes de sustentabilidade que são influenciados por variáveis que controlam as operações mineiras, por exemplo: capacitação dos trabalhadores e dos gerentes, preços dos minérios, disponibilidade de matéria-prima (minérios), financiamentos bancários etc. Este artigo demonstra a utilização da matriz de sustentabilidade como uma ferramenta para avaliar o impacto e os resultados da implementação de políticas públicas, bem como para avaliar as ameaças à sustentabilidade, mediante um exercício aplicado a um arranjo produtivo de rochas ornamentais no Brasil.

Palavras-chave
arranjo produtivo, rocha ornamental, sustentabilidade, matriz de sustentabilidade.

ABSTRACT

Clusters are geographic concentrations of companies and institutions in a particular field linked by commonalities and complementarities, as defined by M. Porter. Brazil released a public policy to incentive and build clusters and, amongst them, the mineral branch. The sustainability matrix, as described in this paper, is a simple tool applied by the authors to provide a qualitative diagnosis of mineral-based clusters in order to check aspects of sustainability that are influenced by variables that control the mineral operations such as, for example: the skills of workers and management; minerals prices; natural resource availability; bank loans; etc. This paper demonstrates the usefulness of the sustainability matrix as a tool for understanding the impact of public policies and threats to sustainability by highlighting the results obtained by applying it to a Brazilian natural stone cluster.

Keywords
cluster, natural stone, sustentability, sustentability matrix.

1 | INTRODUCTION

As pointed out by BRUNDTLAND [1] in her already classical book, a commitment to sustainable development means integration of policies and development strategies so as to satisfy current and future human needs, improve the quality of life, and protect the environment upon which we depend for life support services.

As for minerals resources there is a still open discussion on the degree to which they fit in, since not renewable. Notwithstanding, mineral resources are an integral part of any developed and modern industrial society. Thus, how to achieve a sustainable future, without the services they provide!

Again, BRUNDTLAND brings the answer to this: they need not to be renewable, in the sense that the biological systems are, to be sustainable. Or, lets put as this, several renewable species just vanished away, for one or the other reason, while no one single non-renewable has done so!

However, societies need to be able to track progress toward their sustainability goals, via some sort of indicators. In this way, Agenda 21 laid out actions to forward the goal of sustainability including a call for the development of indicators of sustainable development that could provide a basis for stages of the policy cycle, including decision making at all levels.

Indicators and indices package complex mineral information into understandable forms for stakeholders, decision makers and public use [2]. These mineral indicators must be useful as analytical, explanatory, communication, planning and performance assessment tools. Indicators help people understand the

complexities associated with mineral resource management policy decisions, such as the interconnectedness of physical and environmental systems and the inevitability of making tradeoffs among conflicting management policy objectives [3]. Thus, the information contained in indicators can contribute to public understanding of the state of the world and the potential consequences of fulfilling various objectives, i.e., they can facilitate social learning [4].

Process democracy is one of the most important cornerstones of sustainability and so, as important as is the set of indicators, the process of creating, implementing and monitoring the set of indicators is crucial [idem]. There are many possible processes for defining indicators for various sectors on different scales; recommendations and even requirements for the group defining the indicator set are similar. The conditions are: (a) shared ownership of process, (b) fair decision-making processes, (c) transparency and accountability, (d) adequate participation and representation, (e) a mechanism for future revision, (f) clear grievance procedure, (g) clear structure, and (h) audit ability [5].

Initiatives within the Canada, the European Union, Latin America, the United Kingdom, and the United States, among others, have made substantial progress in creating sets of meaningful sustainable development indicators for. Each process has been unique with regard to its background, methods, and goals, and the indicators for each reflect these differences. This is to be expected for several reasons. First, sustainability is a value-based concept [6]. Values are an expression of culture, history, experience, environment and geography, and necessarily differ across societies. People measure what they want to sustain; sustain those things they believe are important; and decide what is important based on their values. Second,

sustainability is a working concept, a process that focuses attention on existing social-environmental-economic realities and geopolitical constraints that are inherently different across societies and geopolitical regions of the globe. Finally, practical issues of data availability and collection costs necessarily drive the selection of indicators.

2 | BRAZILIAN POLICY SUPPORTING ARTISANAL AND SMALL SCALE MINING CLUSTERS

In Brazil, as in all Latin America, artisan and small-scale mining – ASSM, are mostly oriented towards high value minerals, gems and metals. Industrial minerals are receiving an increasing attention, lately. Amongst the 2,367 total mines that hold legal tenures in Brazil 1,706 (72.8 %) are small-scale operations [7]. Policy makers nowadays are closely following the overall contribution of ASSM to the Brazilian mineral economy due to the positive effects they bring on income distribution amongst poor communities. On the other hand, the generated social and environmental impacts are of great concerns, not only to the policy makers and government officials but also to the general Brazilian society.

Although difficulties still prevail, a major shift is in process and first results can be detected in many places of the country. The background conditions that pushed the federal and some regional governments to establish a more adequate relationship with ASSM are:

- A strong commitment of the present Federal Government to poverty alleviation and job generation.
- Natural and mineral resources weight considerably for a positive external trade balance.
- Micro and small enterprises are playing an increasing role in the economy of the country.
- New ASSM are activities, such as dimension and ornamental stones, are raising at high rates and spreading throughout the country.

As a response to these facts a new industrial policy was set, by the Federal Government, in March 2004 which contains, definitions and tools to render possible strong support to small and medium enterprises, in general, specially those located on the defined production clusters. The classical Porter´s definition of an industrial or production cluster [8] was slightly changed to render it more suitable to Brazilian SME´s conditions.

For the mineral sector, the possibility to promote ASSM was quite positive since new funding were proposed and created. Also, with the help of government and/or NGOs many mining communities might, from now on, change their ways of organization and production to reach better technical, market and socio- environmental standards. Another important fact was the renaming of such mineral sites. Before this new policy, almost all of them were named "*garimpos*", which bears an uncomfortable informality and even illegal mining practices. Many are now recognized as "mineral-based local clusters", or *arranjos produtivos locais de base mineral*, because proved to be socially and regionally essential activities supporting less wealthy communities.

3 | MINERAL BASED LOCAL CLUSTERS (APLS)[1]

Such mentioned new industrial policy, known as PITCE[2], determines the objectives and policy tools to enhance the small and medium enterprises (SME) competitive conditions, especially for those located on predefined clusters sites. A governmental working group evaluates and defines which clusters are able to enter the supporting programme. Four hundred sites were found suitable, where at least one of the working group agencies was developing some previous supporting activity.

There are clusters in almost all industrial sectors of the economy and many features such as size and number of enterprises or level of technological development can define them. Not only the Federal Government and its SME Support Agency, SEBRAE, are undertaking special programs, but many local state governments now have their own policies and activities for APL activities supporting.

Even before the new policy, the Brazilian Ministry of Mines and Energy has had a specific study on mineral clusters and selected 200 small-scale mining sites. Twenty-nine were considered as having good or very good conditions to improve their situations and raise their local communities' social and economical benefits. Figure 1 shows the location in Brazil of some clusters included in the prioritiy list.

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1 APL or *arranjos produtivos locais* are the economic clusters in the Brazilian policy definition (for details see http://www.redesist.ie.ufrj.br/).

2 External trade, technology and industrial policy – PITCE.

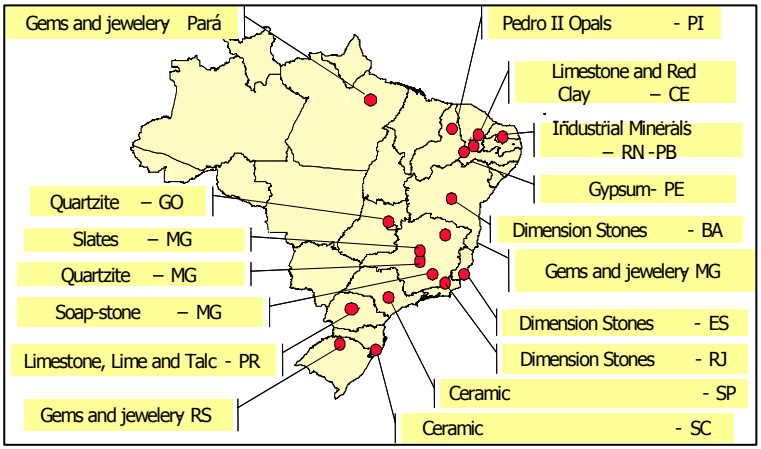

Figura 1. Mineral clusters through the Brazilian territory.

3.1 | Technological support to mineral clusters

Previous analyses pointed out some of the clusters weaknesses and many initiatives have been proposed and implemented to support most of the selected APLs, gathering contributions of high-level research and academic institutions throughout the country.

CETEM (Centre for Mineral Technology) was asked by the Federal Government to lead three mineral APLs communities organization: the APLS of natural stone of Santo Antonio de Padua (State of Rio de Janeiro), the limestone of Cariri region (State of Ceará) and the opal cluster at the city of Pedro II, State of Piaui, all three located on poor or very poor regions. To another two CETEM offered technical support: the soap-stone cluster at Minas Gerais and the ornamental travertine (marble) cluster of Ourolandia, State of Bahia.

An important step now is to evaluate if the political, legal, financial and technological support is effectively changing (or not) the clusters sustainability levels. As a contribution to set a suitable and less complex sustainability diagnosis for clusters, the authors suggest a methodology based on stakeholder consultation and opinion gathering, synthesized on a qualitative cross impact matrix, so called “sustainability matrix”.

3.2 | The sustainability matrix for cluster diagnosis

A bunch of sustainable indicators may be used on mathematical models to establish sustainability levels, but on the other hand it has to be taken into consideration that sustainable development is built over political commitments, on moral aspects and concepts as well, and some scientific knowledge, as stated by SHIELDS [3]. If we consider that representatives of the main stakeholders are conscious of their contributions to the cluster, have an adequate knowledge on how the cluster works and have the perception about what are positive contributions and negative impacts, then an average opinion amongst them should provide some direction for action for many purposes, for instance to evaluate if government aid programmes and policies are contributing, or not, to improve sustainable development. As a consequence, stakeholders consultation methodology may provide reliable diagnosis on the cluster sustainability situation. The sustainability matrix is a simple way to organize and present a qualitative diagnosis of mineral clusters regarding sustainable development[3].

[3] Internet search (Google) showed some useful applications of sustainability matrixes, but we did not find any focusing industrial clusters.

Table 1 shows the proposed matrix framework. The purpose is to evaluate the contribution, or the level of impact, that production factors pose to sustainability aspects. On the first row the sustainability dimensions are set (social, economical and environmental). On the first column a set of production factors or aspects are placed in order to evaluate the cluster organization and needs. For the present case study the following were chosen.

- **Raw material/ore:** the main reason for a mineral cluster to exist
- **Technology (production) model:** it is the most widespread production processing path/flow sheet adopted by companies at the cluster
- **Labour skill level:** reflects the average level of education and/ or technical skills of working people in the cluster
- **Entrepreneurial model:** must reflect usual production/ trade organization procedures at play
- **Government intervention/aid:** reflects the ways institutions and government agencies intervene in the cluster
- **Finance institutions participation:** encompasses all credit and loan organizations contributing to the cluster (banks, development agencies, etc).

Table 1. Sustainability matrix for the Pádua natural stone cluster, year 2000.

Production factors	Sustainable aspects			Factor contribution
	Social	Economic	Environmental	
1. Raw material	(+) wide spread and available	(+) Unique material	(-) Excessive losses	1+
2. Technology (production model)	(++) Labour intensive	(-) Operation costs with low market prices stoped new development	(- -) Promoter high environmental impacts	1-
3. Labour skill level	(-) Low skilled workers	(0) Workforce cannot improve quality of products	(0) Low skills also promote impacts	1-
4. Entrepreneurial model	(+) Better salaries in a jobless region	(-) Low trade management skills	(-) Low environmental concern	2-
5. Government intervention/aid	(-) Only seldom workers safety monitoring	(+) Support from the industrial agencies	(+) Provincial mineral and environmental agencies acting permanently	+
6. Finance institutions participation	(0) Special lab our funds exist but still do not	(-) Loans almost inaccessible due to high interest rates	(0) Technological support well kept by agencies	1-
7. Sustainable aspects and overall evaluation	2+	2-	3-	3-

Fonte: Peiter, 2000.

The evaluation of each intersection of a production factor (column) with the three aspects of sustainable development (row) combined the opinion of individual stakeholders' with a

consensus opinion reached with the assistance of a facilitator. The compilation of these views was a consensus appraisal and an average grade that reflected those views. The authors used a scale of five grades that ranged from a high negative impact (minus 2 or - -) to a high positive contribution to the respective sustainability aspect (plus 2 or + +). The sum of the grades per row represented each production "factor contribution" to the overall sustainability of the cluster, while the subtotals for each of the three vertical columns represented the situation for each of the three aspects of sustainable development for the cluster. The authors are of the view that to provide an easier overview of sustainability levels an overall range of sustainability grades might extend from –36 to +36. This range of grades could be further split into 6 classes of 12 grades each and with one grade being neutral: three negative grades (-36 to -25, -24 to -13, -12 to -1); a neutral grade (zero); and three positive grades (+1 to +11, +12 to +23, +24 to +36). Based on a scale of sustainability that ranges from the worst grade (-36) to the highest grade (+36) the overall evaluation obtained from the above analysis is a grade of minus three (-3) or a slightly unsustainable situation.

3.3 | Sustainability matrix on a mineral cluster: a case study

Some characteristics of the mineral cluster are:

- **Raw material:** natural building stone (gneiss gris and yellow).
- **Location and operational aspects:** Santo Antonio de Pádua, 250 km N of Rio de Janeiro; at least 80 stone quarries and about 70 stone tiles production units (stone tiles cutting facilities) generating 4,000 jobs.

— **Some historical data:** since 1999, a persistent work is being arried out by a group of institutions[4], involving the participation of the majority of the mineral producers and local community. Such joint and interdisciplinary initiative was a unique opportunity to test a multi-stakeholder approach to a mineral cluster formed by several small producers, most of them artisan and informal, operating without legal tenures and licenses. The Padua cluster diagnosis and the multi stakeholder approach were reported by PEITER (2000) and PEITER, VILLAS BOAS & SHINYA (1999).

Picture 1. Typical quarry at Padua cluster.

4 The mineral producers union SINDIGNAISSES, DRM, FEEMA and CODIN (which are local state government institutions), CETEM and INT (R&D federal institutions), FIRJAN, SEBRAE and SENAI (Industrial sector and job training institutions), and the Federal Public Attorney responsible for diligent application.

Picture 2. Typical tile cutting shop at Padua cluster.

Picture 3. Stone saw-cutting mud tailings recovery.

Picture 4. The mortar factory using tailings as input at Padua cluster.

The important conclusions were:

- The “entrepreneurial model” factor is considered to be the most negative to impact sustainability. The main reason is the selfish way quarry owners behave promoting price drop and fostering further increase on informal activity to avoid taxation.
- The “raw material availability” factor, on the other hand, has a positive effect, mainly due to the widespread and homogeneous type of stone (a sort of gneiss), which gave opportunity to several poor people to start its own quarry or to grant work in a jobless region.
- The “finance institutions” factor, amongst them commercial and development banks, as well industrial or job aid agencies, did not offer suitable conditions for small producers to apply even for small loans. One more reason to keep informality.

- The “evaluation of the sustainability aspect” (columns) grade summed up shows that the environmental aspect was the worse, specially due to the bad grades given on the technology model, which revealed the lack of knowledge on good practices in quarry exploitation, thus generating high losses of resources favoured by the need to lower operating costs.
- The “economic aspect” was also revealing a threat since stone price fell down more than 50 % due to the raise of stocks offerings made by extensive informal production and to the lack of actions in getting producers together to discuss ways to solve their common problem.
- The “social aspect”, in terms of jobs generation, was the one that showed the best evaluation and the main reason for the government institutions and agencies to keep trying to organize and help in many ways quarry owners and workers.

As an overall evaluation, taken from a scale for sustainability situation that goes from the worst grade (-36) to the very best (+36), the result obtained grade -3 (minus three) indicates a slight unsustainable situation. On the other hand, certainly the grade was not bad enough that might not be reversed.

How is the situation in 2007, after 6 years after? Many activities were performed during those years to support such a cluster and to address solutions against its main weaknesses. New economy policies emphasized the importance of clusters in the country’s economy and proposed special financial aid and technical support.

Other stakeholders joined, not only to offer solutions but also to pose new challenges, such as the one by the Federal Public Attorney who asked the provincial environment agency to start immediately a protocol to set out a public commitment with mineral producers to improve environment features levels, otherwise their quarries should be shut down and the owners prosecuted under the Environmental Federal and Minerals Law and Code. As a reaction to this threat, the producers association and Union, known as SINDIGNAISSES, under the leadership of a new president, started negotiations to set adequate targets and better conditions to be followed by the small producers. In the meantime, support projects and negotiation initiatives started to help the producers to get to know what it should be done in every quarry and every stone cutting shop facility to follow the Public Attorney/ Union agreement.

On the other hand, a recent provincial industrial development policy created lower taxation and other subsidies for companies to build their facilities in the Padua cluster region.

One important result came from one building materials company, devoted to prefabricated mortars, which is installing a factory that is going to recover one of the tailings produced by the cutting shops, mixing it to the mortar composition and almost eliminating totally this kind of polluting material. The use of very fine particulates that come out of the grinding of stone was developed by CETEM and INT and disseminated through most of the Padua´s stone saw-splitting facilities, promoting 90% water recycling and a sharp decrease of solids release on brooks and small ponders used also by cattle farmers.

Other successful initiative was performed to improve trade and commercialisation skills to promote exports. A group of producers are now partners to meet exports scale contract needs that would not be feasible without a consortia formation.

To evaluate how those initiatives have interfered in the Padua natural stone cluster the new stakeholder consultation was conducted and twenty people, among technical staff from government agencies, clusters subject experts and the president of the mineral producers union, were asked to give their opinions. From them, six gave their complete views by fulfilling an individual matrix. From those, two of them participated in the first exercise and four have been deeply involved in technical projects and/or in political aspects regarding the cluster. Other two experts offered comments on specific topics since they had not a broad view from the cluster.

The contributions were put together on a larger matrix framework in order to reflect the mean stakeholders opinion and translating it into a grade. The previous 2000 year matrix was very useful since made possible to compare specific features inside each sustainability aspect according to the related production factor.

Table 2 shows the “Year 2007” matrix together with the “Year 2000” results to provide easier comparison.

3.4 | Comments on the “Year 2007” Matrix results

The previous list of improvements and/or supporting activities were well reported by stakeholder’s contributions and carefully transferred to 2007-year matrix. The overall “sustainability value” increase indicates a significant positive shift in the cluster sustainability situation.

The matrix reveals that almost all factors underwent positive changes, while only factor 1 kept unchanged. The main push clearly came from the government/private institutions intervention and cluster supporting projects. Despite the minor influence, “finance support” and “entrepreneurial model” factors are closely connected and are expected to be the factors that will soon improve the sustainability indicators in the cluster due to present day initiatives undertaken by development agencies and the Union of the producers.

The “Year 2000” overall result shows 3- grade meaning that the cluster was at a “slight unsustainable level”. The “Year 2007” result (8+) revealed a positive trend in cluster development towards sustainability, despite still requiring several steps before reaching a truly sustainable situation. Three sustainability aspects showed positive trends but the environmental was the one that undertook more improvements in the stakeholders’ opinion. On the other hand, the social aspect kept the main contribution (4+) to the overall sustainability result showing that jobs in the mineral sector still are the better alterative for wealth distribution.

The “economic aspect” has to be seen in a broader way, since the natural stone production is connected to housing, buildings and infrastructure sectors on which recent Brazilian growth rates were very low, what reflected on the low stone selling prices in the domestic market. Exports are another alternative to trade but still very modest if compared to other similar clusters, such as the slate one in Minas Gerais state.

Table 2. Sustainability matrix for years 2000 (blank) and 2007 (shaded)

Production factors	Sustainable aspects			Factor contribution
	Social	Economic	Environmental	
1. Raw material	(+) Wide spread and available	(+) Unique material	(-) Excessive losses	1+
	Many areas were legally required by few companies reducing availability for new small miners Negativa change (0)	Unique material what still does not improves market prices. No change (+)	Extensive diagnosis made for every quarry and saw facility disclosure the problems and show possible solutions for obtaining environmental licensing. Positive change (0)	1+
2. Technology (production model)	(++) Labour intensive	(-) Operation costs with low market prices stoped new developments	(- -) Promoter high environmental impacts	1-
	Still labour intensive Unchanged (++)	Introduction of few technologies did not changed profitability yet. Slight positive change (0)	Environmental performance is improving through negotiations and enforcement for obtaining operational licenses. Tailings new technology recycling caused a positive impact. Positive change (-)	1+

Production factors	Sustainable aspects			Factor contribution
	Social	Economic	Environmental	
3. Labour skill level	(-) Low skilled workers	(0) Workforce cannot improve quality of products	(0) Low skills also promote impacts	1-
	Workers stays low skilled but a the Quarry Training School will operate soon. Positive change (0)	Stays unchanged (0)	Stays unchanged (0)	(0)
4. Entrepreneurial model	(+) Better salaries in a jobless region	(- -) Low trade management skills	(-) Low environmental concern	2-
	Some advances were made trough management training while salaries are almost unchanged (+)	Management training and the formation of an export consortium brought positive results. Slight positive change (-)	Much more environmental concern due to the requirements of the Environmental Performance Agreement signed. Slight positive change (0)	(0)

Production factors	Sustainable aspects			Factor contribution
	Social	Economic	Environmental	
5. Government intervention/ aid	(-) Only seldom workers safety monitoring	(+) Support from the industrial agencies	(+) Provincial mineral and environmental agencies acting permanently	1+
	Government support succeeding on keeping jobs. Health/safety will improved because are included in the Environmental Performance Agreement (0)	Government developing agencies are providing special conditions and subsidies to SMEs to operate in the region (++)	Federal Attorney, the Environmental and Mineral Agencies implemented diligent work (++)	4+
6. Finance institutions support	(0) Special labour funds exist but still do not support workers	(-) Loans almost inaccessible due to high interest rates and informality	(0) Technological support well kept by some of the gov. agencies	1-
	New investments are creating jobs. Slight positive change (-)	Special loan conditions are being offered to SME. Slight positive change (0)	Special loans can only be taken by SMEs that have signed the Environment Agreement Slight positive change (+)	2+
Sustainability aspects and overall evaluations	**2+**	**2-**	**3-**	**3-**
	4+	**2+**	**2+**	**8+**

4 | CONCLUSION

The sustainability matrix is a heuristic model that provides a good appraisal on a cluster situation regarding sustainable development concepts.

Although it works very well for an individual cluster analysis, it may not be useful for a comparison among several clusters. The consultation procedure would be weakened by the fact that it relies on individuals or groups of people “expertise”, which may vary from cluster to cluster.

The result obtained in this paper will help to bring more focus to those production factors that need more attention in order to produce a better balance of their contribution and aiming to enhance local sustainable development.

5 | ACKNOWLEDGEMENTS

We are in great debt with the following experts and colleagues, who kindly sent opinions and suggestions to the stake holder consultation: Oscar Hue, Gilberto Calaes, Flávio Erthal, João Batista F. Lopes “Patinho”, Rosana Coppede and Luis A. Barros.

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