Environmental Indicators to assist Sustainable Intensification implementation in Espírito Santo, Brazil

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Abstract

Family agriculture is essential to economic development, poverty reduction and food security, therefore, world organizations research ways to provide steady and sustainable agriculture, such as Sustainable Intensification. In this sense, there was attempts to develop indicators suitable to agri-environmental diversity. Thus, this project's aim is to identify environmental indicators to assist SI, focusing on family farming and potentially measured at catchment scale. The proposed indicators range from soil's characteristics to water issues. Ultimately, the process of proposing indicators is a technical issue, but also a political process, where the conflicting approaches to achieve sustainable development must be weighted and discussed.

INTRODUCTION

Since the Green Revolution, around the 1950s, the worldwide agricultural production has greatly increased. Meanwhile, the predicted world population to 2050 is approximately 9 billion, so more people will need to be fed, which must happen improving productivity, because increasing agricultural land area is not feasible. Furthermore, food waste reduction and food security must be in the same level of importance of productivity improvement, considering the yield need to reach and efficiently feed the population equally (The Royal Society, 2009).

Therefore, Sustainable Intensification (SI) was proposed to promote a radical reformulation of the whole food production chain. The term itself was introduced to literature around 1990 as an alternative to solve issues faced by Sub-Saharan agriculture, which suffered from lack of investments and infrastructure, political corruption and economic uncertainty. These caused an ill oriented agricultural intensification, low yields, environmental degradation and food insecurity (Garnett et al., 2013; Garnett and Godffray, 2012; Pretty, 2011).

In this context, Godfray (2014) emphasizes that SI is a goal rather than an agricultural practice, and to reach it, both ancient low tech and innovative high tech shall be applied. Anyhow, agricultural intensification has usually been associated to major environmental impacts, so the challenge is to find appropriate methods and agricultural techniques in the face of resources scarcities, satisfying the standards to protect biodiversity, climate, soil, water and landscapes (RISE, 2014).

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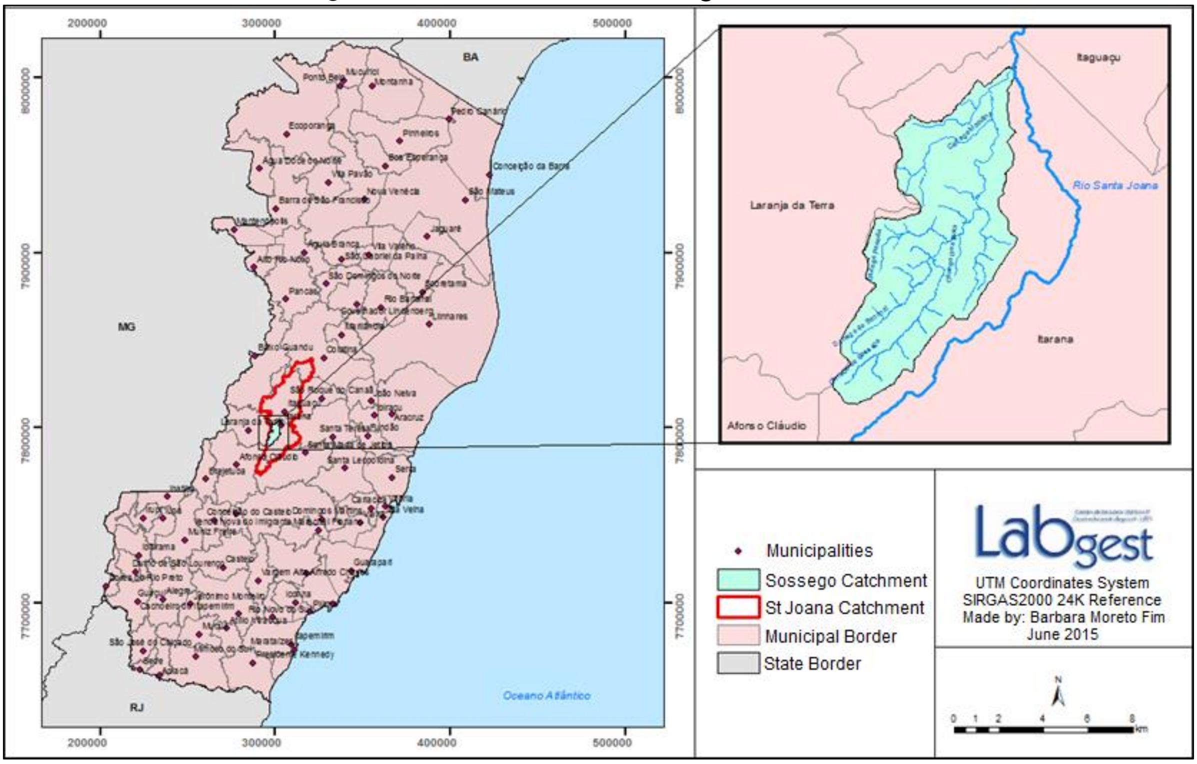
The Brazilian Water Resources Policy exhorts that it is fundamental to recognize the public domain of water, its multiple usage and management at river basin scale. However, each sector prioritizes its own interests, the standard government management is done at municipalities scale, and the Family-based Agriculture Policy is managed at a property scale. Since those policies are not discussed together at a regular basis, water resources allocation to agricultural production has somewhat became a problem. Considering Brazilian agriculture's complexity, the progress made so far in crops diversity and productivity, although admittedly relevant, will hardly guarantee competitiveness and sustainability in the near future (EMBRAPA, 2013).
Presently, in Espírito Santo State, Brazil, some initiatives encourage change in the production processes and better technologies that aim to increase yield, but, only if economically feasible, intend to achieve sustainability. Thus, in this case, sustainability is a possibility, not a priority, conflicting with SI, where both productivity and environmental sustainability must be observed.
The best way to assess sustainability is to use indicators. Since Eco-92 there have been efforts in international institutions to propose and validate sustainability indicators. Amongst these, the Environmental Indicators for Agriculture, elaborated by OECD, assess a variety of aspects on agricultural sustainability and have been replicated in many countries (Fernandes and Woodhouse, 2008). However, in terms of SI environmental indicators, there are a few, and practically none at catchment scale.
Therefore, the project aims to identify, analyse and select environmental indicators to assist Sustainable Intensification practices in Espírito Santo, Brazil, focusing on family farming, with potential to be measured and assessed at catchment scale, contributing to the conceptual model envisioned on the project "Participative governance and collaborative integrated management at catchment scale for sustainable intensification of small holder family farming", in partnership with government secretaries, executing agencies and research institutions.

METHODS

Initially a survey was realized to identify sustainability indicators from scientific and technical literature which were proposed and validated by researchers on the area, but not specific to Sustainable Intensification.
It was observed that the majority of indicators are elaborated for property scale, except the one developed by Batista Junior (2012). Despite sustainable intensification being mainly an agricultural issue, the management of water resources required at farming production must be made at catchment scale.
Moreover, Godfray (2012) emphasizes that applying sustainable intensification should be a matter of increasing overall production maintaining the system's sustainability, but not necessarily increasing production at each property; some locations are better suited to increase production than others, thus it would be beneficial to verify production increase at the catchment as a unity.
Therefore, the methodological model better suited for the present research proposition is a combination of agri-environmental indicators already validated for family-based agricultural properties, but also applicable on the catchment scale.
Additionally, there were meetings with the research group of the project "Participative governance and collaborative integrated management at catchment scale for sustainable intensification of small holder family farming", where was discussed the

potential application of SI indicators in Espírito Santo, as well as defined that the short term indicators had immediate data, while the long term ones would need approximately five years of data consolidation.
Furthermore, interviews were led with collaborators from INCAPER[3] and Geobases and also family-farm owners of the municipalities of Itarana and Itaguaçu, which are part of the Sossego Catchment, an usual pilot catchment at the university, shown in Figure 1. Those were an opportunity to discuss the catchment's representability to Espírito Santo and the possibility of providing data.

Figure 1 – Location of Sossego Catchment



RESULTS AND DISCUSSION

Human activities, such as agriculture and economic development, and changes to these activities as in plans, programmes and policies, are linked to natural systems' ability to absorb the effects of human activities on the environment and determine environmental impacts, both harmful and beneficial, and the long term sustainability of the ecosystem. Figure 2 shows the main components and linkages in sustainability analysis, providing a spatial dimension, which involves property, catchment, municipality, province, country, until the global scale; a temporal dimension, in terms of period of time; and a societal dimension, covering economics, socio-cultural, aesthetics values and attitudes as well as the environment (OECD, 1999).

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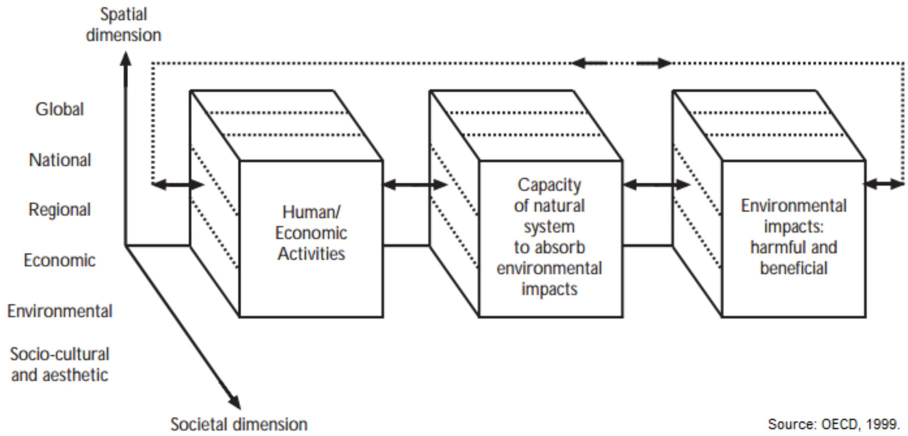

Figure 2 – Main components and linkages in sustainability analysis

Some recent researches propose the adoption of state and response indicators. The state indicators report the data of a resource present situation, but it is not clear if the situation is improving or depleting. Meanwhile, the response indicators show how this resources and being affected by human activities. Accordingly, both are needed to characterize and asses the environment (OECD, 1999; De Muner, 2007).
Based in these characteristics Fernandes and Woodhouse (2008) combined DFID's[4] Sustainable Livelihoods Framework (SLF) and OECD's[5] Driving Force-State-Response (DSR) as shown in Figure 3, and organized workshops with local stakeholders to determine agri-environmental indicators, shown in Table 1.

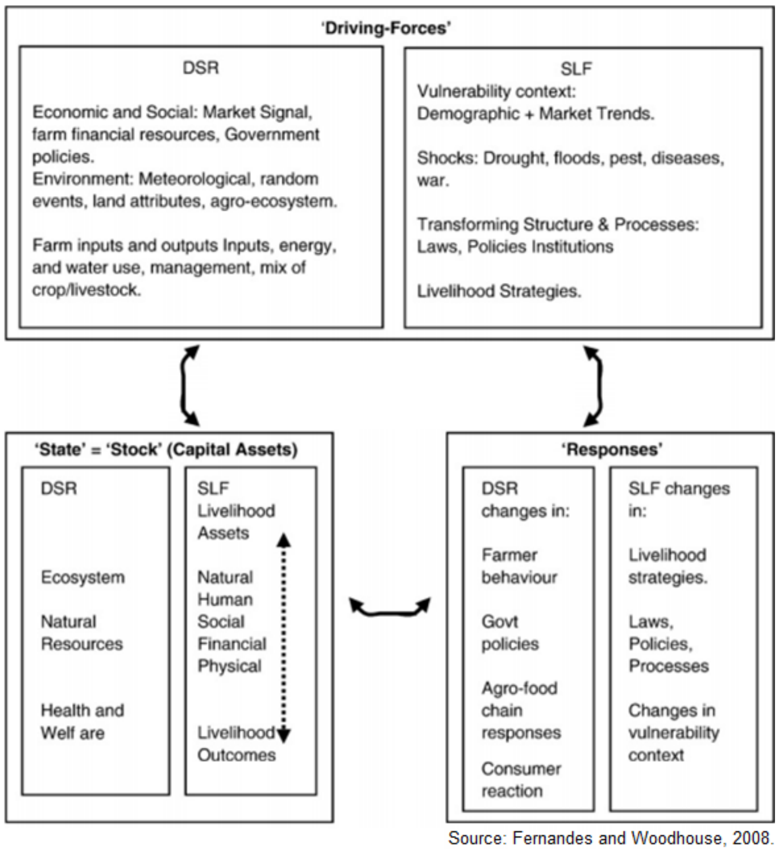

Figure 3 – SLF and DSR frameworks combined

4 Department for International Development, UK
5 Organisation for Economic Co-operation and Development

Table 1 – Indicators selected by Fernandes and Woodhouse
Source: Fernandes and Woodhouse (2008).

Indicator	Livelihood asset category	Sustainability dimension	Scale	Value	
				“ecol”	“non-ecol”
OMC organic matter conservation	Natural	Ecology	Farm	5.02	4.99
IEC inverted energy consumption	Natural	Ecology	Local	8.27	4.61
ISI inverse spatial impact	Natural	Ecology	Regional	5.49	4.70
PAI índice de abstenção de pesticidas	Human	Ecology	Farm	6.57	3.68
ASC average schooling	Human	Society	Local	4.91	5.03
ISMA health and education index	Human	Society	Regional	3.90	3.90
TN technical networking	Social	Society	Local	12.5	1.66
CRED credit access	Social	Society	Local	7.92	4.28
PGI ‘progressive Gini index’	Social	Society	Regional	4.02	4.02
EI electricity index	Physical	Society	Regional	7.0	7.0
INI infrastructure index	Physical	Economy	Local	5.29	4.70
PCR physical capital replacement	Physical	Economy	Farm	6.04	4.71
FGM farm gross margin	Economic	Economy	Farm	4.63	5.10
TPI total per capita income	Economic	Economy	Local	4.73	5.08
IPI input price index	Economic	Economy	Regional	4.3	5.7

De Muner (2011) proposed a compendium of indicators to assess socioeconomic and environmental sustainability of productions systems of Arabica coffee and family farmers who adopt good management practices. Overall, 24 indicators were identified and grouped into seven sustainability attributes: productivity, stability, resilience, reliability, adaptation capacity, equity and self-management, as shown in Table 2.

Table 2 – Relation between attributes, critical issues, diagnostic criteria and strategic indicators to assess sustainability
Source: De Muner (2011). (continue)

Attribute	Critical Issues	Diagnostic Criteria	Indicators
Productivity	Low yield	Efficiency	1 – Physical yield
	Produce inferior quality	Quality	2 – Produce quality
	Low price and high production cost High energetic cost	Efficiency	3 – Economic balance 4 – Energy balance
Self-management	Low level of education	Education	5 – Education level
	Inefficient property management	Self-management	6 – Management level
	Dependency on external input	Self-suffiency	7 – Level of internal use of inputs
	Dependency on financing		8 – Efficiency of bank loan usage
	Dependency on external food		9 – Fraction of food consumed by the family, produced in the farm (%)

Table 2 – Relation between attributes, critical issues, diagnostic criteria and strategic indicators to assess sustainability
Source: De Muner (2011). (conclusion)

Attribute	Critical Issues	Diagnostic Criteria	Indicators
Stability, resilience and reliability	Usage of only one variety Little diversity in crop association Little natural vegetation Little crop diversity	Vegetal biodiversity	10 – Genetic diversity 11 – Number of species cultivated 12 – Natural vegetation 13 – Level of crop diversity
	Losses caused by pests Soil degradation Inadequate management of organic matter Crop inadequate fertilisation Inadequate usage of pesticides	Environmental vulnerability and resources conservation	14 – Crop health (pest occurrence) 15 – Soil and water conservation 16 – Level of organic matter management 17 – Nutrient availability and soil fertility management 18 – Preservation against pesticides pollution
	Economic dependency on only only product Organic fertilisers low availability and usage	Economic vulnerability	19 – Income diversity 20 - Organic fertilisers availability and usage
	Low participation of farmers in associations	Vulnerability and low participation	21 – Level of farmers' affiliation and frequency at meetings and assemblies
Adaptability	Low level of innovation and applied technology	Innovation capacity	22 – Capacity of adoption of appropriate low consumption technologies
Equity	Labour employment and availability Low integration of production processes and decision making	Labour generation and participation	23 – Labour search 24 – Familiar integration and decision making

Ferreira et al. (2012) presented an integrated system to assess economic, social and environmental performance to aid rural properties management. The system is called Agroecosystems Sustainability Indicators (ISA), which are composed by 23 indicators as shown in Table 3. Apart from being useful for farmers, the system can generate data to aid the decision-making process at a public management level, identifying socioeconomic and environmental vulnerability, strengths and weaknesses of agroecosystems, all at a sub-catchment scale.

Table 3 – Description of seven sub-indexes and 23 indicators
Source: Ferreira et al. (2012).

Sub-indexes	Indicator
Economic balance	1 – Accurate productivity and selling price 2 – Income profile and diversification 3 – Patrimonial evolution 4 – Level of bank debt
Social balance	5 – Basic services available 6 – Food security around properties 7 – Schooling/Courses directed to agricultural activities 8 – Quality of generated employment
Rural property management	9 – Property management 10 – Data management 11 – Waste and effluent management 12 – Workplace safety and pesticides usage management
Soil productive capacity	13 – Soil fertility
Water quality	14 – Superficial water quality 15 – Groundwater quality 16 – Risk of water contamination by pesticides
Production system management	17 – Areas with soil in degradation stage 18 – Level of adoption of conservationist practices 19 – Level of conservation of inner and outer roads
Agricultural landscape ecology	20 – Level of conservation of native vegetation 21 – Permanent Preservation Areas (APPs) 22 – Legal Nature Reserve (RL) 23 – Agricultural landscape diversification

In addition to indicators focused on agricultural production and management, it was identified an Indicator of Susceptibility to Drought (ISFS), applied to the Baixo Guandu Catchment, in Espírito Santo. This indicator was developed by the Institute for Strategic and Economic Reseach of Ceará to be applied at State's level. This indicator's use at catchment scale was innovative, therefore some modifications were necessary to fit to the Guandu River, as adjustments to the beginning and ending of the rainy season and parametrization of the seven sub-indicators, which are equally weighted (Batista Junior, 2012).
Ultimately, the selected indicators better suited for sustainable intensification in family-farming properties in Espírito Santo State, potentially measured at catchment scale are shown in Table 4, which also displays the information needed for each indicators and if they are to be applied at short or long term, considering the immediate availability of data.

Table 4 – Indicators better suited for SI in Espírito Santo
Source: elaborated by the author

Indicators	Informations	Source	Term
Soil's agricultural aptitude	Agricultural aptitude map for Espírito Santo State.	Batista Junior (2012).	Short term
Natural soil's vulnerability to erosion	Maps of geomorphology, pedology, rainfall intensity, slope and soil erodibility.	Ferreira et al. (2012).	Short term
Susceptibility to extreme events	Measured by the Indicator of Susceptibility to Drought with the Atlas of Vulnerability to Floodings.	Batista Junior (2012).	Short term
Level of forest cover	Percentage of the catchment covered by forests.	De Muner (2011).	Short term
Level of Permanent Preservation Areas (APP) recovery	APP recovery in a given period of time.	Ferreira et al. (2012).	Short term
Energy usage by productivity	Ratio between the energy usage and the farm's productivity.	De Muner (2011).	Short term
Rainfall distribution	Historic average of rainfall on catchment/region.	Batista Junior (2012).	Short term
Water quality	Water quality in superficial water bodies given by BOD and Water Quality Index.	Ferreira et al. (2012).	Long term
Superficial water availability	Water bodies' flow rate.	Fernandes and Woodhouse (2008).	Long term
Level of adoption of conservationist practices	Percentual of properties where conservationist practices are adopted.	Ferreira et al. (2012); De Muner (2011).	Long term
Pesticides usage by productivity	Ratio between the pesticides usage and the farm's productivity.	Ferreira et al. (2012)	Long term
Water usage by productivity	Ratio between the water usage and the farm's productivity.	Fernandes and Woodhouse (2008).	Long term

A recurring opinion amongst the interviewed collaborators was that the rural sustainability is reliable on water availability, which is a limiting factor for agricultural production, thus, it should be measured and controlled. Another issue is farmers' dependency on both governmental and private organizations, who sometimes impose strict standards and guarantees, and show a lack of communication by not making data available for partners.

Nevertheless, it was emphasized that maps and geographical interfaces are available with hydrography, terrain, geology, geomorfology, pedology, vegetation, land cover, rainfall, climatic zones, natural zones amongst other data. Some of these maps are

made with interpolated data or mathematical models because there aren't stations covering all hydrological and climatic regions.
Agricultural aptitude combined with land use and cover are essential to identify adverse locations to agriculture that even so have high occurrence of land use to this end, marking areas more susceptible to difficulties and probably less resilient (Neves, 2010; Batista Junior, 2012). Thus, it is commendable a crop adequacy to soil management, to avoid excessive usage of pesticides and fertilizers (De Muner, 2011).
The rainfall distribution is especially relevant to agricultural activity for, even if the trend is statistically normal, irregular distribution throughout the year could qualify an agricultural drought, causing yield loss (Suassuna, 2011 apud Batista Junior, 2012).
Physical and climatological indicators may be combined to other socioeconomic factors to identify locations that are more susceptible to extreme events, such as droughts and floodings. Besides, that could be aggravated by disorderly land occupation, river banks silting, riparian deforestation and soil impermeability, so it is important to identify these areas to prevent or assist the consequences of the extreme events (Neves, 2010; Batista Junior, 2012; IEMA, 2013).
These indicators of susceptibility and vulnerability to extreme climate events were chosen because they are the inverse measure the systems resilience, which indicates the natural resources possibility to recover after events that cause impact both to agriculture and environment. In fact, nature is always capable of adapting to adverse conditions imposed by causality, but some systems might take longer, and sometimes is not possible to predict how certain events will affect nature (Garnett et al., 2013).
Even so, a productive system's resilience may be enhanced with practices of soil and water conservation and preservation. Some researchers defend the adoption of conservationist practices, such as crop rotation, intercropping, crop-livestock integration, natural fertilisers, natural pest control, amongst others (Ferreira et al., 2012; De Muner, 2011; Kassam et al., 2011; Rigby et al., 2001).
Furthermore, the level of recuperation of Permanently Protected Areas and vegetation cover indicate farmer's adequacy to environmental legislation, essential to assess compliance to mandatory preservation and protection of rivers and water sources (Ferreira et al., 2012; De Muner, 2011). Apart from being a refuge and food source to insects and crop's predators, keeping those populations controlled, forest are fundamental for biodiversity, to avoid soil's erosion and to maintain water sources (Nicholls, 2001).
These water sources are important to improve agricultural productivity, but must be available at acceptable standards in quantity and quality, according to directives and legislation. Thus, it is necessary to measure water availability, assess quality of both superficial and ground water, searching for ways to improve the parameters, if necessary (Ferreira, 2012; Ochola, 2003).

CONCLUSION

Throughout the research, a diversity of indicators to different purposes were identified. One was specific to sustainable intensification, to assess production and environmental impacts, but not enough variables to assess soil and water. Others more focused on sustainable management of agriculture, these with many variables to assess soil conditions but that underestimated other issues impacts on land management.
Also, Fernandes and Woodhouse (2008) presented complete and validated indicators, where the specificities of each case could be inserted with field data; and De Muner

(2011) made a very specific and complete research, but that could be more widely applied to other crops in Espírito Santo. Therefore, the indicators suggested in the present paper fulfil the role of searching the literature for validated sources while presenting an innovative combination of socioeconomic and environmental aspects that had not yet been approached in sustainable intensification. It also contributes to the research and indicators proposition stage required to develop the conceptual model for the project "Participative governance and collaborative integrated management at catchment scale for sustainable intensification of small holder family farming".

Furthermore, it is observed convergent perception, although not necessarily identical, on involved stakeholders. Institutions that have a closer approach to farmers tend to consider sustainability in agriculture as the farmer's social and economic self-sufficiency. Meanwhile researchers and environmental ONGs members are more focused on ecological and natural resources issues.

Ultimately, it can be highlighted that the process of elaborating and proposing indicators is not only a technical issue, it is also a political process, in which the conflicting priorities of embracing every opinion to achieve sustainable development must be weighted, assessed and discussed.

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