EMERGY SYNTHESIS 5:
Theory and Applications of the Emergy Methodology

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General Model for On-line Emergy Analysis of Agricultural Systems

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ABSTRACT

This paper proposes the construction of tables for emergy synthesis of agricultural systems using internet resources. The general model considered for these tables can be used for simple agricultural systems like chemical farming but also for complex systems as organic, agroecological and forestry-cattle-agriculture systems. The construction of tables was possible due to a research on XML (extensible markup language) and XLST (extensible style-sheet language transformation) technologies. The XML documents were used to hold the data of the inputs resources, outputs products and additional data of farming systems. A XSLT file was used to process the data, calculate the emergy flows and indicators and to present the results as tables in browsers. Besides that, it was made an effort to recover Transformities values for agricultural inputs in emergy literature. The emergy analysis and its indicators consider the renewability fraction of materials and services from economy, the infrastructure used and its depreciation and the payment of loans. A dynamic web page was developed using the JSP (Java Server Pages), Struts Framework and MySQL Database. The web page permits users to modify the data (quantity of each resource used and the quantity of products and their chemical composition and price). The web page ("Emergy Table") provides a powerful tool to obtain the emergy indicators of a farming system and to take decisions to improve its performance. In the next stage of this research the gas emissions and their capture will be considered.

INTRODUCTION

The Internet has become the most important tool for exchange information and knowledge. This study proposes the construction of a dynamic web. In this web page users can modified on-line the tables for emergy synthesis of agricultural systems. This web page shows the emergy indicators as result and it can be visualized very easy and fast and it is very important to make decisions to improve the quality and performance of the systems.

The dynamic web page was developed using the JSP (Java Server Pages), Struts Framework, MySQL Database and XML and XSLT technology.

XML AND XSLT

The extensible markup language (XML) was developed by the XML Working Group formed under the auspices of the World Wide Web Consortium (W3C) in 1996. XML documents are made up of basic units called "elements" that follow a set of restrictions specified on an independent specification called Document Type Definition (DTD) (Bray et al., 2004).

XML is becoming the standard data exchange format among Web applications, providing interoperability and enabling automatic processing of Web resources. An XML document is a hierarchically structured and self-describing piece of information, and consists of simple or atomic elements or complex elements (Abiteboul et al., 2000).

The XML documents can easily be transformed to a webpage by means of the extensible stylesheet language transformation (XSLT). It specifies the presentation of XML documents by describing how their instances are transformed to an XML document that uses a formatting vocabulary, such as HTML, that can be interpreted by any standard browser (Clark, 1999).

XML DEVELOPMENT

The XML documents were developed using the same structure proposed by Ortega et al. (2006). The XML files hold the main information about the agriculture systems and the inputs and outputs flows. The information of agricultural systems stored in XML files are: resource type, renewability factor, amount used, units of measure, unit conversion factors, solar transformities and the emergy flows calculated. A XML document is formed by elements and child elements. The Figure 1 shows the element RENEWABLE and its child elements CODE, ITEM, REN, QUANTITY, UNITS, FACTOR, TRANSFORMITY and EMERGY. The renewable resources data are stored in the element RENEWABLE. The other resources are stored in the elements NONRENEWABLE, MATERIAL and SERVICES. These elements have the same structure of RENEWABLE element, and these elements are the most important to the emergy evaluation. The description of each element is shown in Table 1.

The XSLT document was developed to process the data and show the result tables in an Internet Browser. The XSLT basically get the values stored in the xml documents, process these values and show the results in tables. To calculate the renewable emergy flow the XSLT multiplies the elements REN, QUANTITY, FACTOR and TRANSFORMITY, and to calculate the nonrenewable emergy flow the XSLT multiplies (1-REN), QUANTITY, FACTOR and TRANSFORMITY.

Florida Agricultural Systems

In Emergy Folio #4, Brandt-Williams (2002) presents emergy evaluations of 22 agricultural commodities raised in the state of Florida, U.S.A.. The 22 products are presented in this order: bell pepper, cabbage, corn (sweet), cucumber, eggs, green beans, lettuce, orange, peanuts, pecans, potatoes, tomatoes, watermelon, alligator, beef, corn(grain), milk, oats, soybeans, sugarcane, cotton, Bahia grass. Figure 2 shows the system diagram used to represent Florida agricultural systems.

The XML documents created adopt the same standard; meaning that all files have the same structure in relation with inputs and outputs characteristics. The resources are: sun, rain, evapotranspiration, net topsoil loss, fuel, electricity, machinery, lime, pesticides, potash, phosphate, nitrogen, feed grain, feed livestock, human labor and services from economy. The products data are: mass (wet), moisture, carbohydrates, lipids, protein and price (wet product).

Only one XSLT document was built to process the 22 XML. This XSLT document can process all the XML documents because they follow the same standard. The XSLT document process the calculations of emergy diagnosis and transforms the XML document to a HTML document that can be visualized in a browser. The web page contains two tables that show the resources and product's data,

```
<RENEWABLE>
  <CODE>R1</CODE>
  <ITEM>Sun</ITEM>
   <REN>1.0</REN>
  <QUANTITY>6350000000</QUANTITY>
  <UNITS>J/m2/year</UNITS>
  <FACTOR>10000</FACTOR>
  <TRANSFORMITY>1</TRANSFORMITY>
  <EMERGY>6.3500000000</EMERGY>
 </RENEWABLE>
```

Figure 1. *Element RENEWABLE and its child elements*

Table 1. Description of each element

Element	Description
CODE	Each resource has a code: Ri (renewable), Ni (non renewable), Mi (material from economy) and Si (services from economy)
ITEM	The resource's name.
REN	The renewability fraction of each resource.
QUANTITY	The quantity used in the system.
UNITS	The unit.
FACTOR	Conversion factor.
TRANSFORMITY	The transformity value.
EMERGY	The emergy value.

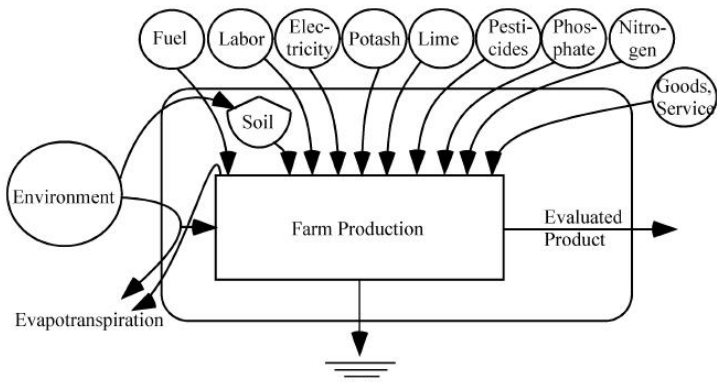

Figure 2. *Diagram of Florida agricultural system.*

and three more tables with the processed results. Files can be obtained from http://www.unicamp.br/fea/ortega/em-folios/ or asking for the author by e-mail.

Tables 2 and 3 show how bell peppers production data is presented on the browser. Table 4 shows the inputs classification, the equations used, and the aggregate flows. Table 5 shows the output data and Table 6 shows the equations used to calculate the emergy indices (transformity, renewability, emergy yield ratio, emergy investment ratio, and emergy exchange ratio) as well as the calculated values for these indices.

Apple production

Three different XML documents were created for three apples systems (organic, familiar and intensive) studied by Francescatto (2007). Each XML archive is processed by a specific XSLT file and the emergy methodology used consider the renewability fraction of materials and services from economy according to Ulgiati et al. (1994), Ulgiati et al. (2005), Ortega et al. (2005). These systems are more complex than Florida agriculture system due to the use of more than 25 resources.

The development of these XML files spent long time because it needs a specific XSLT file for each XML file. To solve this problem, a standard XML document for complex systems like organic, agroecological and forestry-cattle-agriculture systems was created in the next step.

General XML

A standard XML was developed mixing mainly the inputs of Francescato (2007) (apple systems) and Albuquerque (2006) (forestry-cattle-agriculture systems). This new XML has a large number of inputs:

Table 2. How the resources data of bell pepper are presented on the browser.

Code	Item	Quantity	Units	Conversion Factor	Transformities (sej/unit)	Emergy flow E13 sej/ha/yr
R1	Sun	6350000000	J/m2/yr	9200	1	5.8
R2	Rain	1.3716	m3/m2/yr	4.59E11	30240	190.5
R3	Evapotranspiration	54300000000	J/m2/yr	1	25910	140.7
N1	Net Topsoil Loss	8500	kg/ha/yr	904176	123984	95.3
M1	Fuel	57984	litres/ha/yr	960610	110880	617.6
M2	Electricity	208	KWH/ha/yr	3600000	268800	20.1
M3	Machinery	0	kg/ha/yr	1	1.12E13	.0
M4	Lime	0.00	kg/ha/yr	1	1.68E12	.0
M5	Pesticides	131	kg/ha/yr	1	2.52E13	330.1
M6	Potash	172	kg K/ha/yr	1	1.85E12	31.8
M7	Phosphate	52.7	kg P/ha/yr	1	3.70E13	195.0
M8	Nitrogen	44	kg N /ha/yr	1	4.05E13	178.2
M9	-	0	-	0	0	.0
M10	-	0	-	0	0	.0
S1	Human Labor	1200	hours/ha/yr	1308125	4.50E6	706.4
S2	Services from economy	2110	US$/ha/yr	1	2.70E12	569.7

Table 3. How the products data of bell pepper are presented on the browser.

Output data			Caloric value	
Mass (wet)	**28000**	Kg/ha/year		
Moisture	**93.5**	%		
Carbohydrates	**63**	%	17000000	J/kg
Lipids	**11**	%	39000000	J/kg
Protein	**26**	%	24000000	J/kg
Price (wet product)	**0.5**	US$/kg		

Table 4. The inputs classification, the equations used, and the aggregate flows calculated for bell pepper

Inputs classification	Equation	Aggregated flows x E13 sej/ha/yr
Renewable resources from Nature	R=Max(Renewables)	140.69
Non renewable resources from Nature	N=Sum(Non renewables)	95.29
	I = R + N	235.98
Materials from Economy	M=Sum(Materials)	1372.86
Services from Economy	S=Sum(Services)	1276.09
	F = M + S	2648.95
Emergy used	Y= I + F	**2884.93**

Table 5. The output results for bell pepper.

Output results Bell Pepper (USA, 1981)	Value	Units
Total dry mass	**1820**	Kg/ha/year
Energy of product	**386.57**	E10 J/ha/year
Sale	**14000.00**	US$/ha/year
Emergy of Sale	**37.80**	E13 sej/ha/yr
Real value of product	**10684.91**	Em-US$/ha/yr

Table 6. The emergy indices for bell pepper.

Emergy Índices	Equation	Value
Transformity (sej/J)	Tr=Y/E=Emergy/Energy	**7462.92**
Transformity (sej/kg)	Tr=Y/M=Emergy/Dry Mass	**15.85 E12**
Renewability	Ren=(100)*(R/Y)	**4.88%**
Emergy Yield Ratio	EYR=Y/F	**1.09**
Emergy Investment Ratio	EIR=F/I	**11.23**
Emergy Exchange Ratio	EER=Y/sem	**0.76**

- 10 renewable items
- 4 nonrenewable items
- 61 materials items
- 16 services items

The construction of this table takes a long time due to the research of the transformities.

This standard XML only need one XLST file to process the data. The emergy analysis and its indicators consider the renewability fraction of materials and services from economy, the infrastructure used and its depreciation and the payment of loans. To show the importance of the renewability fraction the result table shows the emergy indicator when the renewability fraction is consider and the original indicator without considering it. The data of Francescato (2007) for the 3 apples production and the data of Albuquerque (2005) for 4 forestry-cattle-agriculture systems of Colombia were used to test the new XML model. Table 7 shows the aggregated emergy flow to this XML model Table 8 shows the emergy indicators calculate to the forestry-cattle-agriculture systems El Rodeo (Albuquerque 2006).

There is a great difference between the indicators values when the renewability fraction is considered. This shows the importance of considering the renewability fraction for system like organic, agroecological and forestry-cattle-agriculture.

Table 7. The aggregated emergy flow to the general XML model.

Inputs classification	Equações
Renewable Resources from nature	R=R1+R2+...+Ri
Nonrenewable Resources from nature	N=N1+N2+...+Ni
	I = R + N
Materials from Economy	M=M1+M2+...+Mi
Materials from Economy (Renewable)	Mr=Mr1+Mr2+...+Mri
Materials from Economy (Nonrenewable)	Mn=Mn1+Mn2+...+Mni
Services from Economy	S=S1+S2+...+Si
Services from Economy (Renewable)	Sr=Sr1+Sr2+...+Sri
Services from Economy (Nonrenewable)	Sn=Sn1+Sn2+...+Sni
Infrastructure (Depreciation)	IF=IF1+IF2+...Ifn
Payment of loans	EMP = EMP1+EMP2+...EMPn
	F = M + S +IF +EMP
	Fr = Mr + Sr
	Fn = Mn + Sn +IF +EMP
Emergy used	Y= I + F

Table 8. Emergy indicator for El Rodeo system.

Emergy indicators	Equations	Values	Original indicator
Transformity (sej/J)	Tr=Y/E=Emery/Energy	**222636**	---
Transformity (sej/kg)	Tr=Y/M=Emergy/Dry mass	**5.12** E12	---
Renewability(%)	Ren=(100)*((R+Fr)/Y)	**40.87%**	**33.74%**
Emergy Yield Ratio	EYR=Y/(Fn+IF + EMP)	**1.79**	**1.59**
Emergy Investment	EIR=(Fn+IF+EMP)/(R + Fr	**1.37**	**1.87**
Emergy Exchange Ratio	EER=Y/EmS	**0.82**	---
Emergy Loading Ratio	ELR=(N+Fn+IF+EMP)/(R+Fr)	**1.45**	**1.96**

WEB PAGE

A dynamic web page was developed to allow the online calculation of emergy indicators of agricultural systems. Java Server Pages (JSP) technology, Struts Framework and MySQL Database were used in this work.

Figure 3 shows a diagram that represents the process. The user can access the web page from your personal computer. The JSP pages get data from users and read data from the database. After that, the data are processed and a JSP page with XML tags is created. This page uses the specifications of XSLT file to show the results to the user.

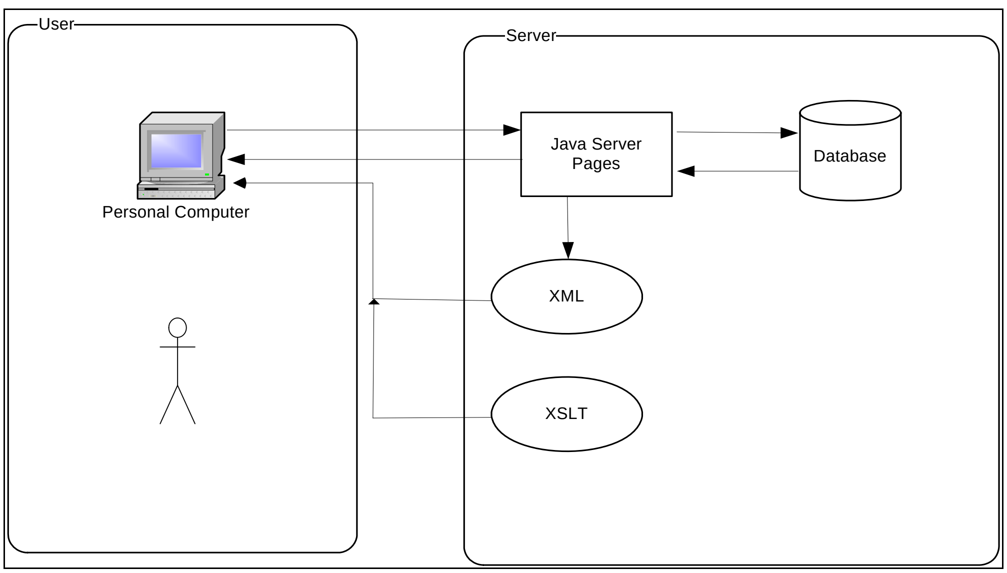

Figure 3. *Diagram of the web page process.*

Figure 4*. Main menu of the web page.*

Currently, the users can choose 2 systems: (a) Florida agriculture (Folios #4); (b) 3 different apple production (organic, familiar and intensive). Users have to sign up to access the system. On the web page users can visualize the original tables, modify and save a new table or open, edit and delete a saved table. The internet address for the English version is:
http://leiaserver.fea.unicamp.br:8080/web/login.jsp. Figure 4 shows the main menu of the web page.

CONCLUSIONS

The XML documents developed are a powerful tool for the emergy diagnosis of agricultural systems because it holds all the information about the system and presents the emergy indicators. The general XML model is better than the specifics XML tables mainly because the general table can be used for any system and this type of XML file requires only one XSLT file to process and show the results. It decreases the development time considerably.

Results obtained were satisfactory because they were in agreement with the results obtained by Francescato (2007) and Albuquerque (2006). The result tables of these systems show the emergy indicators when the renewability fraction is considered and without considering this factor. This result shows the importance of this modified methodology for these systems.

The XML document can be available for a great number of people through the Internet, and the users can visualize the emergy indicator of their system on a very easy way. The web page created actually permit modify and visualize the data of simple chemical farming system (Florida agriculture) and 3 specific Brazilian systems. In the next step, the general XML table will be introduced and it will permit the diagnosis of complex systems like organic, agroecological and forestry-cattle-agriculture on-line.

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