EMERGY PERSPECTIVES ON THE ARGENTINE ECONOMY AND FOOD PRODUCTION SYSTEMS OF THE ROLLING PAMPAS DURING THE TWENTIETH CENTURY

By

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by

Maria Cecilia Ferreyra

To my beloved parents Mabel Valcarlos and Roberto Ferreyra

and

my dear husband Richard Hayman

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Agricultural production in the Rolling Pampas of Argentina during the 20th century was characterized by the low use of external inputs. This tendency changed during the 1990s with the widespread adoption of technological innovation in the region. Macroeconomic policies implemented in Argentina in the same decade, emphasizing free market and deregulation, contributed to the selection of more efficient and cost-effective farming methods. In this context, the sustainability of food production in the Rolling Pampas is becoming a concern.

The purpose of this research was to use Emergy Accounting as a quantitative measurement of the ecological sustainability of agricultural production in the Rolling Pampas during the 20th century. An alternative, ecological interpretation of the history of the Argentine economy was also

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attempted. For that purpose, emergy evaluations of modern and historical agricultural systems and of the economy of Argentina were conducted. Emergy balance of payments resulting from international trade and the international debt of Argentina were also evaluated. Results were compared with past evaluations of other countries and agricultural systems.

The emergy analysis of the Argentine economy throughout the 20th century showed the influence of macroeconomic policies on sustainability.

Argentina started the century relying mostly on the use of renewable energy, with nonrenewable energy increasing its importance as the economy developed.

As an exporter of commodities (oil, minerals, agricultural products), Argentina is providing buyers more emergy than she receives in exchange. In emergy terms, Argentina had already paid its external debt by 1985. In 1996, the accumulated emergy value of total debt service represented 2.9 times the emergy of the total debt stocks.

Liberal economic theory and trade liberalization have led to an increase in the productivity of the agricultural sector, but has also increased the dependency of farmers on external energy inputs. Policies towards the agricultural sector should encourage the more sustainable among the possible options. Besides adaptation of foreign technology to the local conditions, public research should seek alternative, environmentally sound solutions. Emergy accounting, a methodological tool that attempts to balance humanity and environment, constitutes a useful tool for the evaluation of such policies.

CHAPTER 1 INTRODUCTION

Statement of the Problem

One of the main characteristics of agricultural production in the Rolling Pampas of Argentina throughout the 20th century was the low use of external inputs (Diaz Alejandro, 1970; Balze, 1995; Programa de Servicios Agricolas Provinciales [PROSAP], 1997; Viglizzo *et al.*, 2001). However, this tendency changed during the 1990s, when intensification began to redefine the Pampean agriculture (Figure 1.1). This farming "revolution" consisted principally of adopting different technologies, such as fertilizers, pesticides, complementary irrigation, and specific no-tillage machinery (PROSAP, 1997).



Figure 1.1. Agricultural intensification in the Pampas (Source: National Institute of Agricultural Technology [INTA], 1998).

A transformation of this magnitude cannot be understood in isolation. The economic policies implemented under the presidency of Carlos Menem (1989-1999), which emphasized free market and deregulation, contributed to the selection of more efficient and cost-effective farming methods (PROSAP, 1997). As a result, there is a trend in Argentina towards large-scale agricultural operations that parallels the North American model that produces highly technified monocultures (Quiñones, 1998; Pizarro, 1998; Obschatko, 1998). It is within this context that the long-term prospects for sustainable food production in the Rolling Pampas are becoming a concern.

The purpose of this research is to use Emergy Accounting as a quantitative measurement of the ecological sustainability of agricultural production in the Rolling Pampas during the 20th century. As such, it is intended as a contribution towards present and future challenges for the region, ones that must include not only productivity but also resource conservation as their imperatives. An alternative, ecological interpretation of the history of the Argentine economy will also be attempted. The ultimate goal is to add to the discussion of sustainable development in Argentina, and to the evaluation of national and regional policies and management practices towards that direction.

Emergy Accounting

Strategies towards sustainable development require appropriate assessment methodologies. *Ecological economics*, a transdisciplinary field of study

that focuses on the relationships between ecological and economic systems, offers such an integrated approach (Folke *et al.*, 1994). One of the most important research issues in ecological economics is natural resource valuation. Traditional economic analysis does not include environmental degradation in performance evaluations. Moreover, it does not take into account the contributions of nature to human economies (Odum, 1994). As described by Brown and Ulgiati (1999), these contributions encompass renewable energies (sunlight, tide), resource flows (fuels, wood), and environmental services (waste assimilation, aesthetic gratification). However, "money is only paid to people and never to the environment for its work" (Odum, 1996, p 55).

Emergy Accounting is a science-based valuation system that incorporates both environmental and economic values in a single measure: *emergy* (Odum, 1996). Emergy represents all the direct and indirect energies consumed in the production of goods and services, including not only fossil fuel inputs but also the work of nature (Figure 1.2).

Emergy Accounting constitutes a valuable tool for assessing the ecological performance of countries and states. By allowing the valuation of human and natural capital on a common basis, it offers an alternative for the inclusion of environmental goods and services in systems of national accounts.

Emergy analysis has also been proposed as a methodology for the assessment of agricultural sustainability within its ecological dimension

(Stachetti *et al.*, 1998; Lagerberg, 1999). Inputs to food production systems include environmental energies from both renewable sources and non-renewable storages from past biosphere production (Stachetti *et al.*, 1998). Therefore, accounting for all contributions from nature becomes a necessary step towards the implementation of sustainable agricultural systems.

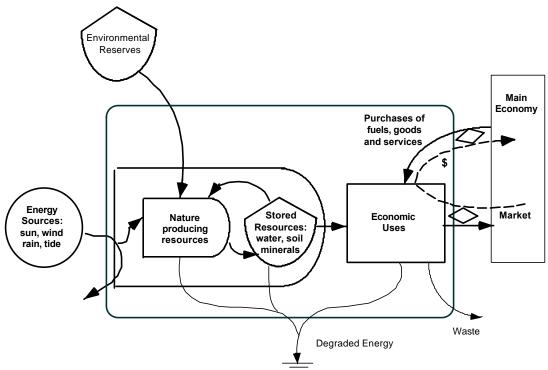


Figure 1.2. Systems diagram of the environmental-economic interface (Source: adapted from Odum, 1996, p. 59).

The Argentine Case

Argentina, the eighth largest country in the world, constitutes an interesting case of study for economists and sociologists as well (Figure 1.3).

Located in South America, the poor economic performance of Argentina during the second part of the 20th century has been considered something of a paradox (Figure 1.4). This perception is reinforced by the fact that the beginning of that century found Argentina's economic development equal to that of some developed countries, as shown in Table 1.1 (Ferrer, 1967; Vitelli, 1999). To a great extent, the causes for this stagnation have been explained in terms of the economic policies undertaken during that period (Veganzones & Winograd, 1997). The preponderant role of the changes in the world economy in the Argentine development has been also emphasized (Ferrer, 1967).

Table 1.1 Comparison of Per Capita GDP indexes (base= Argentina) and growth rates between 1900 and 1997

Year	Argentina	Australia	Canada	USA	Norway	Sweden	Brazil
1900	100	156.0	100.1	148.6	63.9	92.9	25.5
1997	100	208.3	220.7	279.9	221.3	211.2	59.2
1900/97	-	33.5%	120.5%	88.3%	246.1	127.2%	127.2%

(Source: Vitelli, 1999, p. 11).

Another approach towards the interpretation of the complexities of the Argentine economic puzzle focuses on non-economic factors. As clearly described by Diaz Alejandro (1970, p. xiii), "even to an economist untrained in other social sciences, the influence of political, social, and psychological factors on the Argentine economy is striking".



Figure 1.3. Map of Argentina. (Source: National Geographic Cartographic Division, 1995).

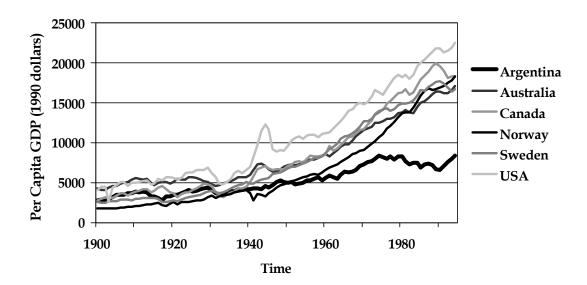


Figure 1.4. Comparison of Per Capita GDP levels expressed in 1990 Geary-Khamis Dollars (Source: Maddison, 1995, Appendix D).

Argentina's economic history cannot be separated from its natural resource base. A nation abundant in resources and land, Argentina started the century as a leader in agricultural exports (Giberti, 1988; Veganzones & Winograd, 1997). The country still benefits from the exceptional Pampean Region¹ (Figure 1.5), a fertile agricultural plain of almost 55 million hectares and temperate climate (Giberti, 1988). The relevance of the Pampas for the national economy can be explained in part by the fact that the region (1) gives the country substantial gains in terms of export earnings, (2) accounts for great part of the population's food requirements, and (3) constitutes an important source of state revenue through export retentions (Busnelli, 1992). The Rolling Pampas, the most productive area within the region, accounts for a great part of these three aspects. Argentina is also rich in energy reserves, including oil and natural gas (EIA, 2000a). Water resources are being developed at a rapid rate. Currently, Argentina relies mostly on hydropower and natural gas to fuel its electricity sector (EIA, 2000a).

Argentina was in 1997 the world largest exporter of sunflower flour and sunflower and soy oil and the second largest exporter of maize, sorghum, and soy flour (Solá, 1997). Nevertheless, oil, gas and electricity are growing in importance as exports. It is estimated that Argentina could become the major energy supplier of the Southern Cone region (EIA, 2000a).

¹For a detailed description of the Pampean Region, refer to Barsky (1991).

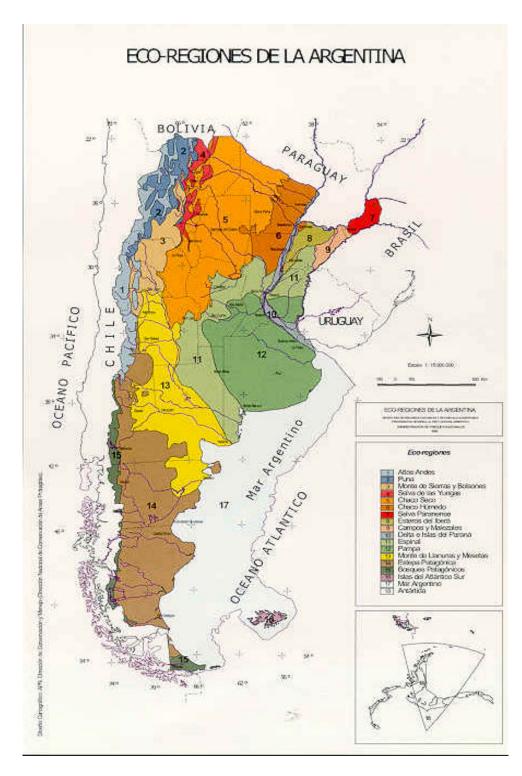


Figure 1.5. Ecological regions of Argentina. Pampean region (# 12) shown in dark green (Source: Sistema de Informacion Ambiental [SIA], 2001).

The trade balance tends to be favorable to Argentina when world demand for food is high. Export growth slowed sharply in 1998 due to lower world prices for petroleum and agricultural commodities (US State Department, 1999).

MERCOSUR, the regional customs union of the Southern Cone that includes Argentina, Brazil, Paraguay and Uruguay, has proven to be very important for the country's trade. However, there has been escalating stress after the Brazilian devaluation in 1999 (Australian Department of Foreign Affairs and Trade [ADFAT], 2001).

Argentina's external debt to GDP ratio is the highest among the three largest economies of Latin America (Mexico, Brazil, and Argentina). In 1998, this ratio was approximately 47% of annual GDP. While Argentina's external debt to GDP ratio is the highest, the external debt is the lowest. In 1998 debt service as a percentage of all exports for the same year was significantly lower than it was at the outset of the 1980s debt crisis (Janada, 1999).

The current state of Argentina's environment, as in the case of its economy, is rather disappointing. Soil erosion, deforestation, and water contamination are some of the consequences of a development style that chose not to -or was not able to- conserve the quality of its vast natural resources (Ministerio de Economia [MECON], 2000). Environmental degradation in Argentina has been a matter of analysis in numerous studies (Brailovsky and Foguelman, 1991; Secretaria de Recursos Naturales y Ambiente Humano

[SRNyAH], 1992; Vila and Bertonatti, 1993; World Bank, 1995; Programa
Cooperativo para el Desarrollo Tecnologico Agropecuario del Cono Sur
[PROCISUR], 1997; PROSAP, 1997). However, the assessment and quantification of the interrelations between environment and economy remain a complex task.

Emergy Accounting goes beyond the artificial boundaries of socioeconomic systems and acknowledges the intricate relationships between human societies and the biosphere. It brings a more holistic perspective to the sustainability issue, and in doing so, becomes a useful methodological tool for the incorporation of environmental concerns to the policy making process of the Rolling Pampas and the rest of Argentina.

Literature Review

Analysis of Nations

In the past two decades, the field of environmental accounting for nations has aroused increasing attention around the world (Hecht, 1999). Repetto *et al.* (1989) adjusted Indonesia's GDP by including the net depletion of some of the country's natural resources. After petroleum, timber, and soils exploitation was considered, the estimated annual net domestic product (NDP) for the 1971-1984 period was almost 40% less than the conventionally measured GDP.

Peskin (1989) focused on the accounting of forest resources to alter the 1980 conventional accounts for Tanzania. The accounting framework used by the

author was based on neo-classical economic theory (Peskin and Lutz, 1990). According to the results, that natural forest depreciation had no effect on the country's GDP, but lowered the NDP by about 5%.

Tongeren et al. (1993) adapted the UN's System of Integrated
Environmental and Economic Accounts (SEEA) for Mexico. Using
environmentally adjusted NDP measurements they showed increases in final
consumption and decreases in net capital accumulation and environmental
assets.

Bartelmus *et al.* (1993) used the same approach for the evaluation of Papua New Guinea. For the 1986-1989 period the authors found that environmentally adjusted NDP reduces NDP levels by amount ranging from 1 to 10%.

Oda *et al.* (1998) applied the SEEA to the Japan economy for 1985 and 1990. They found that for that period the environmentally adjusted product increased 0.1% more than the conventional NDP. Kim *et al.* (1998) used a similar approach to study the 1985-1992 period for the Republic of Korea. They found an increase in the share of environmentally adjusted product to NDP.

The analysis of Philippines by Domingo (1998) revealed depletion in that economy decreased from around 4% in 1988 to less than 1% in 1992. The author found the SEEA framework adequate for environmental accounting.

Keuning and de Haan (1998) showed the National Accounting Matrix including Environmental Accounts (NAMEA) results for the Netherlands. This

methodology contains a complete system of national flow accounts including emissions of pollutants, extraction of natural resources, and their effects.

According to the authors, total pollution per unit of final demand decreased form 1987 to 1992. In the later year, more than half the greenhouse effect, the acidification, and the eutrophication were caused by industries that generated less than 10% of GDP. At a more detailed level, NAMEA showed that most wastes were generated by exports. Direct pollution by the chemical industry and total environment intensity of the final demand for chemical products were substantially above average.

Emergy Accounting has been used to evaluate different national economies from a large-scale perspective. An overview of these studies was given by Odum (1996), along with a complete evaluation of the USA for 1983. Results for the US economy were consistent with what was expected for a developed economy, with less than 10% of total emergy derived form locally renewable sources.

Brown (1998) used the same methodology to evaluate Chile's performance during 1994. The emergy analysis indicated a relatively sustainable economy, because of the relatively high levels of renewable energy flows obtained form within the country. However, Chile showed a negative emergy balance of payments, exporting about 1.66 times as much emergy as is imported.

An emergy evaluation of the Brazilian economy during 1995 showed a transitional state between a developed and undeveloped economy. High use of renewable energy and low import of purchased emergy and materials characterized Brazil as a highly self-sufficient economy.

Lagerberg *et al.* (1999) used emergy accounting to evaluate the Swedish economy for 1988 and 1996. They found that the 30% growth in the total economy was based on greater use of local resources, and an even greater increase in imported goods and services. Renewable resources were considered constant over the period, and the environmental loading increased due to the greater reliance on non-renewable resources.

Analysis of Food Production Systems

Most researchers agree on the essential role of quantitative evaluation in the agriculture sustainability issue (Smit and Smithers, 1991; Hailu and Runge-Metzger, 1992; Stachetti *et al.*, 1998; Sands and Podmore, 2000). However, attempts towards the appraisal of sustainability in agriculture have been hindered by conceptual inconsistencies and lack of practical definitions (Brklacich *et al.*, 1991; Sands and Podmore, 2000).

Franzluebbers and Francis (1995) determined the energy output: input ratio of several maize and sorghum management systems in eastern Nebraska.

They concluded that rotation of cereals and legumes under dryland conditions in the western Corn Belt may be more sustainable for the future based on energy

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use efficiency of lower fossil fuel requirements from N fertilizer and irrigation.

Ramirez and Martinez (1995) studied the assessment of the sustainability of peasant production systems focusing on soil erosion in Chile. Using neoclassic economic theory, they found a trade off between erosion and farm returns in one of the regions under analysis.

Viglizzo *et al.* (1998) studied the trade-offs between productivity, stability, and sustainability during one century of low external-input farming in the pampas of Argentina. Comparing components, diversity patterns, and connectance of farming systems they found that productivity had increased all over the region at the expense of stability and sustainability.

Hellkamp *et al.* (1998) measured the condition and sustainability of agricultural lands in five Mid-Atlantic states in 1994. Using indicators of crop productivity and land stewardship on annually harvested herbaceous cropland, they found that the overall condition in the region was good.

Halberg (1999) developed a set of farm level indicators of environmental impact that was tested on 20 Danish dairy and pig farms. Included were the surplus and efficiency of N, P and Cu, the energy use per kg grain and per kg milk or meat, pesticide treatment index and indicators of nature quality. The indicators reflected differences in management practices on comparable farms.

Bouman *et al.* (1999) used SOLUS (Sustainable Options for Land Use), a framework for (sub-) regional land use that quantifies biophysical and economic

sustainability trade-offs, in Costa Rica. SOLUS consists of technical coefficient generators, a linear programming model, and a geographic information system. Results showed that introduction of alternative technologies may sometimes satisfy both economic and biophysical sustainability. However, negative trade-offs were found among different dimensions of biophysical sustainability.

Sands and Podmore (2000) propose a generalized sustainability index for agricultural systems. A case study was developed based on prevalent corn and wheat agricultural production systems in Baca County (Colorado). For all the soil types being evaluated, the corn system was the least sustainable. Rotational systems were found to be more sustainable than the other two continuous-crop management systems. In general, the degree of distinction among soil types regarding sustainability was much less pronounced than that exhibited among crop management systems.

Tellarini and Caporali (2000) used an input/output methodology to evaluate farms as sustainable ecosystems in both energy and monetary values in Central Italy. They found differences between low and high-input farming systems, but concluded that energy and monetary values did not offer a single, coherent account of the functioning of farm systems.

Andreoli and Tellarini (2000) used a simplified approach for farm sustainability evaluation in Tuscany. Results showed that farms might have very different performances according to the way they are managed, regardless of

their location. Since some productive types were less environmentally satisfactory, they concluded that it is important to find relatively positive styles of farming for these production types.

Di Pietro (2001) studied sustainable land use in agriculture at the landscape level in France. Indicators of sustainability were based on the contribution of the environment to the choice of agricultural practices by farmers, and on relationships between agro-ecological units and farms. Results showed that ecological sustainability of larger territories seemed to be in opposition with the standard criteria judging economical sustainability of farms.

Xu and Mage (2001) presented a preliminary case study of southern

Ontario using a model of agroecosystem health. They found that the overall level
of structural and organizational health of the agroecosystem has declined in that
area. However, functional health had improved greatly. The maintenance of
agroecosystem function and structure in the study region had become
increasingly dependent upon external inputs.

As in the case of analysis of national economies, Emergy Accounting has been used to evaluate ecological performance of different agricultural production systems. Odum (1984) studied corn production in USA and found that modern agriculture is based on massive contributions of emergy.

Lagerberg *et al.* (1999) used the same approach to assess the sustainability of greenhouse tomatoes in Sweden. The intensive tomato production system

investigated was shown to be highly dependent on non-renewable resources and human service fed-back from the economy.

Using Emergy accounting, five different Swedish greenhouse tomato production systems were analyzed by Lagerberg *et al.* (1999). Conventional systems were shown to utilize resource inputs more efficiently than organic systems due to higher yields of the formers. They concluded that replacing fossil fuels with more renewable fuels is an important strategy for the sustainability of tomato production systems.

Plan of Study

To evaluate agricultural production in the Rolling Pampas and to gain insight into its sustainability, emergy evaluations were conducted of modern and historical agricultural systems. To place in perspective the role of the Pampas agriculture in the national economy and effects of international trade on production, the economy of Argentina was evaluated using emergy. Emergy balance of payments resulting from international trade and the international debt of Argentina were also evaluated.

Historical data on the economy of Argentina and agricultural production in the Rolling Pampas were collected from a variety of sources. Five time periods were analyzed as "typical" windows of economic and technological characteristics. Data were averaged using these windows. The economy of

Argentina and agricultural systems of the Rolling Pampas were compared with other countries.

Using data on international debt and the emergy buying power of the Argentine economy, as well as emergy per dollar of exports, an emergy debt service was calculated to evaluate the relative position of Argentina with regard to its international debt.

CHAPTER 2 METHODS

The methodological approach undertaken in this study consisted of an emergy evaluation of the economy of Argentina during five time periods. Food production systems of the Rolling Pampas, characteristic of these same time periods, were also evaluated. First a general description of the time periods is given, followed by a description of the agricultural production systems.

Description of Periods Analyzed

Argentina

Five stages of economic development were analyzed, following the model proposed by Veganzones & Winograd (1997).

- 1900-1929: The Golden Age of Argentine Growth.
- 1930-1943: The World Depression and Destabilization of the Argentine Model.
- **1944-1975**: Import Substitution and Increasing Economic and Political instability.
- **1976-1989**: The Attempt to Liberalize the Economy, the Debt Crisis and Extreme Macroeconomic Volatility.
- **1990-1995**: Hyperinflation and Change in the System. Return of Sustainable Growth?

The reliance on economic interpretation for the selection of the study periods acknowledged the interdependence of natural capital and economic development. Moreover, the selection was made with the purpose of attaining another perspective for that economic history, incorporating the point of view of Emergy Accounting. A detailed description of each of the five periods can be found in Veganzones and Winograd (1997). A synthesis based on the work of these authors follows.

The rapid growth that had begun in the early 1880s continued in the 1900-29 period. . . . This growth was closely linked to rising exports and investment . . . agriculture was the most important sector. . . . State intervention in the economy was limited. . . . The country was heavily dependent on the free flow of merchandise and capital (p 24).... The 1930s crisis revealed the fragility of the development model chosen by Argentina. . . . Awareness of this fragility led the country's leaders in 1943 to adopt an import-substitution policy. . . . Against a background of chronic and accelerating inflation, economic and political instability arising primarily from existing policies, led to loss of control of the economy by the early 1970s (p 33). . . . The 1975 breakdown marked the definitive limit of the import-substitution regime. . . . By 1981 the military government's mishandling of its stabilization programmes and economic liberalisation policy had plunge the country into a serious crisis of unprecedented length . . . liberalisation was gradually reintroduced by the Radical Government elected in 1983. . . . The high degree of instability and demonetisation of the economy resulted in two bouts of hyperinflation: one in 1989, under the Radicals; and another in 1990, during the Peronist government (p 38). . . . In this short period from 1990 to 1995, economic performance was exceptional compared to the two preceding decades. . . . Profound economic reforms were undertaken that set in motion a change in growth strategy. Liberalisation of the economy was completed and stabilization was achieved. It may be too soon to announce the complete success of the reforms; the slow recovery of financial intermediation and the financial crisis of 1995 are signs that the economy is still fragile (p 40).

Description of Farming Systems Analyzed

Four stages of the evolution of the Rolling Pampas during the 20th century were identified, based on the work by Giberti (1988) and Pizarro (1998):

- **Agricultural predominance**. From 1900 to 1940 tenant farmers, most of them immigrants without capital coexisted with colonial ranchers. Ranchers, owners of enormous extensions of land devoted to cattle raising, lent fields to farmers for crop production for three years. Farmers would turn the field into alfalfa pastures before moving to the next field, and paid a percent of the harvest to the owner. As the international prices of the grains increased, large landowners reduced their herds, and tenants were in demand not for the alfalfa fields but for the income from grain production.
- Mixed Farming. After World War II Argentine grain was left without foreign markets. Farmers who own their land incorporated livestock to diversify production. Tenants, limited by their contracts did not have this option. Legal measures and political transformations improved the conditions of landless farmers. By 1960, most of the land was being farmed by its owners. During this period, mechanization replaced human and animal labor.
- Agriculturization. A strong predominance of grain over cattle characterized this stage. The introduction of soybean in the 1970s allowed a double crop in the same calendar and led to a propensity towards continuous agriculture. Technological innovations, such as improved genetic material, pesticides, and specialized machinery, improved the general productivity. However, soils suffered the consequences of such pressure.
- **Intensification**. This is the current stage, which started in the 1990s. Management skills and production scale are as important as technological innovation to produce in the competitive global market.

The dominant agricultural systems that characterized these four periods in the Rolling Pampas were evaluated: Low energy tenant farming (1900-1940), Mixed grain and livestock production (1940-1970), Agricultural industrialization (1970-1990), and Agricultural Intensification (1990-). Since recently irrigation and no-tillage methods of farming have gained importance in the Rolling Pampas,

three different n production systems were evaluated for the Agricultural intensification period: (1) Rainfed-intensive agriculture, (2) Irrigated-intensive agriculture, and (3) No-tillage intensive agriculture. The main technical characteristics of these production systems follow.

- Low energy tenant farming. Tenant farmers worked 80 ha in the north of the province of Buenos Aires. Of the total land area, 25 ha were planted flaxseed, 50 ha corn, and the rest was used for grazing of draft animals. The capital consisted of 20 Creole horses, and some agricultural machinery. The system yielded 150,000 kg of corn and 20,000 kg of flaxseed. (Source: Ministerio de Agricultura, 1929)
- **Mixed grain and livestock production**. Landowners worked 100 ha in the north of the province of Buenos Aires, using the following rotation: 4 years of corn production, 2 years of wheat and sunflower, and 5 years of grassland for cattle raising. About 70% of the total land is under crop cultivation; the rest is for livestock production. The system yielded annually 3,100 kg of corn, 2,200 kg of wheat, 1,000 kg of sunflower, and 182 kg of meat per ha. (Source: Pereyra and Tricco; 1968; Kugler and Nocetti, 1969)
- **Agricultural industrialization**. Landowners worked 100 ha in the north of the province of Buenos Aires, devoted mainly to soybean production. Around 35% of the land is planted with soybean, 35% with soybean combined with wheat, and the rest is for corn production. The system yielded 4,500 kg of corn, 2,500 kg of wheat, and 2,000 kg of soybean per ha. (Source: Pizarro and Cacciamani, 1980; Barsky, 1988)
- Rainfed-intensive agriculture. Medium-size farms (100 to 500 ha) in the north of Buenos Aires are devoted to corn, wheat and soybean production (50% of the land area for corn production, 50% with soybean or soybean combined with wheat). Fertilizers were used for the first two crops. The system yielded 7,000 kg of corn, 4,000 kg of wheat, and 3,200 kg of soybean per ha. (Source: PROSAP, 1997)
- **Irrigated-intensive agriculture**. Similar to the rain fed intensive system, but irrigation was also used as an input to the system. Irrigation accounted for 120, 90, and 100 mm of the water requirements of corn, wheat, and soybean, respectively. The system yielded 13,000 kg of corn, 6,000 kg of wheat, and 3,500 kg of soybean per ha. (Source: PROSAP, 1997)

- **No-tillage intensive agriculture**. Similar to the rain fed intensive system, but specific no-tillage machinery was used in all the crops of the rotation. The system yielded 6,000 kg of corn, 2,900 kg of wheat, and 3,200 kg of soybean per ha. (Source: Daza, 1998)

Emergy Evaluation

Emergy evaluations of Argentina and the selected food production systems were based on the environmental accounting methodology set out by Odum (1996).

General Procedure

- Delimitation of boundaries and elaboration of a systems diagram representing the main components and energy sources.
- Identification of relevant processes. These may comprise flows, interactions, production, consumption, and money transactions.
- Development of evaluation tables for emergy flows.
- Elaboration of aggregated summary tables and diagrams for the emergy flows.
- Computation of emergy based parameters and indices.

Emergy Analysis has been described in great detailed elsewhere (Odum, 1994, 1996; Brown, 1998; Brown and Ulgiati, 1999). A summary of the main energy systems symbols used for emergy diagrams is given in Annex A. An overview of the basic emergy concepts and definitions is presented in Annex B.

Emergy Evaluation of Argentina's Economy

Emergy driving the Argentine economy comes from three main sources, as follows:

- Renewable inputs of biospheric emergy (outside sources),
- Imported, non-renewable sources (purchased goods, fuels, services), and,
- Indigenous non-renewable energy sources (soils, wood, fuels harvested from within Argentina).

These inputs were evaluated for each of the time periods described above using mean data for each time period. A summary of aggregated flows is presented in Figure 2.1, including the circulation of money. Using this figure as a guide, the following inputs and exports were evaluated:

Renewable inputs (R) include sunlight, wind, waves, tidal influence, rain, and geologic contributions of the land. All renewable inputs were evaluated, but only the largest was used in subsequent evaluations and indices to avoid double counting. Non-renewable resources originated within the country's boundaries comprise:

- N_0 , rural resources used faster than their regeneration rate,
- N_1 , the reserves of fuels and minerals, and,
- N_2 , resources passing through the country economy without appreciable transformation (emergy of these commodities is not considered as an emergy contribution to the nation economy).

Imports included flows of energy (F), goods that have emergy in addition to services involved (G), and total imported services (P₂I). In general, the emergy

of imported services was estimated using the monetary value and the emergy/money ratio of the country of origin. Exports, comprised of resources (N_2) , goods (B), and services (P_1E) , were also evaluated. The emergy exported as services (P_1E_3) was estimated using the monetary value of exports and the emergy/money ratio of Argentina for the year of the evaluation.

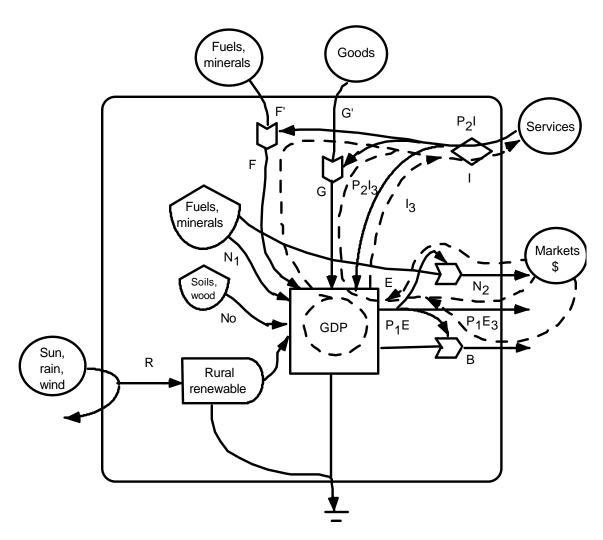


Figure 2.1. Pathways for evaluating the overall energy use of a state or a nation (Source: adapted from Odum, 1996, p. 198).

A summary of national parameters and indices based on the main emergy inflows and outflows of Argentina is given in Table 2.1. Further aggregation of main flows (Figure 2.2) in *indigenous sources* (I= R+N), *purchased inputs* (F= M+S), along with the flow of *yields*, allows the calculation solar transformities and other emergy based sustainability ratios given in Table 2.2.

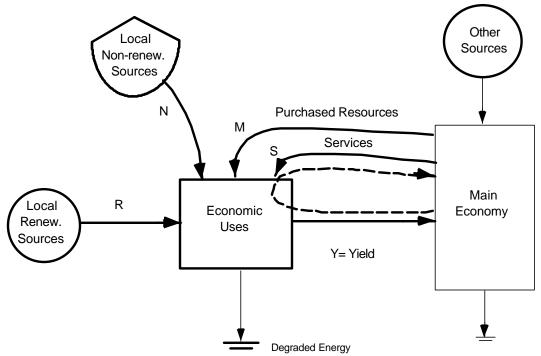


Figure 2.2. Aggregated diagram of emergy flows (Source: Odum, 1996, p. 83).

Solar transformities of final products were obtained by dividing the total solar emergy of inputs (I + F) by the available energy of the yield (Y). Of special interest is the Emergy Index of Sustainability (formerly known as Emergy Sustainability Index). According to Brown (1998), the EIS summarizes the main aspects of ecological sustainability: yield, renewability, and load on the environment.

Table 2.1 National indices based on emergy analysis.

Name of Index	Expression
Renewable Emergy flow	R
Indigenous nonrenewable reserves	N
Flow of imported emergy	$F + G + P_2I_3$
Total emergy inflows	$R + N + F + G + P_2I_3$
Total emergy used, U	$N_0 + N_1 + R + F + G + P_2I_3$
Total exported emergy	$N_2 + B + P_1 I_3$
Fraction of emergy used derived from local sources	$(N_O + N_1 + R)/U$
Imports minus exports	$(F + G + P_2I_3) - (N_2 + B + P_1I_3)$
Ratio of exports to imports	$(N_2 + B + P_1I_3)/(F + G + P_2I_3)$
Fraction used, locally renewable	R/U
Fraction of use purchase	$(F + G + P_2I_3)/U$
Fraction used, imported service	$P_2I)/U$
Fraction of use that is free	$(N_O + R)/U$
Ratio of concentrated to rural	$(F + G + P_2I_3 + N_1)/(R + N_0)$
Use per unit area	U/area
Use per capita	U/population
Renewable carrying capacity at present living standard	(R/U)(population)
Developed carrying capacity at same living standard	8(R/U)(population)
Emergy/money ratio (ratio of use to GDP)	$F_1 = U/GDP$
Ratio of electricity to use	Electricity/U
Fuel use per capita (Source: Odum 1006 p. 100)	Fuel/population

(Source: Odum, 1996, p. 199)

Table 2.2 Emergy ratios for evaluation of economic use of resources.

Name of Index	Expression
Percent Renewable (% Renew)	R/(R+N+F)
Emergy Yield Ratio (EYR)	Y/F
Environmental Loading Ratio (ELR)	(F+N)/R
Emergy Index of Sustainability (EIS)	EYR/ELR

(Source: Brown, 1998)

Finally, the *environmental emergy signature* of the country was determined. It represents the relative importance of the energy flows for that country expressed in the common basis of emergy. The procedure consisted of plotting the emergy flows in a bar graph, according to increasing transformities.

Data Gathering and Processing

Data Sources

Most of the data for the evaluation of Argentina were obtained from published sources that account for the evolution of the country throughout the century analyzed. Data corresponding to more recent years were also obtained from databases maintained by public institutions of Argentina, such as the Ministry of Economy (MECON) and the National Institute of Statistics (INDEC), and from international and foreign organizations, such us the Food and Agricultural Organization (FAO) and the Energy Information Administration (EIA) of the United States.

National emergy-based indices of other economies for comparative purposes were obtained from past studies, especially those concerning MERCOSUR¹ countries (Kent, 1996; Brown, 1998; Brown *et al.*, 2000; Ferreyra, 2000).

Regarding food production in the Rolling Pampas, information was obtained mainly from technical papers and reports prepared by the National Institute of Agricultural Technology (INTA), and the Secretariat of Agriculture, Fisheries, and Food (SAGPyA).

Physical Flows

All flows across the Argentine boundary –inputs and exports- were expressed in physical units. Data series for the 20th century were used to obtain the annual average inflows and outflows for each evaluation period. In case of missing data, averages from available years were used. In the case of the Rolling Pampas, physical information of inputs, outputs, and yields reflected the common production practices at the different stages in the evolution of the area.

In both cases, inflows and outflows were transformed to joules of energy using the corresponding caloric contents on a dry weight basis. Minerals, chemicals, and machinery data were expressed as dry weight units. All calculations and data sources are given in the footnotes of the emergy evaluation tables.

¹MERCOSUR is the common name of the Southern Common Market, a customs union formed by Argentina, Brazil, Uruguay, and Paraguay in 1991. Free trade agreements were signed with Chile and Bolivia in 1996 and 1997 respectively.

Values of transformities were taken from past studies, especially those from Odum (1996) and Brown (1998). These transformities were used to transform energy values to units of emergy (solar emjoules).

Money Flows

GDP was expressed in constant dollars in order to reduce distortions caused by inflation. This information, along with population data, was obtained from the work by Maddison (1995), which provided a comprehensive economic database for fifty-six countries over the period from 1820 to 1992, among them Argentina. Maddison used the Geary-Khamis approach to transform annual GDP levels into a common unit, 1990 dollars. A detailed description of the methodology, as well as the information sources used for Argentina's GDP estimations can be found in Maddison (1995).

Emergy value of international loans was calculated by multiplying the monetary value of the loans by the world emergy/money ratio. The emergy value of external debt service was evaluated using the annual monetary payments multiplied by the national emergy money ratio for that period. A ratio of emergy in loans to emergy value of debt repayment was calculated using the emergy of loans and emergy of total payments.

Human Services

Emergy/money ratios of Argentina, obtained as a result of the emergy evaluations, were used to estimate the transformity for human labor in the

Rolling Pampas. According to Odum (1996), this transformity can be calculated by dividing the total emergy use for a country by its working population. The resulting emergy per person is then distributed using the number of hours per calendar year.

Emergy in human services related to the production of hybrids and genetically modified seeds for agricultural production was estimated by calculating the difference in price between seeds and yields, and multiplying the result for the emergy/money ratio of Argentina for the corresponding time period.

CHAPTER 3 RESULTS

Emergy Evaluation of the Economy of Argentina

The Overall Economy

A summary diagram for the Argentine economy is shown in Figure 3.1. It identifies main inflows of environmental energies as well as relevant indigenous resources and production processes within the country. An emergy evaluation for the 1990-1995 period of the Argentine economy is given in Table 3.1.

Summaries of aggregated flows and national indices are presented in Tables 3.2 and 3.3 respectively. Evaluation and summary tables for four historical periods (1900-1929, 1930-1943, 1944-1975, 1976-1989) that were also evaluated can be found in Annex C. The evolution of the emergy signature of Argentina during the 20th century, shown in Figure 3.2, was compiled based on the detailed analysis given in these tables.

The contribution of renewable resources-sunlight, rain, wind, waves, tides, and earth cycle- to the economy were considered to remain constant throughout the century. Since local renewable emergy inputs are coproducts of the main geobiospheric processes of the earth, their emergies are not independent (Odum, 1996). In order to avoid double counting only the largest

one, rainfall chemical potential, was used to obtain the emergy flow of renewable resources for each period (item R on summary flow tables).

Table 3.1. Annual emergy flows supporting the Argentine economy during the 1990-1995 period.

Note Item	Raw Unit	Emergy/unit (sej/unit)	Solar Emergy (E20 sej)	EmDollars (E9 1990 US\$)
Renewable resources:				_
1 Sunlight	1.68E+22 J	1.00E+00	167.99	8.60
2 Rain, chemical	1.47E+19 J	1.82E+04	2680.46	137.18
3 Rain, geopotential	7.03E+18J	2.79E+04	1958.65	100.24
4 Wind, kinetic energy	2.07E+19 J	1.50E+03	309.67	15.85
5 Waves	8.05E+17 J	3.06E+04	245.93	12.59
6 Tide	3.19E+18 J	1.68E+04	538.03	27.54
7 Earth Cycle	2.78E+18 J	3.44E+04	955.82	48.92
Indigenous renewable energy	y:			
8 Hydroelectricity	9.67E+16 J	1.65E+05	159.49	8.22
9 Agriculture Production	1.39E+17 J	1.00E+05	138.57	7.14
10 Livestock Production	4.65E+16 J	1.00E+06	465.32	23.97
11 Fisheries Production	3.44E+15 J	1.00E+06	34.40	1.77
12 Fuelwood Production	4.38E+10 J	1.87E+04	0.00	0.00
13 Forest Extraction	4.75E+16 J	1.87E+04	8.89	0.46
Nonrenewable sources from	within system	:		
14 Natural Gas	1.02E+18 J	4.80E+04	491.43	25.15
15 Oil	1.43E+18 J	5.40E+04	770.32	39.42
16 Coal	7.65E+15 J	4.00E+04	3.06	0.16
17 Minerals	4.82E+13 g	1.00E+09	482.34	24.69
18 Metals	2.02E+11 g	1.00E+09	2.02	0.10
19 Top Soil	1.70E+17 J	7.40E+04	125.45	6.42

Table 3.1 (continued)

Note	Item	Raw Unit	Emergy/unit (sej/unit)	Solar Emergy (E20 sej)	EmDollars (E9 1990 US\$)
Impor	ts and outside source	es:			
200	Oil Derived Products	1.06E+17J	6.60E+04	70.04	3.61
211	Metals	9.91E+11 g	1.80E+09	17.85	0.92
221	Minerals	4.41E+12g	1.00E+09	44.14	2.27
231	Food & Ag Products	1.34E+16J	2.00E+05	26.70	1.38
240	Coal	3.63E+16J	4.00E+04	14.54	0.75
251	Plastics & Rubber	1.21E+16J	6.60E+04	7.97	0.41
260	Chemicals	1.88E+12g	3.80E+08	7.15	0.37
271	Wood,Paper,Textiles	1.29E+16J	3.49E+04	4.49	0.23
281	Mech.& Trans Eqp.	7.40E+11 g	6.70E+09	49.60	2.56
299	Service in imports	3.23E+10\$	1.24E+12	401.10	20.66
Expor	ts:				
30 4	Agricultural Crops	8.72E+16J	2.00E+05	174.40	8.98
311	Fishery Products	4.95E+13J	1.00E+06	0.49	0.03
321	Forest Products	6.71E+15J	3.49E+04	2.34	0.12
330	Crude Oil	4.78E+17J	5.30E+04	253.12	13.04
341	Metals / Minerals	1.57E+13 g	1.00E+09	156.69	8.07
351	Paper & Wood	9.17E+15J	3.49E+04	3.20	0.16
360	Chemicals	5.93E+11g	3.80E+08	2.26	0.12
375	Service in exports	2.74E+10\$	1.94E+12	531.28	27.37
389	Service external debt	9.31E+09\$	1.94E+12	180.63	9.31

Calculations and references for basic data are given in Appendix C.

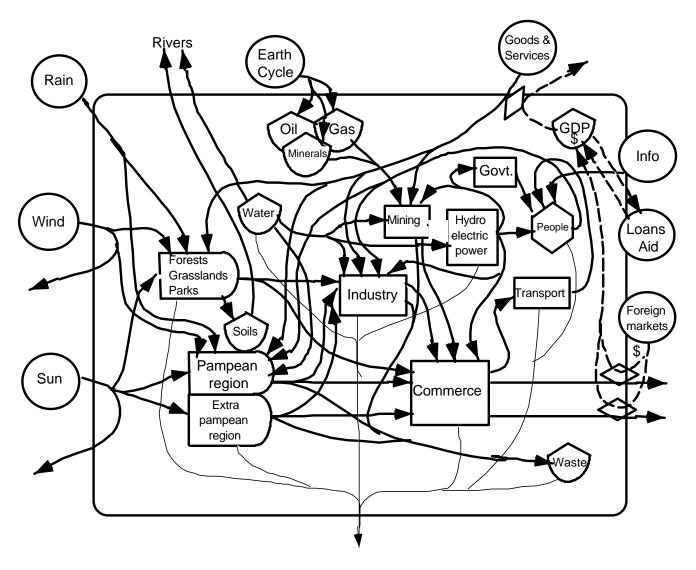


Figure 3.1. Emergy diagram of Argentina.

Table 3.2. Summary of annual major emergy and monetary flows for Argentina during the 1990-1995 period.

Variable		Solar Emergy (E20 sej/y)	Dollars
R	Renewable sources (rain chemical)	2680.46	
	Rain Chemical, item 2		
N	Nonrenewable resources from within Argentina	1917.91	
	$N_0 + N_1 + N_2$		
N_0	Dispersed Rural Source	166.40	
	Items 11, 12, 13, and 19 less item 33		
N_1	Concentrated Use	1339.35	
	Sum of items 14, 15, 16, 17, and 18 less 33, 34 and 3	35	
N_2	Exported without Use	412.16	
	Items 33, 34 and 35		
F	Imported Fuels and Minerals	146.56	
	Items 20, 21, 22, and 24		
G	Imported Goods	95.91	
	Items 23, 25, 26, 27, and 28		
I	Dollars Paid for Imports		3.23E+10
	Item 29		
P_2I	Emergy of Services in Imported Goods & Fuels	401.10	
	Item 29		
E	Dollars Received for Exports		2.74E+10
	Item 37		
P_1E	Emergy Value of Goods and Service Exports	531.28	
	Item 37		
x	Gross Domestic Product		2.49E+11
	(1990 dollars)		
P_2	World emergy/\$ ratio, used in imports	1.24E+12	
P ₁	Argentina Emergy/\$ ratio (total emergy used/GDP)	1.94E+12	

Table 3.3. Overview indices of annual solar emergy use for Argentina during the 1990-1995 period.

Item	Name of Index	Expression	Quantity	Unit
1	Renewable emergy flow	R	2.68E+2	3 sej/y
2	Flow from indigenous nonrene	ewable		
	reserves	N	1.92E+2	3 sej/y
3	Flow of imported emergy	F+G+P ₂ I	6.44E+2	2 sej/y
4	Total emergy inflows	$R+N+F+G+P_2I$	5.24E+2	3 sej/y
5	Total emergy used, U	N_0 + N_1 + R + F + G + P_2I	4.83E+2	3 sej/y
6	Total exported emergy	P_1E	5.31E+2	2 sej/y
7	Fraction emergy use derived			
	from home sources	$(N_O+N_1+R)/U$	0.87	
8	Imports minus exports	$(F+G+P_2I)-(N_2+P_1E)$	-3.00E+2	2 sej/y
9	Export to Imports	$(N_2+P_1E)/(F+G+P_2I)$	1.47	
10	Fraction used,			
	locally renewable	R/U	0.55	
11	Fraction of use purchased	$(F+G+P_2I)/U$	0.13	
12	Fraction imported service	P_2I/U	0.08	
13	Fraction of use that is free	$(R+N_0)/U$	0.59	
14	Ratio of concentrated to rural	$(F+G+P_2I+N_1)/(R+N_0)$	0.70	
15	Use per unit area	U/(area)	1.74E+1	1 sej/m²
16	Use per person	U/population	1.46E+1	6 sej/person
17	Renewable carrying capacity			
	at present living standard	(R/U) (population)	1.83E+0	7 people
18	Developed carrying capacity			
	at same living standard	8(R/U)(population)	1.47E+0	8 people
19	Ratio of use to GDP,			
	emergy/dollar ratio	$P_1=U/GDP$	1.94E+1	2 sej/\$
20	Ratio of electricity to use	(el)/U	0.09	
21	Fuel use per person	fuel/population	3.32E+1	5 sej/person

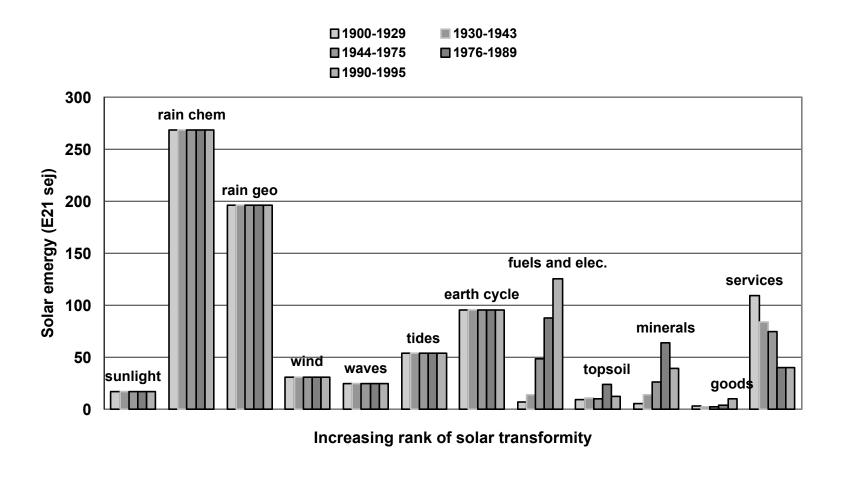


Figure 3.2. Emergy signature of Argentina during the 20th century.

A time series graph of GDP and emergy/money ratio for Argentina is given in Figure 3.3. The emdollar value of rain chemical potential, which represents "the dollars of GDP equivalent wealth measured in emergy" (Odum, 1996, p 298), depended on the economy. Since the emergy to GDP ratio declined throughout the historical periods, the emdollar value of the rain chemical potential emergy increased proportionally although its emergy contribution remained constant (Figure 3.4)

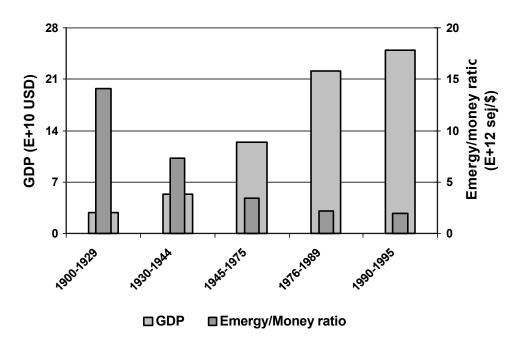


Figure 3.3. Evolution of GDP and emergy/money ratio of Argentina during the 20th century.

Renewable and Nonrenewable Inputs

A summary of the annual resource flows and GDP for the Argentine economy during the 1990-1995 period is shown in Figure 3.5.

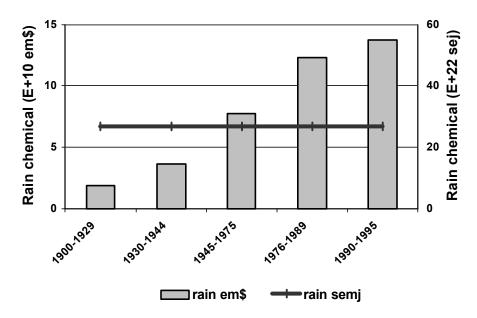


Figure 3.4. Evolution of emdollars and solar emjoules value of rain chemical potential in Argentina during the 20th century.

The proportion of total emergy used in the economy that was derived from renewable resources during that period was 55%, which is a much higher value than that of most developed economies (Figure 3.6). Among the MERCOSUR countries, Argentina and Brazil have the lowest percentage of total emergy resulting from renewable emergy sources (less than 60%). Use of renewable emergy relative to the total emergy budget of Argentina decreased almost 20% throughout the century, from 67% for 1900-1929 to 55% for 1990-1995.

A partial emergy signature of Argentina that includes all flows but renewable resources is shown in Figure 3.7. The end of the 20th century finds Argentina's economy driven mostly by non-renewable resources. The production

of hydrocarbons has doubled over the past decade, and total installed power generation capacity has increased by one-third. Consumption of energy has risen by more than 30% since 1990, and has almost doubled since 1980 (EIA, 2000a).

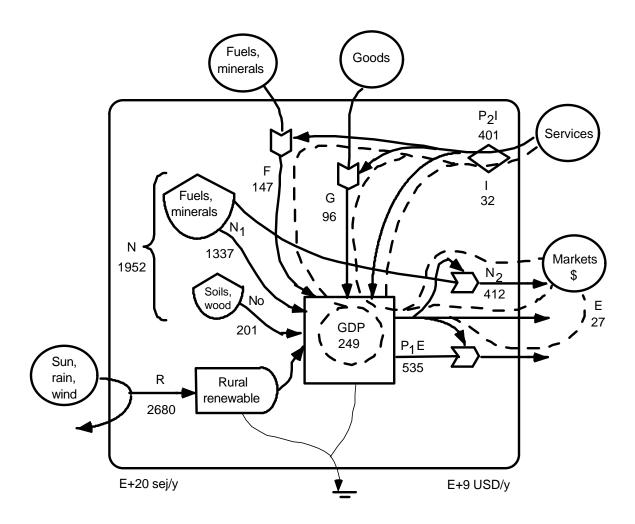


Figure 3.5. Systems diagram summarizing annual emergy (E+20 sej/y) and money flows (E+9 USD/y) for the 1990-1995 period in Argentina. Flow values are given in Table 3.2, p 6.

Importance of imported services has decreased dramatically over the historical periods analyzed, but has remained relatively constant for the last two

decades. Use of geological materials-fuels and minerals-represented almost 30% of the total emergy used in Argentina during the 1990-1995 period, a great increase compared to only 0.6% at the beginning of the century.

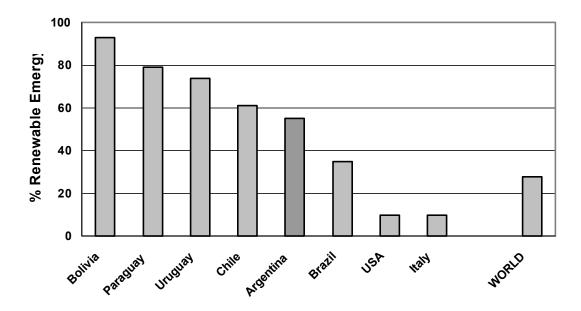


Figure 3.6. Contribution of renewable energy flows to national economies, including the 1990-1995 period for Argentina. (Sources: Kent, 1996; Brown, 1998; Brown et al., 2000; Ferreyra, 2000)

Regarding topsoil, the 1976-1989 period presented the higher emergy value, a consequence of very high soil erosion rates in the Pampean Region. It was in that period that soybean was introduced in the Pampas to be cultivated in combination with wheat in the same calendar year. Impacts on the Pampean soils were detrimental, and efforts towards the recovery of their quality are still required.

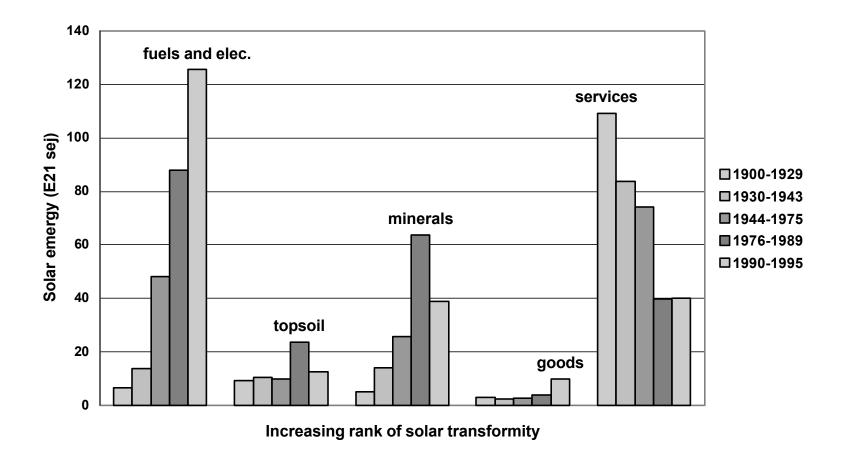


Figure 3.7. Partial emergy signature of Argentina during the 20th century.

Indigenous Renewable Emergy Inputs

The principal forms of indigenous emergy used in Argentina are shown in Table 3.4. These emergies represent primary inputs to the economy whose base of support is largely renewable, although they are often exploited at rates greater than they are produced, rendering then nonrenewable in character.

Table 3.4. Comparison of indigenous emergy uses in Argentina, expressed as percent of total indigenous emergy use.

Period	Hydroelectricity	Agriculture	Livestock	Fisheries	Forestry
1900-1929	0.4	27.7	70.5	0.4	0.9
1930-1943	0.5	28.7	67.4	0.7	2.7
1944-1975	0.9	22.2	74.5	1.3	1.1
1976-1989	7.9	21.4	67.3	2.8	0.5
1989-1995	11.1	19.2	64.4	4.8	0.6

Agricultural production is one of the main activities of the Argentine economy. Livestock and general agricultural production accounted for almost 98% of indigenous emergy inputs in the early part of the century and by the end of the century still represented more than 80% of indigenous inputs.

Hydropower accounted for almost half of the electric generation during 1998 (EIA, 2000a).

Throughout the 20th century, agricultural and livestock production were the most important uses of indigenous emergy. Hydroelectricity exhibited the greatest increase in relative importance. Fisheries production also increased

considerably, but in the last decade concern has arisen that exploitation of this resource is overcoming its rate of replenishment.

Figure 3.8 shows the historical perspective of emergy contributions to the economy of Argentina from the four largest economic activities. In the early part of the century agricultural activities dominated, but in the last two to three decades the emergy of mineral sectors have become prevalent.

Imports, Exports, and Balance of Payments

Imports of goods, fuels and services (Figure 3.9), accounted for 13% of the total emergy used in Argentina during the 1990-1995 period; services represented 60% of that value (Items 11 and 12, Table 3.3). Services account for the emergy supporting human labor involved in the processing of purchased fuels and goods. At the beginning of the century, emergy flows purchased outside Argentina represented 30% of the total emergy budget, and services accounted for most of the emergy of these purchased inputs (90%).

The difference in relative importance of services throughout the century can be explained in part by the fact that there was a declining trend in the emergy/money ratio of the world as economic activities of humans increased (1998) and in part by increased imports of primary energy of raw materials relative to finish products from trading partners.

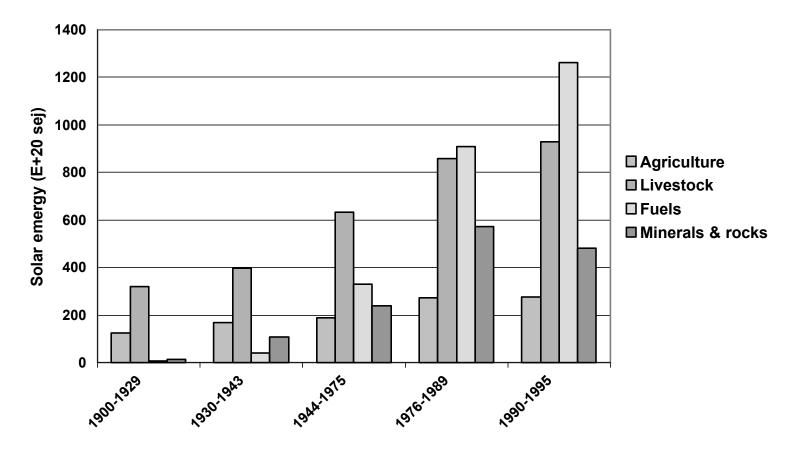


Figure 3.8. Emergy input to Argentina's economy during the 20th century resulting from main economic sectors.

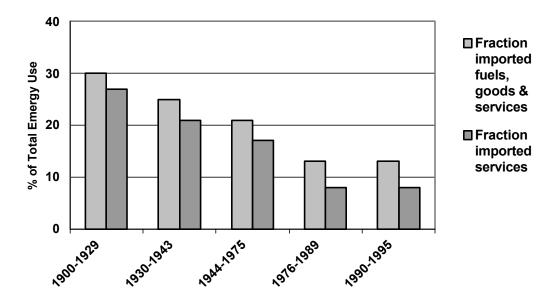


Figure 3.9. Contribution of imports to the total emergy budget of Argentina during the 20th century.

Figure 3.10 shows the composition of imports throughout the century. Fuels and minerals, combined, remained the main import during the century. Regarding exports, Figure 3.11 shows the overwhelming dominance of the agricultural sector. The emergy in exported agricultural products accounted for nearly 100% of all exports for the first three quarters of the century and had only recently been eclipsed by oil and mineral exports.

The emergy analysis of Argentina shows the evolution of the balance of payments in emergy terms (Figure 3.12). During the 1990-1995 period, Argentina exhibited a negative emergy balance of payments, exporting about 1.5 times as much emergy as it imported.

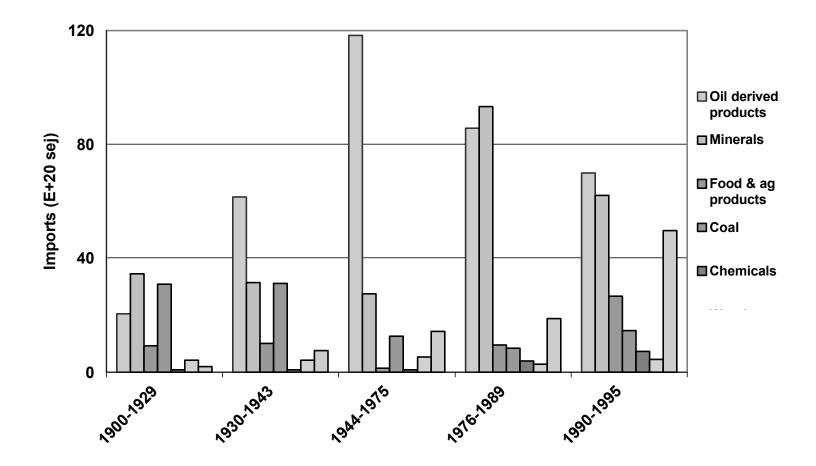


Figure 3.10. Main emergy import flows of Argentina during the 20th century.

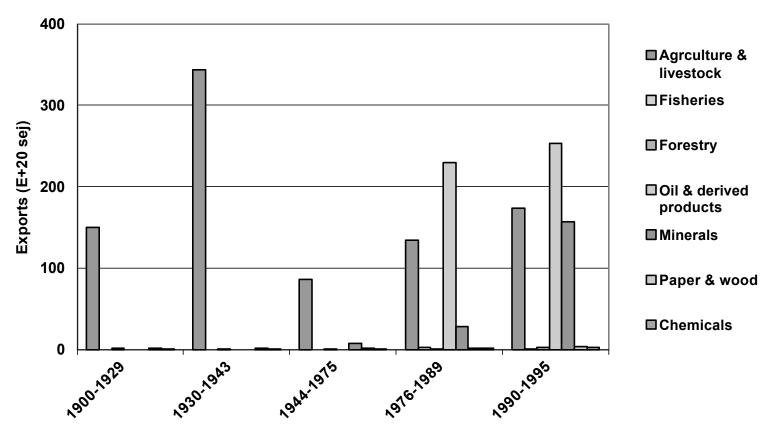


Figure 3.11. Main emergy export flows of Argentina during the 20th century.

The country started the century with a positive balance, and the increasing trend resulted in a ratio of over 2.0 to 1 at mid century. However, the situation changed thereafter, declining to a ratio of almost 0.5 to 1 by the end of the century.

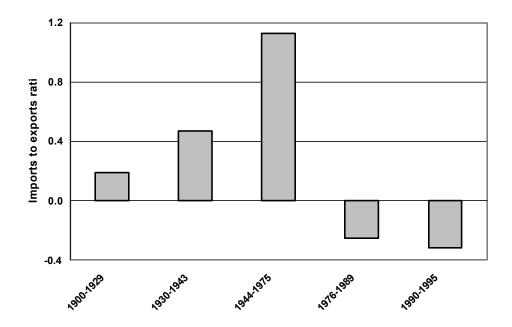


Figure 3.12. Emergy ratio of imports to exports in Argentina during the 20^{th} century.

Indices of Sustainability

A summary of the emergy flows and indices for the Argentine economy during the 1990-1995 period is given in Table 3.5. For comparative purposes, the 1983-emergy flows and indices for the US and the 1995 values for the Brazilian economy are also presented. The total emergy budget of Argentina increased almost 25% throughout the century, but there was a decreasing trend in the ratio

of emergy use to the GDP (86%), a consequence of increasing participation of human activities in the emergy flows of the country.

Table 3.5. Comparison of solar emergy indices of Argentina during the 20th century, including 1983 indices for USA and 1995 indices for Brazil.

Period	Total emergy used (E+23 sej/y)	Emergy/\$ ratio (E+12 sej/\$)	Emergy use per unit area (E+11 sej/m²)	Emergy use per person (E+16 sej/p)	Fuel use per person (E+14 sej/p)
1900-1929	4.0	14.1	1.4	5.1	7.9
1930-1943	3.9	7.3	1.4	2.9	10.0
1944-1975	4.3	3.5	1.5	2.1	22.8
1976-1989	4.8	2.2	1.7	1.6	26.6
1990-1995	4.8	1.9	1.7	1.5	33.2
Brazil	27.4	4.6	3.2	1.8	12.0
USA	78.5	2.4	8.4	3.4	150.0

Fuel use per person exhibited the most significant increase, growing about 400% as the country developed its oil resources. The emergy use per person decreased approximately 70%, suggesting a continuous trend of lower standards of living in recent periods.

Table 3.6 shows several sustainability indices for the Argentine economy during the 1990-1995 period, and the 1997 values for the remaining MERCOSUR

countries. The 1983-emergy flows and indices for the US and the 1995 values for the World economy are also presented. These indices assess the relative importance of renewable, non-renewable and purchased emergy inflows. In general, the renewable inputs accounted for about 50% of total inputs, while nonrenewable and purchased inputs represented about 37% and 13% of the imported emergy, respectively. When compared to other countries and the world, the Emergy Index of Sustainability (EIS) of Argentina indicates a relatively sustainable economy, based on the use of renewable energy, dependency on imports, and load on the environment.

The emergy indices of sustainability for Argentina during the last century are summarized in Table 3.7. Essentially, there were no differences in EIS among the different periods considered for the Argentine economy. The EYR, measuring the productivity of the economy per unit import, doubled during the century. The same trend is observed for the ELR, which relates nonrenewable emergy use to renewable use and is a relative measure of the load on the environment due to economic activity.

Emergy Evaluation of Agriculture in the Rolling Pampas

Intensive Agricultural Production in the Rolling Pampas

Figure 3.13 is an input summary diagram of the Intensification period of agriculture in the Rolling Pampas, corresponding to the last decade of the 20th century.

Table 3.6. Comparison of solar emergy indices of Argentina during the 20th century, including 1983 indices for USA and 1995 indices for Brazil. (Source: Odum, 1996; Brown, 1998; Brown *et al.*, 2000)

		EMERGY Flow (sej/y)			EMERGY Indices			
Country	Total EMERGY	Renew (R)	Non Renew (N)	Purchased (F)	% Renew	EYR	ELR	ESI
Bolivia	1.92 E22	1.82 E22	8.32 E20	4.59 E20	93%	41.8	0.1	418.0
Paraguay	4.84 E22	3.82 E22	2.70 E21	7.50 E21	79%	6.5	0.3	21.7
Uruguay	3.08 E22	1.96 E22	3.00E21	8.20 E21	74%	3.8	0.6	6.3
Chile	2.79 E23	1.21 E23	1.01 E23	5.78 E22	79%	4.8	1.3	3.7
Brazil	1.79 E24	6.87E23	8.83 E23	2.22 E23	35%	8.1	0.6	13.5
Argentina	4.86 E23	2.68 E23	1.92 E23	6.44 E22	55%	8.2	1.0	8.4
USA	790.50 E22	8.24 E23	5.18 E24	1.90 E24	10%	4.2	8.6	0.5
WORLD	33.60 E24	9.43 E24	8.21 E23	2.34 E25	28%	1.4	2.6	0.6

Percent Renewable= R/(R+N+F)

EMERGY Yield Ratio (EYR)= (R+N+F)/F

Environmental Loading Ratio (ELR)= (F+N)/R

Emergy Index of Sustainability (EIS)= EYR/ELR

Table 3.7. Comparison of emergy indices for Argentina during the 20th century.

Period	%Renew	EYR	ELR	ESI
1900-1929	67	3.4	0.5	6.8
1930-1943	68	4.0	0.5	8.5
1944-1975	66	4.4	0.5	8.4
1976-1989	56	8.1	0.9	9.1
1990-1995	55	8.2	1.0	8.4

Percent Renewable= $R/(R+N_0+N_1+F)$

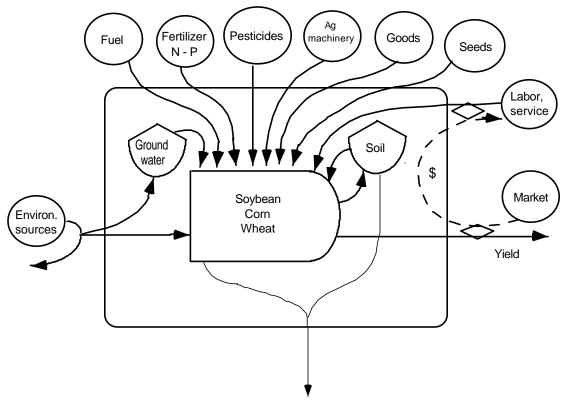
EMERGY Yield Ratio (EYR)= $(R+N_0+N_1+F)/F$

Environmental Loading Ratio (ELR)= $(F + N_0 + N_1)/R$

Emergy Index of Sustainability (EIS)= EYR/ELR

The three systems analyzed for this period (Rainfed-intensive agriculture, Irrigated-intensive, and No-tillage intensive agriculture) differed mainly in the intensity of soil tillage, and the use of irrigation. Fertilizers were used in all these production systems to restore the natural fertility after the Agriculturization period.

Emergy evaluation tables for the three production systems are given in Tables 3.8, 3.9, and 3.10. Flows of emergy in these tables were organized according to their sources. Renewable resources were represented by the chemical potential energy in rain, the largest environmental flow in Argentina (see country evaluations).



3.13. Intensive food production systems in the Rolling Pampas.

In the Irrigated intensive system the emergy of rain was complemented with an input of groundwater as irrigation. The emergy of irrigation was relatively small compared to that of the rain since complementary irrigation does not involve large amounts of water. The inclusion of complementary irrigation as a renewable resource flow was based on the study by PROSAP (1997), which reported the existence of sufficient ground water supplies for sustainable irrigation in the area.

In general, the renewable inputs accounted for about 30% of total inputs in Rainfed-intensive and Irrigated-intensive systems, and about 40% in Notillage intensive systems.

Table 3.8. Emergy evaluation of 1 ha of rain fed intensive agricultural production in the Rolling Pampas.

Note Item	Unit	Data (unit/ha/y)	Emergy/unit (sej/unit)	Solar E (E+13 sej/y)	Em\$ Value (1990 US\$)
Renewable resc	ources:				
1 Rain, chei	mical J	4.28E+10	1.82E+04	77.9	399.7
Nonrenewable	resources use	from within sy	stem:		
2 Net Top S	Soil Loss J	1.36E+10	7.40E+04	100.4	514.7
Sum of free inp	uts			178.3	914.4
Purchased reso	urces:				
3 Fuel	J	5.99E+09	6.60E+04	39.5	202.7
4 seeds (en	ergy) J	1.69E+09	2.47E+04	4.2	21.5
5 seeds (inf	o) US\$	5.27E+01	1.95E+12	10.3	52.7
6 Nitrogen	gN	5.75E+04	3.80E+09	21.9	112.1
7 Phosphate	e gP	6.30E+03	3.90E+09	2.5	12.6
8 Herbicide	s g	4.00E+03	1.48E+10	5.9	30.4
9 Human la	ibor h	4.35E+00	1.68E+12	0.7	3.7
10 Machiner	y g	5.33E+03	6.70E+09	3.6	18.3
11 Goods	US\$	1.50E+01	1.95E+12	2.9	15.0
Sum of purchas	ed inputs			91.4	469.0
Products of the	agricultural p	hase			
12 Yield (dry	y) g	7.00E+06	3.85E+08	269.8	1383.4
			3.84E+08	269.0	1383.4
	j	8.14E+10	3.31E+04	269.8	1383.4
			3.30E+04	269.0	1379.6

Calculations and references for basic data are given in Appendix D.

Emergy/mass (w/ labor): 3.85 E+8 sej/g

(w/o labor): 3.84 E+8 sej/g

Transformity (w/labor): 3.31 E+4 sej/j

(w/o labor): 3.30 E+4 sej/j

Table 3.9. Emergy evaluation of 1 ha of irrigated intensive agricultural production in the Rolling Pampas.

Note Item	Unit	Data (unit/ha/y)	Transformity (sej/unit)	Solar E (E+13 sej/y)	Em\$ Value (1990 US\$)
Renewable resources:					
1 Rain, chemical	J	4.28E+10	1.82E+04	77.9	399.7
2Ground water	J	9.11E+08	2.79E+04	2.5	13.0
Nonrenewable resource	es use fi	rom within syst	em:		
3 Net Top Soil Loss	s J	1.36E+10	7.40E+04	100.4	514.7
Sum of free inputs				180.9	927.4
Purchased resources:					
4 Fuel	J	1.06E+10	6.60E+04	69.7	357.6
5 seeds (hybrid)	J	1.74E+09	2.47E+04	4.3	22.0
6 seeds (info)	US\$	6.20E+01	1.95E+12	12.1	62.0
7 Nitrogen	gN	9.66E+04	3.80E+09	36.7	188.2
8 Phosphate	gP	9.00E+03	3.90E+09	3.5	18.0
9 Herbicides	g	5.00E+03	1.48E+10	7.4	37.9
10 Human labor	h	5.15E+00	1.68E+12	1.0	5.2
11 Machinery	g	1.03E+04	6.70E+09	6.9	35.5
12 Goods	US\$	1.50E+01	1.95E+12	2.9	15.0
Sum of purchased inpu	ıts			144.6	741.4
Products of the agricult	tural ph	ase			
12 Yield (dry)	g	1.30E+07	2.50E+08	325.4	1668.9
			2.50E+08	324.4	1663.7
	j	1.34E+11	2.43E+04	325.4	1668.9
			2.42E+04	324.4	1663.7

Calculations and references for basic data are given in Appendix D.

Emergy/mass (w/ labor): 2.50 E+8 sej/g

(w/o labor): 2.50 E+8 sej/g

Transformity (w/ labor): 2.43 E+4 sej/j

(w/o labor): 2.42 E+4 sej/j

Table 3.10. Emergy evaluation of 1 ha of no-tillage intensive agricultural production in the Rolling Pampas.

Note Item	Unit	Data	Transformity	Solar E	Em\$ Value	
		(unit/ha/y)	(sej/unit)	(E+13 sej/y)	(1990 US\$)	
Renewable resources:						
1 Rain, chemical	J	4.28E+10	1.82E+04	77.9	399.7	
Nonrenewable resources	s use fr	om within syste	em:			
2 Net Top Soil Loss	J	6.78E+09	7.40E+04	50.2	257.3	
Sum of free inputs Purchased resources:				128.1	657.1	
3 Fuel	J	3.18E+09	6.60E+04	21.0	107.7	
4 seeds (energy)	J	1.33E+09	2.47E+04	3.3	16.9	
5 seeds (info)	US\$	5.15E+01	1.95E+12	10.0	51.5	
6 Nitrogen	gN	6.40E+04	3.80E+09	24.3	124.7	
7 Phosphate	gP	2.34E+03	3.90E+09	0.9	4.7	
8 Herbicides	g	7.45E+03	1.48E+10	11.0	56.5	
9 Human labor	hr	1.50E+00	1.68E+12	0.3	1.5	
10 Machinery	g	3.33E+03	6.70E+09	2.2	11.5	
11 Goods	US\$	1.50E+01	1.95E+12	2.9	15.0	
Sum of purchased input	s			76.0	390.0	
Products of the agricultu	ıral pha	ase				
12 Yield (dry)	g	5.70E+06	3.58E+08	204.2	1047.0	
			3.58E+08	203.9	1047.0	
	j	7.36E+10	2.77E+04 2.77E+04	204.2 203.9		

Calculations and references for basic data are given in Appendix D.

Emergy/mass (w/ labor): 3.58 E+8 sej/g

(w/o labor): 3.58 E+8 sej/g

Transformity (w/ labor): 2.77 E+4 sej/j

(w/o labor): 2.77 E+4 sej/j

Soil loss represented about 35% of inputs in Rainfed-intensive and Irrigated-intensive systems (Tables 3.8 and 3.9) but was much reduced in the Notillage intensive system. Purchased inputs made up from 35% to 45% of total inputs. Human services (labor) accounted for a relatively small percentage of purchased inputs reflecting the industrialized nature of modern agriculture in the Rolling Pampas.

Transformities and emergy per mass of agricultural yield from the evaluated production systems are given in Tables 3.8 to 3.10. Since the yields are represented as total mass of yield (dry weight) and it is the sum of all crops grown on an annual basis, the emergy per mass and transformity represent the average yield rather than individual commodities. Emergy per mass ranges from 2.54E+08 to 3.85E+08 sej/g and transformities range from 2.47E+04 to 3.31E+04 sej/j. Emergy per mass and transformities are given with and without the inclusion of labor to facilitate their use in other analysis where labor might be evaluated separately. On the average, labor inputs represent less than 1% of the total inputs in these production systems.

Soil erosion was considered as a non-renewable resource flow in the evaluation of the Rolling Pampas agriculture. Puricelli (1992) noted that erosion is affecting the soil of the region since the beginning of the last century. During the Agriculturization stage soil erosion reached its highest proportions. Since that period efforts have been made to implement practices that would conserve the resource. The most impressive results have been those of the no-tillage

systems (Lattanzi, 1998; Marelli, 1998). The relative emergy of soil loss is graphed for each of the time periods in Figure 3.14, showing the significant increase during agriculturization.

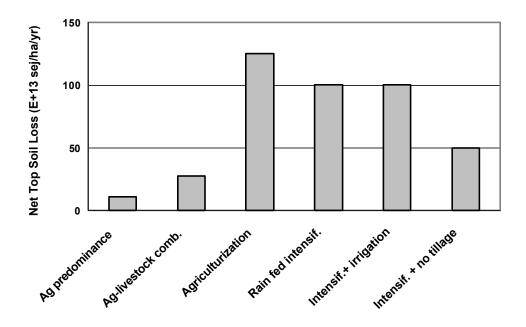


Figure 3.14. Emergy value of net topsoil loss in the production systems of the Rolling Pampas during the 20th century.

A division of labor concerning use of agricultural machinery characterizes farming in the area. The farmer often contracts out harvesting and other productive functions to someone owning appropriate machinery. This arrangement maximizes machine use and reduces the amount of capital investment for the area as a whole (Barsky *et al.*, 1988), as shown by the low values corresponding to the flows of agricultural machinery in the Emergy evaluation tables.

Yields of production systems are expressed both in mass and energy units in the Emergy evaluation tables. The highest outputs per unit area were obtained under intensive production systems with complementary irrigation (Figure 3.15). Moreover, the adoption of this technology stabilizes the yields, since occasional conditions of droughts are the main cause of yield variability in the area (PROSAP, 1997; Pizarro, 1998).

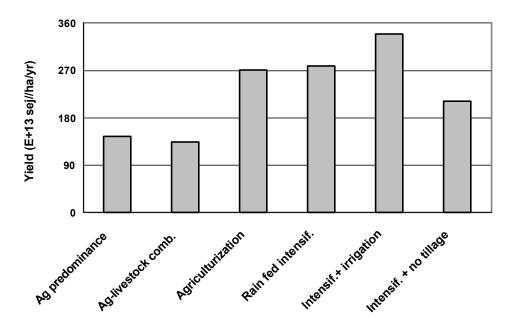


Figure 3.15. Emergy yields in the Rolling Pampas during the 20^{th} century.

From an emergy perspective, systems performance involves more than physical outputs and purchased inputs. Environmental energies, from both renewable sources and storages of past biosphere production are also considered (Brown, 1998). Transformities for the analyzed production systems, relating total emergy used and energy yielded, are shown in Figure 3.16. According to the

results, irrigated intensive systems are the most emergy-efficient, as the increment in the use of inputs for irrigation is overcome by the impressive yields.

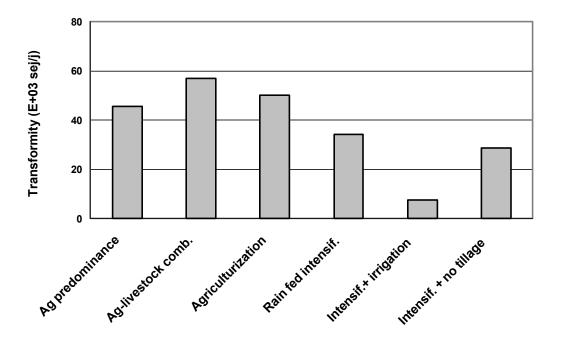


Figure 3.16. Transformities for agricultural production in the Rolling Pampas during the 20th century.

Historical Evaluation of Agricultural Systems

Systems diagrams for each of the three historical agricultural systems

(Low energy tenant farming, Mixed grain and livestock production, and

Agricultural industrialization), along with emergy evaluation tables are given in

Appendix D.

Figure 3.17 shows the changes in inputs in the last century. Generally, the fuel use has increased significantly, while human labor has decreased.

Obviously, the use of inorganic fertilizers and pesticides has increased as well. In

the early periods renewable inputs accounted for about 60% of total inputs, while renewable inputs in the modern production systems are only about 30% of total. Soil erosion had increased until the mid century and has declined in recent years, as shown in Figure 3.14 (p 29).

Empower density (Emergy/time/unit area) of agricultural production, shown in Figure 3.18 has increased during the past century. In the early part of the century empower density of agricultural production systems was about 1.4E+15 sej/ha/y, and by the century's end had doubled, reaching about 3.0E+15sej/ha/y.

Grain production during the Agricultural predominance stage relied on human and animal labor. No agrochemicals were used for crop production.

Throughout the Mixed farming period horses were slowly replaced with tractors. The rotation, including both agriculture and cattle raising, helped to conserve the nutrient balance of the soils. This situation changed radically with the Agriculturization of the Rolling Pampas, in which the agriculture-livestock rotation was replaced by continuous agriculture.

Figure 3.19 shows the ratio between the emergy of purchased goods and services respect to the free emergy coming from the environment. Purchased resource flows increased their relative importance throughout the century, especially for the Intensification period. However, it is important to note that the low ratio for the Agriculturization period is related to the significant soil erosion, also a "free" flow from nature.

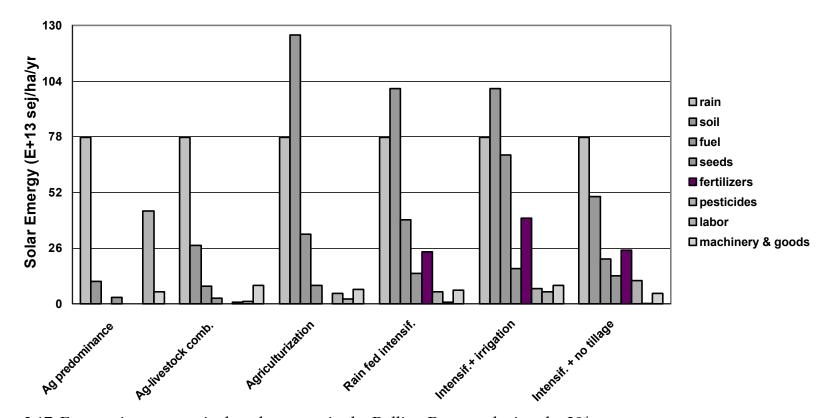


Figure 3.17. Emergy input to agricultural systems in the Rolling Pampas during the 20th century.

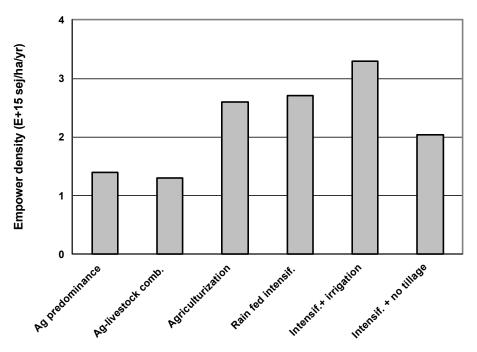


Figure 3.18. Empower density of agricultural production in the Rolling Pampas during the 20^{th} century.

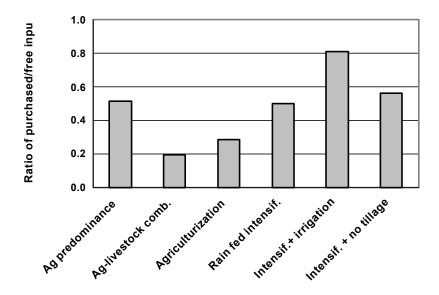


Figure 3.19. Relative importance of purchased inputs in the Rolling Pampas during the 20^{th} century.

At the beginning of the century, the most important external input was human labor. However, after 1940 the productivity of hand labor experienced a sharp increment. Use of tractors, herbicides, and mechanical harvest are among the factors that reduced human labor requirements (Coscia and Torcelli, 1968). The proportion between service inputs (human labor) and total purchased emergy for each of the periods is shown in Figure 3.20.

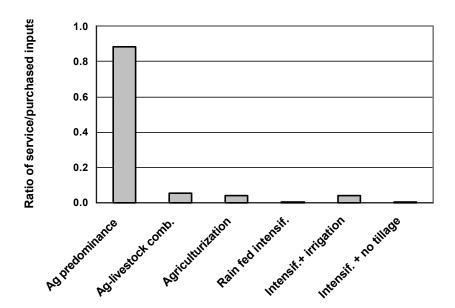


Figure 3.20. Relative importance of human labor in the Rolling Pampas during the 20th century.

At the beginning of the century, the country's natural advantages allowed production systems to be competitive despite slow adoption of technological innovation (Figure 3.15, p 30). However, during the Mixed farming period the productivity of the Pampean systems remained stagnant. At the same time other

countries, such as Australia and the United States, exhibited significant improvement in agricultural performance resulting from technological innovation (Giberti, 1988). The tendency in the Rolling Pampas began to change during the Agriculturization period, when improved techniques, genetic material, agrochemicals and specialized machinery resulted in increasing productivities (Giberti, 1988; Obschatko; 1988).

Although productivity increased during the Agriculturization stage, the excessive amount of fuel used for mechanical weed control together with alarming erosion rates, resulted in higher amounts of emergy invested per unit of energy output and therefore, a higher transformity.

Emergy Indices of Agricultural Sustainability

Emergy based indices of sustainability are summarized in Table 3.11. For comparative purposes, indices for corn production in Italy and bio-ethanol in Brazil are also included. These ratios give a better insight to the issue of agricultural efficiency and performance, and its relationship to natural capital and sustainability.

According to the results, the more sustainable alternative in the present conditions of intensification of agricultural production in the Rolling Pampas were the No-tillage intensive systems, with relatively high emergy yield ratios and small loads on the environment. Moreover, reliance on flows of renewable

emergy for these systems was 1.3 and 1.6 times higher than for Rainfed-intensive and Irrigated-intensive systems, respectively (Figure 3.21).

Figure 3.22 shows the EYR and ELR for each of the analyzed systems. Production systems from the Mixed farming period were the most emergy efficient. Although productivity was not as high as in the more recent periods, agricultural production was characterized by low use of external inputs.

Table 3.11. Emergy indices for production systems of the Rolling Pampas during the 20th century, including corn production in Italy and bio-ethanol in Brazil.

Production System	% Renew	EYR	ELR	EIS
Ag predominance	59	2.95	0.70	4.19
Mixed farming	63	6.16	0.58	10.67
Agriculturization	31	4.53	2.18	2.08
Rain fed intensification	31	2.99	2.27	1.32
Intensification + irrigation	25	2.23	2.95	0.76
Intensification + no tillage	40	2.78	1.48	1.87
Corn (1 ha- Italy)*	25	1.4	3.0	0.45
Bio-ethanol (1 ha-Brazil)*	12	2.0	7.7	0.26

Agriculturization yielded also high amount of emergy compared to the emergy of external inputs. However, as already described, production systems of this stage relied heavily on emergy flows of a local non-renewable storage, the soil.

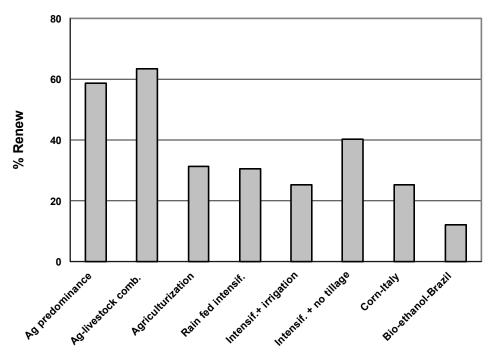


Figure 3.21. Percent renewable energy contribution to agricultural production in the Rolling Pampas during the 20th century.

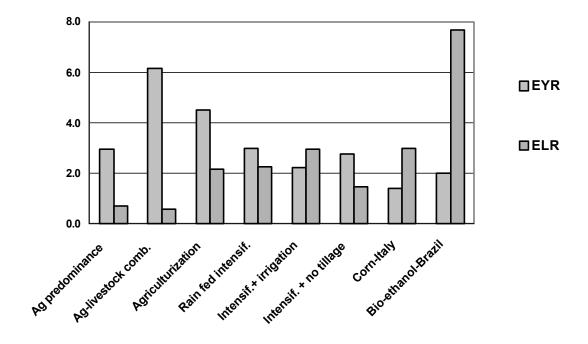


Figure 3.22. Emergy yield ratio and Environmental loading ratio for agricultural production in the Rolling Pampas during the 20th century.

Farming systems that combined agriculture with livestock production had the highest EIS value (Figure 3.23). On the other hand, intensive agriculture with complementary irrigation had the lowest EIS. This type of production systems is typically dominated by the flows of purchased resources

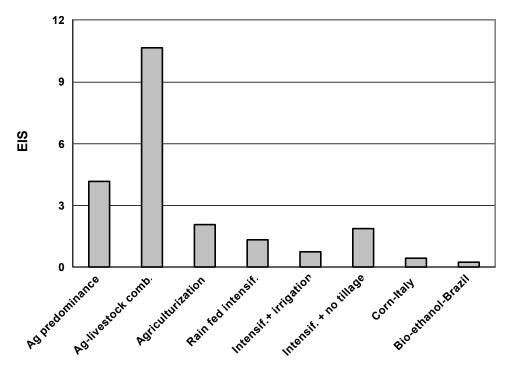


Figure 3.23. Emergy Index of Sustainabilty in the Rolling Pampas during the 20^{th} century.

CHAPTER 4 DISCUSSION

Argentina

The emergy analysis of the Argentine economy throughout the 20th century shows the influence of macroeconomic policies on sustainability.

Argentina started the century relying mostly on the use of renewable energy, with nonrenewable energy increasing its importance as the economy developed. Policies implemented after World War II slowed the growth of the economy (Veganzones and Winograd, 1997) and also affected its productivity in emergy terms. This was reflected by the low EYR values exhibited by Argentina during the first two thirds of the century.

Emergy exports in Argentina shifted from being mainly agricultural towards oil and primary industrial products. Before World War II, Argentina was responsible for approximately 70% of the linseed, 60% of the maize, 20% of the wheat, 40% of the chilled and frozen meat and 12% of the wool in the world market for these commodities (Ferns, 1973). During the World Depression agricultural exports declined as countries around the world adopted protectionist strategies. However, an agreement signed with the United Kingdom encouraged livestock raising, and there was a reorientation of

production and exports from plant to livestock products (Veganzones and Winograd, 1997). During the 1944-1975 period, economic policies implemented in the country towards industrialization were detrimental for the agricultural sector. As described by Balze (1995), reduced investment levels and low technological innovation led to a decrease in production and fewer agricultural exports. The last two periods of the century represented a significant shift in the Argentine exports towards oil and primary industrial products, although agriculture participation was still significant. This diversification was due in part to privatization and trade liberalisation, completed by the early 1990s (Veganzones and Winograd, 1997).

In 1996, crude oil dominated exports from the energy sector, followed by gasoline, gas oil, and liquid gas (Consejo Tecnico de Inversiones [CTI], 1996). Exported emergy per dollar of crude oil in Argentina was approximately 6.5 times larger than the exported emergy per dollar of soybean during that year (1.13E+13 sej/US\$ and 1.75E+12 sej/US\$, respectively). Although the increment in trade after the liberalisation of the economy is considered positive for the recovery of the economy, an export strategy based on the exploitation of non-renewable resources should not be evaluated only in economic terms.

The Emergy Sustainability Index for Argentina during the 20th century was considerably higher than that of more developed economies. This is explained in part by the combination of high flows of renewable emergy and low reliance on purchased emergy. Yet, environmental degradation is present in

Argentina. Soil erosion, water pollution, and deforestation are among the problems that remain to be solved in the future (Programa de las Naciones Unidas para el Desarrollo [PNUD], 1996). However, the radical transformations that redefined the direction of the economy during the 1990s were not accompanied by the necessary policies towards the protection of the environment. Moreover, the fragmentation of the environmental management into numerous environmental departments depending on national, provincial and municipal levels produces an overlapping of jurisdiction, control weakness and non-compliance of existing standards (World Bank, 1995).

Sustainable development in Argentina, a developing country, can be particularly challenging. As described by Walker (1989, qtd. in Bryant, 1992), there is "an inherent, continuing potential for conflict between the state's role as a developer and as a protector and steward of the natural environment on which its existence ultimately depends". Moreover, the process of policy formulation involves a complicity of competing actors (government departments and agencies, national and transnational corporations, non-governmental organizations, multilateral agencies, foreign governments) seeking to influence the outcome (Bryant, 1992). In this context, it is of particular interest to examine the burden of the external debt in Argentina. As described by Manzetti (1991, p6)

The stop-go performance of the Argentine economy since the early 1950s has been closely related to balance-of-payments difficulties. Each period of expansion was cut short by a balance-of-payments crisis and increasing arrears, which led to a foreign debt of over \$60 billion in 1989. What started as primarily a current-account problem caused by the stagnation

of exports in the early 1950s turned into a capital-account squeeze caused by heavy annual service payments on the external debt in the early 1980s. Every conceivable policy was applied at one time or another to the balance-of-payments problem, from strict regulation of imports deposits and exchange surcharges to multiple exchange rates or fluctuating rates. This frequent change in policy translated into not only the rapid turnover of government officials with different policy approaches, but also into the successive failure of the measures previously adopted. Sometimes this was due to poor conceptualization, poor management, and often to external factors beyond the control of policymakers.

At the end of the 20th century doubts are again arising regarding the capability of Argentina to pay off its external obligations. According to Janada (1999) "although the ratio of exports that Argentina should use to honor its external debt is not that large, the country is not generating enough foreign currency (or alternatively, it is consuming much more foreign currency than it should)". In emergy terms, however, the situation is just the opposite.

As an exporter of commodities (oil, minerals, agricultural products),
Argentina is providing buyers more emergy than she receives in exchange.

Money payments account only for the services to process these environmental commodities and do not reflect the emergy investment of nature to make them (Odum, 1996). Table 4.1 shows several indicators of the external debt in Argentina. Dollar values of total debt stocks were converted to solar emjoules of emergy using the emergy/money ratio of the world corresponding to each year (Brown and Ulgiati, 1999); for total debt service values, an emergy/money ratio of 2.95E+12 sej/USD was applied. This last ratio was calculated as a weighted average between the emergy/money ratio of Argentina, the exported emergy per

dollar of agricultural products (1.75E+12 sej/USD) and per dollar of crude oil (1.13E+13 sej/UDS). Although these last two ratios varied along the period of time analyzed, they were considered constant for calculation purposes. However, the highest prices for crude oil and agricultural products were used to compute these ratios, obtaining as a result the lowest emergy per dollar levels and, therefore, making this approach a very conservative one. Exports during the analyzed period were considered to come from the agroindustrial (65 %), energy (10%), and industrial (25%) sectors of the economy (MERCOSUR, 1998).

According to the results, Argentina had already paid its total debt stocks by 1985. In 1996, the accumulated emergy value of total debt service represented almost 3 times the emergy of the total debt stocks. Emergy values of total debt service might be overestimated in this analysis, since Argentina has been using not only higher-emergy export revenues but also lower-emergy external refinancing to repay debt interests and principal. However, the implications of the results still add to the discussion and reflect the need to incorporate environmental considerations in the Argentine external debt issue. As long as external trade is balanced only in economic terms, developing countries will continue the transfer of their natural resources to the developed economies in order to cancel an external debt that has already been paid. Emergy accounting, which reflects the real value of commodities and raw materials, can become a key methodology to achieve environmental justice in international trade.

Table 4.1. External debt of Argentina during the 1980-1996 period.

Year	Global emergy/\$ ratio (1)	Debt service ratio (2)	Total debt stocks		Total debt service		Accumulated TDS
	E+12 sej	%	E+06 USD (2)	E+18 sej	E+06 USD (2)	E+18 sej	E+18 sej
1980	1.50	37.3	27157	40736	4182	12337	
1983	1.38	69.7	45920	63370	6805	20075	32412
1984	1.34	52.4	48857	65468	5197	15331	47743
1985	1.30	58.9	50945	66229	6089	17963	65705
1986	1.28	82.8	52450	67136	7323	21603	87308
1987	1.27	74.3	58458	74242	6244	18420	105728
1988	1.26	44.5	58741	74014	5023	14818	120546
1989	1.25	36.2	65257	81571	4357	12853	133399
1990	1.24	37.0	62233	77169	6161	18175	151574
1991	1.24	34.4	65403	81100	5545	16358	167932
1992	1.22	29.7	68345	83381	5003	14759	182691
1993	1.19	36.7	70576	83985	6556	19340	202031
1994	1.15	30.9	77434	89049	6693	19744	221775
1995	1.10	34.2	83536	91890	9692	28591	250367
1996	1.07	44.2	93841	100410	14021	41362	291728

⁽¹⁾ Source: Brown and Ulgiati, 1999.

Rolling Pampas

Macroeconomic policies targeting fiscal, monetary, trade, investment, and other issues, as well as specific policies towards the agriculture sector, affect the environment in which a farmer has to produce (Kiker, 1993). National policies

⁽²⁾ Source: European Parliament, 1999.

and programs during the 20th century had an enormous impact on the evolution of the Pampean agriculture. Although intended for the evaluation of external influences on tropical agriculture, a model by Kiker is particularly useful to explain linkages between macroeconomic policies and ecological sustainability in the Rolling Pampas. The model focuses particularly on prices of products and inputs, which are established either in markets or by government, farmers having virtually no control over them. Based on these premises, the author proposed three possible outcomes, shown in Figure 4.1.

Intense colonization of the territory, along with rapid development of infrastructure and immigration during the second half of the 19th century, ensured the prosperity of an agro-export model that integrated Argentina with Europe (Veganzones and Winograd, 1997). The natural conditions of the Pampean region for agricultural production are reflected by the relatively high emergy yields during the Agriculture Predominance period, which largely depended upon flows of renewable emergy.

The collapse of trade and prices and worldwide adoption of protectionist policies as a result of the Great Depression and World War II had a negative impact on the Argentine agricultural export model (Veganzones and Winograd, 1997). Soon after the end of World War II, the Argentine government implemented an industrialization program that would radically change the country's economic and social structure (Diaz Alejandro, 1970; Veganzones and Winograd, 1997).

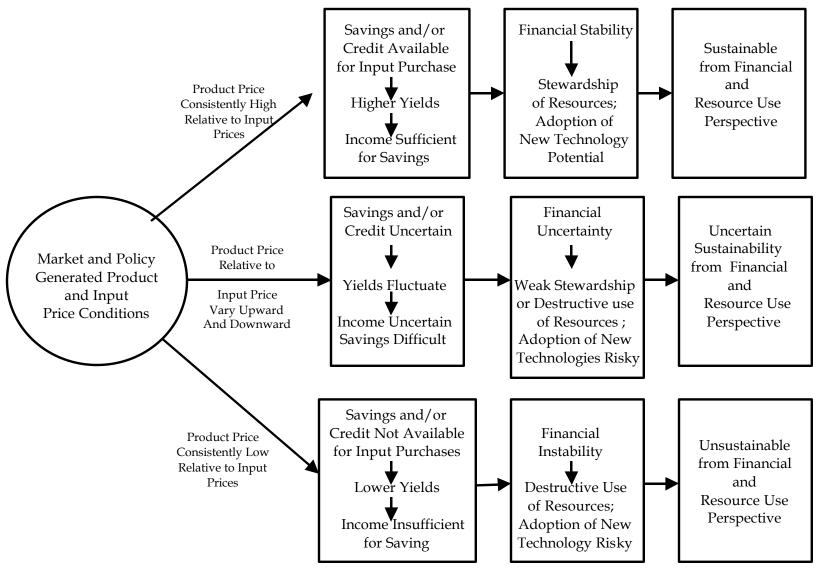


Figure 4.1. Different scenarios stemming from product and input price conditions (Kiker, 1993).

The Argentine industrialization process was made possible at the expense of agriculture. During that period, there was a reorientation towards livestock production and exports that compensated partially the decrease in grain production (Barsky *et al.*, 1988). The Argentine Trade Promotion Institute (IAPI) controlled the price of the agricultural products, benefiting urban activities over agricultural exports (Veganzones and Winograd, 1997). Return rates for farmers producing exportables were also lowered by increases in rural wages, resulting from the competition represented by urban centers (Diaz Alejandro, 1970). Adoption of modern inputs and machinery from North America and Western Europe was hindered by excessive prices and discriminating tax policies (Balze, 1995). Technological innovation was also held up by the lack of investment in public agricultural research and extension (Diaz Alejandro, 1970).

From an emergy perspective, agricultural production was extremely sustainable during this period. The EIS reached the highest value for the century, a consequence of relatively large emergy yields and small stress on the environment. Mixed farming systems benefited from the positive effects of cattle raising on the quality of soils, not only decreasing erosion rates but also conserving the nutrients balance. However, the remarkable ecological conditions of the Argentine Pampas could not compete with the improvement in productivity fueled by technological innovation in other countries. As a result, the country lost foreign markets (Giberti, 1988).

During the 1950s measures for supporting agriculture were taken. However, they failed in restoring agricultural export production. This trend was gradually reversed after the 1960s, due to improved production conditions in the agricultural sector (Veganzones and Winograd, 1997). Most important technological changes occurred in grain production: agronomic practices, machinery, genetic material, and agrochemicals were responsible for the recovery in grain output that lasted until the crisis of the international grain market in 1985 (Obschatko, 1988).

Although agricultural productivity was improved during this period, it represented a setback from the point of view of ecological sustainability. During the agricultural industrialization of the Rolling Pampas, use of renewable emergy decreased approximately 50%. Load on the environment, measured through the ELR, increased 5 times. This was a direct consequence of soil erosion, enhanced by continuous agriculture and excessive tillage for weed control.

After a brief re-closure of the economy in the early 1980s, a gradual trade reform was undertaken. This liberalization process, intensified during the 1989-1991 period, resulted in Argentina shifting from "being one of the most protected economies to being one of the least" (Pols, 1999, p. 20). The liberalization of the economy exposed farmers to the world grain market, characteristically unstable with price variations occurring annually. The reduction in the number of tariff lines subject to import licensing and the elimination of different taxes decreased

the price of inputs. The private agricultural sector reaction included adoption of technological innovation, vertical integration, and concentration of land. A general improvement in productivity, production and exports was accomplished. The transformation of the economy also improved the country's financial system, resulting in lower interest rates. However, farmers with high debit/asset ratios could not take advantage of these improved terms of credit (Obschatko, 1998).

From an emergy perspective, the intensification of the production systems in the Rolling Pampas implied a larger reliance on purchased inputs. This is reflected by the EYR, approximately half of the value obtained for Mixed grain and livestock production systems. The most promising among the three analyzed alternatives for this period was intensification with adoption of no-tillage production practices. The positive impact of these production systems on soil conservation reduces the load on the environment and increases the use of renewable emergy. Similar values for transformity were obtained with and without the inclusion of human labor in all agricultural systems except in the case of Low energy tenant farming, corresponding to the first decades of the 20th century. However, it is important to note that throughout the century the management skills required to produce in a competitive global market may result in differences between the two types of transformities in the other agricultural production systems as well.

Concerning the environmental impact of the intensification, there is a lack of appropriate legislation. As an example, farmers starting irrigation projects in the Rolling Pampas do not have to comply with any regulation. Moreover, there is not enough information regarding the sustainable volumes of water to be extracted from the aquifers. State programs encouraging conservation practices through economic incentives are practically nonexistent.

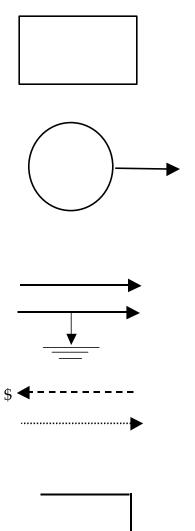
Conclusions

For the century that is just starting, Argentina has not only the opportunity but also the responsibility to seek economic development that includes the conservation of its vast resource base. As an exporter of emergy rich materials, the country should seek the recognition of environmental value in international commerce. The unfair terms of trade for Argentina and many developing countries are at the heart of the external debt issue. Changing them should be the base for a realistic strategy towards solving this issue.

Liberal economic theory and trade liberalization has lead to an increase in the productivity of the agricultural sector, but has also increased the dependency of farmers on external energy inputs. Moreover, agriculture in the Rolling Pampas is increasingly relying on foreign technological innovation (Pizarro, 1998). Under the current socio-economic conditions, production systems similar to those of the Mixed farming period are no longer achievable (Viglizzo, 2001). In this context, policies towards the agricultural sector should encourage the more

sustainable among the possible options. Besides adaptation of foreign technology to the local conditions, public research should seek alternative, environmentally sound solutions. Strategic alliances between farmers, municipalities, and industry, to take advantage of by-products and wastes (by-product synergy) might be a step in that direction. Emergy accounting, a methodological tool that attempts to balance humanity and environment, constitutes a useful tool towards that challenge.

APPENDIX A ENERGY SYSTEMS SYMBOLS¹



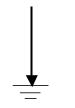
System Frame. A rectangular box is drawn to represent the boundaries that are selected. Boundaries selected must define a three dimensional prism around the system.

Source. Any input that crosses the boundaries is a source, including pure energy flows, materials, information, genes, services, and inputs that are destructive. Sources are arranged around the outside border from left to right in order of their solar transformity, starting with sunlight on the left and information and human services on the right.

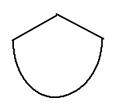
Pathway line. Any flow is represented by a line, including pure energy, materials and information. Money is shown with dashed lines. Where material flows of one kind are to be emphasized, use dotted lines. Barbs (arrowheads) on the pathways mean that the flow is driven from behind the flow (donor driven) without appreciable backforce from the next entity. Lines without barbs flow in proportion to the difference between two forces and may flow in either direction.

Outflows. Any outflow that still has available potential, materials more concentrated than the environment, or usable information is shown as a pathway from any of the three upper system borders, but not out the bottom.

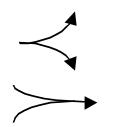
Adapted from Odum, 1996, p 290.



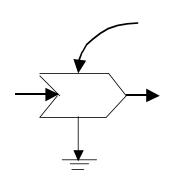
Heat Sink. This symbol represents the dispersal of available energy (potential energy) into a degraded, used state, not capable of further work. Representing the second energy law, heat-sink pathways are required from every "transformation" and tank symbols. Using finer lines for heat sinks keep them from dominating the diagram. No material, available energy, or usable information ever goes through heat sinks, only degraded energy.



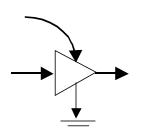
Storage Tank. Any quantity stored within the system is given a "tank" symbol, including materials, pure energy, money, assets, information, image, and quantities that are harmful to others. Every flow in or out of a tank must be the same type of flow and measured in the same units.



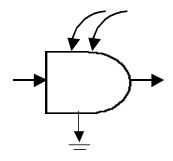
Adding Pathways. Pathways add their flows when they join or when they go into the same tank. No pathways should join or enter a common tank if they are of a different type of transformity or are measured in different units. A pathway that branches represents a split of flow into two of the same type.



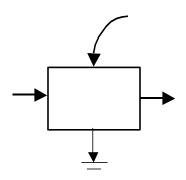
Interaction. Two or more flows that are different and both required for a process are connected to an "interaction" symbol. The flows to an interaction are drawn to the symbol from left to right in order of their transformity, with the lowest quality one connected to the notched left margin. The output of an interaction is an output of a production process, a flow of product. These should usually go to the right, since production is a quality-increasing transformation.



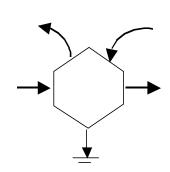
Constant Gain Amplifier. A special interaction symbol is used if the output is controlled by one input (entering the symbol from the left), but most of the energy is drawn from the other input (entering from the top).



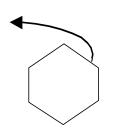
Producers. "Producers" symbols are used for units on the left side of the systems diagram that receive commodities and other inputs of different types interacting to generate products. The "producer" symbol implies that there are intersections and storages within. Sometimes it may be desirable to diagram the details of interactions and processes inside. Producers include biological producers, such as plants, and industrial production.



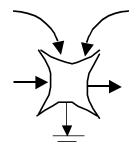
Miscellaneous Box. The rectangular box is used for any subsystem structure and/or function. Often these boxes are appropriate for representing economic sectors such as mining, power plants, commerce, and so on. The box can include interactions and storages with products emerging to the right. Details of what goes on within the consumer are not specified unless more details are described or diagrammed inside.



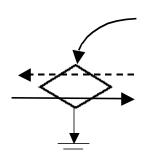
Consumers. "Consumer" symbols are used for units on the right side of the systems diagram that receive products and feedback services and materials. Consumers may be animal populations or sections of society, such as the urban consumers. A consumer symbol usually implies autocatalytic interactions and storages within. However, this symbol is a class symbol, and details of what goes on within are not specified exactly unless more details are diagrammed inside.



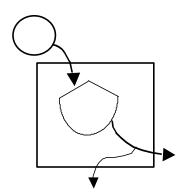
Counterclockwise Feedbacks. High-quality inputs from consumers, such as information, controls, and scarce materials, are fed back from right to left in a diagram. Feedbacks from right to left represent a diverging loss of concentration; the service is usually being spread out to a larger area. These flows should be drawn with a counterclockwise pathway (up, around, and above the originating symbol-not under the symbol). These drawing procedures are related to representing energy hierarchies.



Switch. The concave-sided box represent switching processes, those that turn on and off. The flows that are controlled enter and leave from the sides. The pathways that control the switches are drawn entering from above to the top of the symbol. This includes thresholds and other information. Switching occurs in natural processes as well as with human controls. Examples are earthquakes, reproductive actions, and water overflows of a riverbank.



Exchange Transaction. Where quantities in one flow are exchange for those of another, the "transaction" symbol is used. Most often the exchange is a flow of commodities, goods, or services exchanged for money (drawn with dashed lines). Often the price that relates one flow to the other is an outside source of action representing world markets; it is shown with a pathway coming from above to the top of the symbol.



Material Balances. Since all inflowing materials either accumulates in system storages or flow out, each inflowing material, such as water or money, needs to have outflows drawn.

APPENDIX B SUMMARY OF DEFINITIONS AND CONCEPTS¹

Available energy: Potential energy capable of doing work and being degraded in the process (exergy). Units: kilocalory, joule, etc.

Useful energy: Available energy used to increase system production and efficiency.

Power: Useful energy flows per unit time. Unit: kcal/time.

Emergy: Available energy of one kind previously required directly and indirectly to make a product or service. Sometimes is convenient to think of emergy as energy memory. Unit: emjoule.

Empower: Emergy flow per unit time. Unit: emjoule/time.

Transformity: Emergy per unit available energy. The ratio is obtained by dividing the total emergy that was used in a process by the energy yielded by the process. Transformities are used to convert energies of different forms to emergy of the same form. Unit: emjoule/joule.

Solar emergy: Solar energy required directly and indirectly to make a product or service. Unit: solar emjoule.

Solar empower: Solar emergy flow per unit time. Unit: solar emjoule/time.

Solar transformity: Solar emergy per unit available energy. Unit: solar emjoule/joule.

Emdollar: a measure of the money that circulates in an economy as the result of some process. In practice, to obtain the emdollar value of an emergy flow or storage, the emergy is multiplied by the ratio of total emergy to the GDP of the national economy.

¹ Adapted from Odum (1996, p 13) and Brown (1998, p 51).

Maximum Empower Principle: One of the fundamental organizing principles of Emergy Accounting. The principle states that "systems that will prevail in competition with others, develop the most useful work with inflowing emergy sources by reinforcing productive processes and overcoming limitations through system organization.

Energy transformation hierarchy: energy flows of the universe are organized in an energy transformation hierarchy; the position in the energy hierarchy is measured with transformities.

Percent Renewable (% Renew): the percent of the total energy driving a process that is derived from renewable sources. In the long run, only processes with high % Renew are sustainable.

Emergy Yield Ratio (EYR): the ratio of the emergy of the output divided by the emergy of those inputs to the process that are fed back from outside the system under study. It is an indicator of the yield compared to inputs other than local and gives a measure of the ability of the process to exploit local resources.

Environmental Loading Ratio (ELR): the ratio of purchased and nonrenewable indigenous emergy to free environmental emergy. It is an indicator of the pressure of the process on the local ecosystem stress due to production activity.

Emergy Index of Sustainability (EIS): an index that accounts for yield, renewability, and environmental load. It is the incremental emergy yield compared to the environmental load and is calculated as the ratio of emergy yield to environmental load (EYR/ELR).

APPENDIX C EMERGY EVALUATION TABLES AND FOOTNOTES FOR ARGENTINA

Table C.1. Annual emergy flows supporting the Argentine economy during the 1900-1929 period.

Note	Item	Raw Unit	Emergy/unit (sej/unit)	Solar Emergy (E20 sej)	EmDollars (E9 1990 \$)	
Renev	Renewable resources:					
19	Sunlight	1.68E+22J	1.00E+00	167.99	1.19	
21	Rain, chemical	1.47E+19J	1.82E+04	2680.46	19.06	
31	Rain, geopotential	7.03E+18J	2.79E+04	1958.65	13.93	
41	Wind, kinetic energy	2.07E+19J	1.50E+03	309.67	2.20	
51	Waves	8.05E+17J	3.06E+04	245.93	1.75	
67	Гide	3.19E+18J	1.68E+04	538.03	3.83	
7 I	Earth Cycle	2.78E+18J	3.44E+04	955.82	6.80	
Indigenous renewable energy:						
81	Hydroelectricity	1.21E+15J	1.65E+05	2.00	0.01	
91	Ag. Production	6.30E+16J	1.00E+05	62.97	0.45	
10 I	Livestock Production	1.60E+16J	1.00E+06	160.40	1.14	
11 I	Fisheries Production	9.91E+13J	1.00E+06	0.99	0.01	
12 I	Fuelwood Production	3.21E+16J	1.87E+04	6.01	0.04	
13 I	Forest Extraction	2.04E+16J	1.87E+04	3.81	0.03	
Nonrenewable sources from within system:						
141	Vatural Gas	2.61E+15J	4.80E+04	1.25	0.01	
150	Oil	1.02E+16J	5.40E+04	5.52	0.04	
161	Minerals and rocks	1.54E+12g	1.00E+09	15.43	0.11	
17 N	Metals	1.02E+10g	1.00E+09	0.10	0.00	
187	Гор Soil	1.25E+17J	7.40E+04	92.86	0.66	

Table C.1 (continued)

Imports and outside sources:						
3.11E+16 J	6.60E+04	20.54	0.15			
8.02E+11 g	1.80E+09	14.44	0.10			
2.01E+12 g	1.00E+09	20.08	0.14			
4.57E+15 J	2.00E+05	9.15	0.07			
7.69E+16 J	4.00E+04	30.75	0.22			
1.87E+11 g	3.80E+08	0.71	0.01			
1.18E+16 J	3.49E+04	4.13	0.03			
2.70E+10 g	6.70E+09	1.81	0.01			
6.83E+09\$	1.60E+13	1092.16	7.77			
Exports:						
2.59E+16 J	1.00E+05	25.93	0.18			
4.89E+15 J	1.00E+06	48.94	0.35			
4.22E+15 J	3.49E+04	1.47	0.01			
4.37E+15 J	3.49E+04	1.53	0.01			
1.47E+11 g	3.80E+08	0.56	0.00			
7.11E+09\$	1.41E+13	999.71	7.11			
	8.02E+11 g 2.01E+12 g 4.57E+15 J 7.69E+16 J 1.87E+11 g 1.18E+16 J 2.70E+10 g 6.83E+09 \$ 2.59E+16 J 4.89E+15 J 4.22E+15 J 4.37E+15 J 1.47E+11 g	8.02E+11 g 1.80E+09 2.01E+12 g 1.00E+09 4.57E+15 J 2.00E+05 7.69E+16 J 4.00E+04 1.87E+11 g 3.80E+08 1.18E+16 J 3.49E+04 2.70E+10 g 6.70E+09 6.83E+09\$ 1.60E+13 2.59E+16 J 1.00E+05 4.89E+15 J 1.00E+06 4.22E+15 J 3.49E+04 4.37E+15 J 3.49E+04 1.47E+11 g 3.80E+08	8.02E+11 g 1.80E+09 14.44 2.01E+12 g 1.00E+09 20.08 4.57E+15 J 2.00E+05 9.15 7.69E+16 J 4.00E+04 30.75 1.87E+11 g 3.80E+08 0.71 1.18E+16 J 3.49E+04 4.13 2.70E+10 g 6.70E+09 1.81 6.83E+09\$ 1.60E+13 1092.16 2.59E+16 J 1.00E+05 25.93 4.89E+15 J 1.00E+06 48.94 4.22E+15 J 3.49E+04 1.47 4.37E+15 J 3.49E+04 1.53 1.47E+11 g 3.80E+08 0.56			

Footnotes to Table C.1 Renewable resources:

```
Solar energy:
```

```
Cont Shelf Area =
                     8.71E+11 m2 at 200 m depth
                                                                   (Brown, 1998)
                                                                  (INDEC, 2000)
 Land Area = 2.78E+12 m2
this figure excludes Islas Malvinas and the Argentinean Antarctic territory
 Insolation = 1.57E+02 \text{ kcal/cm2/y}
                                                                  (Brown, 1998)
 Albedo =
                                                                       * estimate
              30%
 Energy (J) = (area including shelf)*(average insolation)*(1-albedo)
              (4186 J/kcal)
              1.68E+22 J/y
Rain, chemical potential energy:
```

2

Land Area = 2.78E+12 m2

Cont Shelf Area = 8.71E+11 m2

Rain (land) = 0.94 m/y(Oxford Encyclopedic World Atlas) Rain (shelf) = 0.42 m/y estimated as 45% of total rain

Energy (land) (J) = (area)(rainfall)(G)(1000 kg/m3)

where G corresponds to Gibbs free energy number= 4940 J/kg = 1.29E+19 J/y

Energy (shelf) (J)= (area of shelf)(rainfall)(G)(1000 kg/m3)

= 1.82E + 18 J/y

Total energy (J) = 1.47E+19 J/y

Table C.1 (continued)

```
3
       Rain, geopotential energy:
        Land Area = 2.78E+12 \text{ m}
        Rain (land) = 0.94 \text{ m}
        Evapotranspiration rate= 0.65 m/y
        Average Elevation =889.87 m
                                                          (estimated from INDEC, 2000)
        Runoff rate = 31\%
                                                                           (Brown, 1998)
        Energy (J) = (area)(% runoff)(water density)(rainfall)(average
                      elevation)(gravity)
                      7.03E+18 J/v
4
       Wind energy:
       Energy (J) = 2.07E+19 J/y
                                                                           (Brown, 1998)
5
       Wave energy:
       Energy (J) = 8.05E+17
                                     J/y
                                                                           (Brown, 1998)
6
       Tidal energy:
       Continental Shelf Area = 8.71E+11 m2
       Average Tide Range = 1.00 m
                                                                           (Brown, 1998)
       Density = 1.03E+03 \text{ kg/m}
                                                                           (Brown, 1998)
       Tides/vear = 7.30E+02
                                                                Estimated as 2 tides/day
       Energy (J) = (shelf)(0.5)(tides/y) (mean tidal range)2(density of
                    seawater)(gravity)
                      3.19E+18
                                                                           (Odum, 1996)
                                     J/y
7
       Earth cycle
       Land Area = 2.78E+12 m2
       Heat flow = 1.00E+06 J/m^2
                                                                            (Odum, 1996)
       Energy (J) = (area)(heat flow)
                  = 2.78E + 18 J/v
Indigenous renewable energy
       Hydroelectricity:
       Production = 2.90E+04 t.e.p./y
                                                                             (Shell, 1969)
       Energy (J) =(t.e.p./y)*(4.184 E+10 J/t.e.p.)
                                                                            (Olade, 2001)
                 = 1.21E + 15 J/v
9
       Agricultural production:
       Production = 1.88E+07 \text{ ton/y}
                                                                  (Díaz Alejandro, 1970)
       Energy (J) = (ton)*(1E06 g/ton)*(20\%)*(4.0 kcal/g)*(4186 J/kcal)
                   = 6.30E + 16
                                     J/y
10
       Livestock production:
       Production = 3.83E+06 \text{ ton/v}
                                                       (Díaz Alejandro, 1970; BAC, 1982)
        Energy (J) = (ton)*(1.00 E+06 g/ton)*(20\%)*(5 kcal/g)*(4186 J/kcal)
                   = 1.60E+16 J/v
11
       Fisheries production:
        Fish Catch = 2.37E+04 \text{ ton/v}
                                                                             (BAC, 1982)
         Energy (J) = (ton)*(1E+06 g/ton)*(5 kcal/g)*(20\%)*(4186 J/kcal)
                    = 9.91E+13 J/v
```

Table C.1 (continued)

```
12
       Fuelwood production
       Production = 3.65E+06 \text{ ton/v}
                                                                                (Bunge, 1940)
       Energy (J) = (ton)(1E+06g/ton)(80\%)(2.625 \text{ kcal/g})(4186 \text{ J/kcal})
                     = 3.21E+16 \text{ J/v}
13
        Forest extraction
         Harvest = 1.60E+06 \text{ ton/y}
                                                                         (Santamarina, 1912)
         Energy(J) = (ton)(1E+06g/ton)(80\%)(3.8 \text{ kcal/g})(4186 \text{ J/kcal})
                    = 2.04E+16
Nonrenewable resources from within
14
        Natural gas
        Production = 6.70E+07 \text{ m}3/\text{y}
                                                                                 (BAC, 1982)
        Energy (J) = (m3/y)(3.9 E+17 J/m3)
                   = 2.61E+15 J/y
15
        Oil
         Production = 2.43E+05 \text{ m}3/\text{y}
                                                                                 (BAC, 1982)
         Energy(J) = (m3/y)(0.87ton/m3)(4.2 E+10 J/ton)
                    = 1.02E+16 J/y
16
        Minerals non metallic/ rocks
         Production = 1.54E+06 \text{ ton/y}
                                                                                 (BAC, 1982)
            Mass(g) = (ton)*(1E6 g/ton)
                    = 1.54E+12 g/y
17
        Metals
         Production = 1.02E+04 ton/y
                                                                                 (BAC, 1982)
            Mass(g) = (ton)*(1E6 g/ton)
                    = 1.02E+10 g/y
18
        Topsoil:
        Arable Land = 1.85E+07 ha
                                                                                (Bunge, 1940)
        Rate of Loss = 1.00E+07 g/ha
        Soil loss = 1.85E+14 \text{ g/y}
        Energy (J) = (2.22 \text{ E}14 \text{ g/y})*(0.03 \text{ OM})*(5.4 \text{ kcal/g})(4186 \text{ J/kcal})
                       1.25E+17 J/y
Imports of outside energy sources:
19
        Crude oil and derivative products
         Imports =
                       7.41E+05 ton
                                                                              (INDEC, 1945)
            Energy (J) = (ton/v)*(4.20 E10 J/ton)
                      = 3.11E+16 J/y
20
        Metals
         Imports =
                       8.02E+05 \text{ ton/y}
                                                                              (INDEC, 1945)
            Mass (g) = (ton/y)*(1.00E+06 g/ton)
                       8.02E+11 \text{ g/y}
21
        Minerals non-metallic/ rocks
         Imports =
                       2.01E+06 ton/y
                                                                              (INDEC, 1945)
            Mass (g) = (ton/y)*(1.00E+06 g/ton)
                       2.01E+12 g/v
```

Table C.1 (continued)

```
22
       Food and agricultural products
        Imports = 3.12E+05 ton/y
                                                                       (INDEC, 1945)
        Energy (J) = (ton/y)*(1E+06g/ton)*(3.5 kcal/g)*(4186 J/kcal)
                  = 4.57E+15 J/v
23
       Coal
        Imports = 2.65E+06 \text{ ton/y}
                                                                       (INDEC, 1945)
        Energy (J) = (ton/y)*(2.9 E10 J/ton)
                  = 7.69E+16 J/y
24
       Chemicals
        Imports = 1.87E+05 ton/y
                                                                       (INDEC, 1945)
                   = 1.87E+11 g/y
25
       Wood, paper, textiles, leather
        Imports =
                     7.89E+05
                                   ton/y
                                                                       (INDEC, 1945)
        Energy(J) =
                     (ton/y)*(1E+06g/ton)*(15E+3J/g)
                     1.18E+16 J/y
26
       Machinery, transportation, equipment
                     2.70E+04
       Imports =
                                   ton/y
                                                                          (Azar, 1977)
                     (ton/y)*(1E+06g/ton)
       Mass(g) =
                     2.70E+10
                                   g/y
27
       Imported services:
        Dollar Value = 6.83E+09
                                   $US
                                                                          (BAC, 1982)
Exports of energy, materials and services
28
       Eood and agricultural products
        Exports: 8.85E+06 ton/y
                                                                       (INDEC, 1945)
        Energy (J) = (ton)*(1E+06 g/ton)*(20\%)*(3.5 kcal/g)*(4186 J/kcal)
                     2.59E+16 J/y
29
       Livestock
        Exports: 1.17E+06 ton/y
                                                                       (INDEC, 1945)
        Energy (J) = (ton)*(1.00 E+06 g/ton)*(20\%)*(5 kcal/g)*(4186 J/Cal)
                  = 4.89E+15 J/y
30
       Forestry products
        Exports = 3.50E+05 ton/y
                                                                        (INDEC, 1945)
        Energy (J) = (ton)(1.0E+06 g/ton)(80\%)(3.6 kcal/g)(4186 J/kcal)
                     4.22E+15 J/y
31
       Paper, textile, leather products
        Exports =
                     2.61E+05
                                   ton/y
                                                                          (Azar, 1977)
        Energy (J) = (ton)(1.0E+06 g/ton)(4.0 kcal/g)(4186 J/kcal)
                     4.37E+15 J/y
32
       Chemicals:
                                   ton/y
        Exports =
                     1.47E+05
                                                                          (Azar, 1977)
        Energy (g) = (ton)*(1E+06 g/ton)
                     1.47E+11
                                   g
33
       Services in exports:
        Dollar Value =
                                          $US
                            7.11E+09
                                                                         (BAC, 1982)
```

Table C.2. Summary of annual major emergy and monetary flows for Argentina during the 1900-1929 period.

Variable	Item	Solar Emergy (E20 sej/y)	Dollars
R	Renewable sources (rain chemical) Item 2	2680.46	
N	Nonrenewable resources from within Argentina $\label{eq:N0} N_0 + N_1 + N_2$	125.98	
N_0	Dispersed Rural Source Items 11, 12, 13 and 18 less item 30	102.19	
N_1	Concentrated Use Sum of items 14, 15, 16 and 17	22.31	
N_2	Exported without Use Item 30	1.47	
F	Imported Fuels and Minerals Items 19, 21 and 23	71.36	
G	Imported Goods Items 22, 24, 25 and 26	30.23	
I	Dollars Paid for Imports Item 27		6.83E+09
P ₂ I	Emergy of Services in Imported Goods & Fuels Item 27	1092.16	
E	Dollars Received for Exports Item 33		7.11E+09
P ₁ E	Emergy Value of Goods and Service Exports Item 33	999.71	
x	Gross Domestic Product (1990 dollars)		2.84E+10
P_2	World emergy/\$ ratio, used in imports	1.60E+13	
P_1	Argentina Emergy/\$ ratio (total emergy used/GDP)	1.41E+13	3

Table C.3. Overview indices of annual solar emergy use for Argentina during the 1900-1929 period.

Item	Name of Index	Expression	Quantity	Unit
1	Renewable emergy flow	R	2.68E+23	sej/y
2	Flow from indigenous nonrene	ewable		
	reserves	N	1.27E+22	sej/y
3	Flow of imported emergy	F+G+P ₂ I	1.19E+23	sej/y
4	Total emergy inflows	$R+N+F+G+P_2I$	4.00E+23	sej/y
5	Total emergy used, U	$N_0+N_1+R+F+G+P_2I$	4.00E+23	sej/y
6	Total exported emergy	P_1E	1.00E+23	sej/y
7	Fraction emergy use derived			
	from home sources	$(N_O+N_1+R)/U$	0.70	
8	Imports minus exports	$(F+G+P_2I)-(N_2+P_1E)$	1.92E+22	sej/y
9	Export to Imports	$(N_2+P_1E)/(F+G+P_2I)$	0.84	
10	Fraction used,			
	locally renewable	R/U	0.67	
11	Fraction of use purchased	$(F+G+P_2I)/U$	0.30	
12	Fraction imported service	P_2I/U	0.27	
13	Fraction of use that is free	$(R+N_0)/U$	0.70	
14	Ratio of concentrated to rural	$(F+G+P_2I+N_1)/(R+N_0)$	0.44	
15	Use per unit area	U/(area)	1.44 E+11	sej/m²
16	Use per person	U/population	5.07E+16	sej/person
17	Renewable carrying capacity			
	at present living standard	(R/U) (population)	5.28E+06	people
18	Developed carrying capacity			
	at same living standard	8(R/U)(population)	4.23 E+07	people
19	Ratio of use to GDP,			
	emergy/dollar ratio	P_1 =U/GDP	1.41 E+13	sej/\$
20	Ratio of electricity to use	(el)/U	0.00	
21	Fuel use per person	fuel/population	7.94E+14	sej/person

Table C.4. Annual emergy flows supporting the Argentine economy during the 1930-1943 period.

Note Item		Raw Unit	Emergy/unit (sej/unit)	Solar Emergy (E20 sej)	EmDollars (E9 1990 US\$)
Renewable resou	ırces:				
1Sunlight		1.68E+22J	1.00E+00	167.99	2.29
2 Rain, chem	ical	1.47E+19J	1.82E+04	2680.46	36.52
3 Rain, geop	otential	7.03E+18J	2.79E+04	1958.65	26.69
4Wind, kine	tic energy	2.07E+19J	1.50E+03	309.67	4.22
5Waves		8.05E+17J	3.06E+04	245.93	3.35
6Tide		3.19E+18J	1.68E+04	538.03	7.33
7Earth Cycle	<u>.</u>	2.78E+18J	3.44E+04	955.82	13.02
Indigenous rene	wable energy	y:			
8Hydroelect	ricity	1.51E+15J	1.65E+05	2.49	0.03
9 Agricultur	e Production	8.43E+16J	1.00E+05	84.28	1.15
10 Livestock I	Production	1.98E+16J	1.00E+06	198.33	2.70
11 Fisheries P	roduction	1.97E+14J	1.00E+06	1.97	0.03
12Fuelwood	Production	1.22E+16J	1.87E+04	2.28	0.03
13 Forest Extr	action	8.41E+16J	1.87E+04	15.73	0.21
Nonrenewable s	ources from	within syster	n:		
14 Natural Ga	S	2.12E+16J	4.80E+04	10.19	0.14
15Oil		5.63E+16J	5.40E+04	30.38	0.41
16 Minerals ar	nd rocks	1.07E+13 g	1.00E+09	107.28	1.46
17 Metals		4.75E+10g	1.00E+09	0.48	0.01
18Top Soil		1.41E+17J	7.40E+04	104.36	1.42
Imports and out	side sources:	:			
190il Derived	d Products	9.33E+16J	6.60E+04	61.57	0.84
20 Metals		6.51E+11 g	1.80E+09	11.71	0.16
21 Minerals ar	nd rocks	1.96E+12g	1.00E+09	19.59	0.27
22Food & Ag	ric. Products	5.00E+15J	2.00E+05	10.01	0.14
23 Coal		7.76E+16J	4.00E+04	31.02	0.42
24 Chemicals		1.91E+11 g	3.80E+08	0.72	0.01
25 Wood, Pape	er,Textiles	1.20E+16J	3.49E+04	4.18	0.06
26 Mech.& Tra	ans Eqp.	1.13E+11 g	6.70E+09	7.57	0.10
27Service in i	mports	6.97E+09\$	1.20E+13	836.88	11.40

Table C.	4 (continued)					
Exports:						
28 Agr	icultural Crops	3.07E+16	6J	1.00E+05	30.74	0.42
29 Liv€	estock	1.72E+16	6J	1.00E+06	172.32	2.35
30Fore	est Products	3.22E+15	5J	3.49E+04	1.12	0.02
31 Pap	er & Wood Products	3.95E+15	5J	3.49E+04	1.38	0.02
32Che	emicals	1.68E+11	l g	3.80E+08	0.64	0.01
33Serv	vice in exports	9.12E+09	O	7.34E+12	668.99	9.12
Renewab 1 So 1 I	s to Table C.4 le resources: blar energy: Cont Shelf Area = Land Area = 2.78E+1 his figure excludes Is	l2 m2 slas Malvin	as and th	•	ean Antarctic	
I	Insolation = 1.57E+(Albedo = 30%) Energy (J) = (area in (4186 J/)) = 1.68E+2	cluding sho kcal) 22 J/y	. ,	age insolati		(Brown, 1998) * estimate
I (I I	ain, chemical potenti Land Area = 2.78E+1 Cont Shelf Area = 8.7 Rain (land) = 0.94 m Rain (shelf) = 0.42 Energy (land) (J) = (a where G corresp	12 m2 /1E+11 m2 /y m/y rea)(rainfa		e 0 kg/m3)	stimated as 45	c World Atlas) 5% of total rain
Eı	= 1.29E+19 nergy (shelf) (J)=	J/y				ō
3 Ra	ain, geopotential ene and Area = 2.78E+1	12 m2 0.94 m				
Rı	verage Elevation = unoff rate = 31% nergy (J) = (area)(9 = 7.03E+1	%runoff)(w		·		INDEC, 2000) (Brown, 1998) ion)(gravity)
	/ind energy: Energy (J) = 2.07E+1					(Brown, 1998)
	ave energy:	·				(
	0,	8.05E+17	J/y			(Brown, 1998)

```
6
       Tidal energy:
       Continental Shelf Area =
                                    8.71E+11
                                                   m2
                                                                          (Brown, 1998)
       Average Tide Range =
                                    1.00
                                           m
                                                                          (Brown, 1998)
       Tides/year = 7.30E+02
                                                               Estimated as 2 tides/day
       Energy (J) =
                      (shelf)(0.5)(tides/y)(mean tidal range)2(den. seawater)(gravity)
                                                                          (Odum 1996)
                      3.19E+18
                                    J/y
7
       Earth cycle
       Land Area = 2.78E+12
                                    m2
       Heat flow = 1.00E+06
                                    J/m2
                                                                          (Odum 1996)
       Energy (I) = (area)(heat flow)
                      2.78E+18
                                    J/y
Indigenous renewable energy
       Hydroelectricity:
        Production = 3.60E+04
                                    t.e.p./v
                                                                           (Shell, 1969)
        Energy (J) = (t.e.p./y)*(4.184 E+10 J/t.e.p.)
                                                                          (Olade, 2001)
                      1.51E+15
                                    J/y
9
       Agricultural production:
       Production = 2.52E+07
                                                                 (Díaz Alejandro, 1970)
                                    ton/v
       Energy (J) =
                      (ton)*(1E06 g/ton)*(20\%)*(4.0 kcal/g)*(4186 J/kcal)
                     8.43E+16
10
       Livestock production:
        Production =
                                            ton/y
                                                      (Díaz Alejandro, 1970; BCA, 1982)
                             4.74E+06
           Energy (J) =
                              (ton)*(1.00 E+06 g/ton)*(20%)*(5 kcal/g)*(4186 J/Cal)
                      1.98E+16
                                    J/y
11
       Fisheries production:
        Fish Catch = 4.70E+04
                                    ton/y
                                                                            (BAC, 1982)
           Energy(J) = (ton)*(1E+06 g/ton)*(5 kcal/g)*(20\%)*(4186 J/kcal)
                     1.97E+14
                                    J/y
12
       Fuelwood production
       Production = 1.39E+06
                                    ton/v
                                                 (Revista de Economia Argentina, 1940)
           Energy (J) = (ton)(1E+06g/ton)(80\%)(2.625 \text{ kcal/g})(4186 \text{ J/kcal})
                     1.22E+16
                                    J/y
13
       Forest extraction
        Harvest =
                      6.61E+06
                                    ton/y
                                                                         (Cozzo, 1967)
           Energy(J) = (ton)(1E+06g/ton)(80\%)(3.8 \text{ kcal/g})(4186 \text{ J/kcal})
                      8.41E+16
                                    J/y
Nonrenewable resources from within
13
       Natural gas
        Production
                                    m3/v
                                                                         (BAC, 1982)
                     = 5.44E + 08
        Energy (J) = (m3/y)(3.9 E+17 J/m3)
                      2.12E+16
                                    J/y
14
       Oil
        Production = 1.34E+06
                                    m3/v
                                                                         (BAC, 1982)
                      (m3/y)(0.87ton/m3)(4.2 E+10 J/ton)
        Energy(J) =
                      5.63E+16
                                    J/y
```

```
15
       Minerals non metallic/ rocks
        Production =
                            1.07E+07
                                          ton/y
                                                                       (BAC, 1982)
           Mass(g) = (ton)*(1E6 g/ton)
                     1.07E+13
                                   g/y
16
       Metals
        Production
                            4.75E+04
                                                                       (BAC, 1982)
                                          ton/y
        Mass(g) =
                     (ton)*(1E6 g/ton)
                     4.75E+10
                                   g/y
17
       Topsoil:
       Arable Land = 2.08E+07
                                                               (Díaz Alejandro, 1970)
                                   ha
       Rate of Loss = 1.00E+07
                                   g/ha
        Soil loss =
                     2.08E+14
                                   g/y
                            (2.22 E14 g/y)*(0.03 OM)*(5.4 kcal/g)(4186 J/kcal)
           Energy (J) =
                     1.41E+17
Imports of outside energy sources:
18
       Crude oil and derivative products
        Imports =
                     2.22E+06
                                   ton
                                                                       (INDEC, 1945)
                            (ton/y)*(4.20 E10 J/ton)
           Energy (I) =
                     9.33E+16
                                   J/y
19
       Metals
        Imports =
                     6.51E+05
                                                                       (INDEC, 1945)
                                   ton/v
           Mass (g) = (ton/y)*(1.00E+06 g/ton)
                     6.51E+11
                                   g/y
20
       Minerals non metallic/ rocks
        Imports =
                     1.96E+06
                                   ton/v
                                                                       (INDEC, 1945)
                     (ton/y)*(1.00E+06 g/ton)
        Mass(g) =
                     1.96E+12
                                   g/y
21
       Food and agricultural products
        Imports =
                     3.42E+05
                                   ton/y
                                                                       (INDEC, 1945)
        Energy (J) = (ton/y)*(1E+06g/ton)*(3.5 kcal/g)*(4186 J/kcal)
                     5.00E+15
                                   J/y
22
       Coal
        Imports =
                                   ton/y
                                                                       (INDEC, 1945)
                     2.67E+06
        Energy (J) = (ton/y)*(2.9 E10 J/MT)
                     7.76E+16
                                   J/y
23
       Chemicals
                                                                (INDEC, 1945)
                                   MT/v
        Imports =
                     1.91E+05
Mass(g) =
              (2.01 E+06 ton/ y)*(1E+06g/ton)
                     1.91E+11
                                   g/y
24
       Wood, paper, textiles, leather
        Imports =
                     7.99E+05
                                   ton/y
                                                                       (INDEC, 1945)
                     (ton/y)*(1E+06g/ton)*(15E+3J/g)
        Energy(J) =
                     1.20E+16
                                   J/y
```

Dollar Value =

```
25
       Machinery, transportation, equipment
       Imports =
                     1.13E+05
                                                                          (Azar, 1977)
                                   ton/y
        Mass(g) =
                      (ton/y)*(1E+06g/ton)
                     1.13E+11
                                   g/y
26
       Imported services:
                                          $US
        Dollar Value =
                            6.97E+09
                                                                          (BAC, 1982)
Exports of energy, materials and services
       food and agricultural products
        Exports =
                     1.05E+07
                                   ton/y
                                                                        (INDEC, 1945)
                     (ton)*(1E+06 g/ton)*(20%)*(3.5 kcal/g)*(4186 J/kcal)
        Energy (I) =
                     3.07E+16
                                   J/y
28
       Livestock
        Exports =
                                   ton/y
                                                                        (INDEC, 1945)
                     4.12E+06
        Energy (J) = (ton)*(1.00 E+06 g/ton)*(20\%)*(5 kcal/g)*(4186 J/Cal)
                     1.72E+16
                                   J/y
29
       Forestry products
        Exports =
                     2.67E+05
                                   ton/y
                                                                       (INDEC, 1945)
        Energy (J) =
                     (ton)(1.0E+06 g/ton)(80%)(3.6 kcal/g)(4186 J/kcal)
                     3.22E+15
30
       Paper, textile, leather products
        Exports =
                     2.36E+05
                                   ton/v
                                                                          (Azar, 1977)
        Energy (J) = (ton)(1.0E+06 g/ton)(4.0 kcal/g)(4186 J/kcal)
                     3.95E+15
37
       Chemicals:
        Exports =
                     1.68E+05
                                   ton/y
                                                                          (Azar, 1977)
        Energy (g) = (ton)*(1E+06 g/ton)
                     1.68E+11
                                   g
32
       Services in exports:
```

\$US

(BAC, 1982)

9.12E+09

Table C.5. Summary of annual major emergy and monetary flows for Argentina during the 1930-1943 period.

Variable	Item	Solar Emergy (E20 sej/y)	Dollars
R	Renewable sources (rain chemical) Item 2	2680.46	
N	Nonrenewable resources from within Argentin	a 272.67	
	$N_0 + N_1 + N_2$		
N_0	Dispersed Rural Source	123.22	
	Items 11, 12, 13 and 18 less item 30		
N_1	Concentrated Use	148.33	
	Sum of items 14, 15, 16 and 17		
N_2	Exported without Use	1.12	
	Item 30		
F	Imported Fuels and Minerals	123.90	
	Items 19, 20, 21 and 23		
G	Imported Goods	22.49	
	Items 22, 24, 25, 26		
I	Dollars Paid for Imports		6.97E+09
	Item 27		
P_2I	Emergy of Services in Imported Goods & Fuels Item 27	836.88	
E	Dollars Received for Exports		9.12E+09
	Item 33		
P_1E	Emergy Value of Goods and Service Exports	668.99	
	Item 33		
x	Gross Domestic Product		5.36E+10
	(1990 dollars)		
P_2	World emergy/\$ ratio, used in imports	1.2013E+13	
P_1	Argentina Emergy/\$ ratio (total emergy used/GDP)	7.34E+12	

Table C.6. Overview indices of annual solar emergy use for Argentina during the 1930-1943 period.

Item	Name of Index	Expression	Quantity	Unit
1	Renewable emergy flow	R	2.68E+23	sej/y
2	Flow from indigenous nonrend	ewable		
	reserves	N	2.75E+22	sej/y
3	Flow of imported emergy	F+G+P ₂ I	9.83E+22	sej/y
4	Total emergy inflows	$R+N+F+G+P_2I$	3.94E+23	sej/y
5	Total emergy used, U	$N_0+N_1+R+F+G+P_2I$	3.94E+23	sej/y
6	Total exported emergy	P_1E	6.69E+22	sej/y
7	Fraction emergy use derived			
	from home sources	$(N_O+N_1+R)/U$	0.75	
8	Imports minus exports	$(F+G+P_2I)-(N_2+P_1E)$	3.13E+22	sej/y
9	Export to Imports	$(N_2+P_1E)/(F+G+P_2I)$	0.68	
10	Fraction used,			
	locally renewable	R/U	0.68	
11	Fraction of use purchased	$(F+G+P_2I)/U$	0.25	
12	Fraction imported service	P_2I/U	0.21	
13	Fraction of use that is free	$(R+N_0)/U$	0.71	
14	Ratio of concentrated to rural	$(F+G+P_2I+N_1)/(R+N_0)$	0.40	
15	Use per unit area	U/(area)	1.42E+11	sej/m²
16	Use per person	U/population	2.94E+16	sej/person
17	Renewable carrying capacity			
	at present living standard	(R/U) (population)	9.12E+06	people
18	Developed carrying capacity			
	at same living standard	8(R/U)(population)	7.30E+07	people
19	Ratio of use to GDP,			
	emergy/dollar ratio	$P_1=U/GDP$	7.34E+12	sej/\$
20	Ratio of electricity to use	(el)/U	0.00	
21	Fuel use per person	fuel/population	1.00E+15	sej/person

Table C.7. Annual emergy flows supporting the Argentine economy during the 1944-1975 period.

Note Item	Raw Unit	Emergy/unit	Solar Emergy	EmDollars
		(sej/unit)	(E20 sej)	(E9 1990 US\$)
Renewable resources:				
1Sunlight	1.68E+22J	1.00E+00	167.99	4.84
2 Rain, chemical	1.47E+19J	1.82E+04	2680.46	77.20
3 Rain, geopotential	7.03E+18J	2.79E+04	1958.65	56.41
4Wind, kinetic energy	2.07E+19 J	1.50E+03	309.67	8.92
5Waves	8.05E+17 J	3.06E+04	245.93	7.08
6Tide	3.19E+18 J	1.68E+04	538.03	15.50
7Earth Cycle	2.78E+18 J	3.44E+04	955.82	27.53
Indigenous renewable energ	gy:			
8Hydroelectricity	4.54E+15 J	1.65E+05	7.49	0.22
9 Agriculture Production	n 9.39E+16J	1.00E+05	93.93	2.71
10 Livestock Production	3.16E+16 J	1.00E+06	315.77	9.11
11 Fisheries Production	5.65E+14 J	1.00E+06	5.65	0.16
12Fuelwood Production	4.73E+16 J	1.87E+04	8.85	0.26
13 Forest Extraction	4.59E+16 J	1.87E+04	8.58	0.25
Nonrenewable sources from	n within syster	n:		
14 Natural Gas	1.56E+17J	4.80E+04	74.97	2.16
15Oil	4.74E+17J	5.40E+04	256.13	7.38
16 Coal	6.79E+15J	4.00E+04	2.72	0.08
17 Minerals and rocks	2.36E+13g	g 1.00E+09	236.10	6.80
18 Metals	2.66E+11 g	g 1.00E+09	2.66	0.08
19Top Soil	1.36E+17J	7.40E+04	100.49	2.89
Imports and outside source	s:			
20Oil Derived Products	1.79E+17J	6.60E+04	118.28	3.41
21 Metals	8.43E+11 g	g 1.80E+09	15.17	0.44
22 Minerals and rocks	1.23E+12g	g 1.00E+09	12.28	0.35
23 Food & Agric. Product	s 6.45E+14J	2.00E+05	1.29	0.04
24 Coal	3.12E+16J	4.00E+04	12.48	0.36
25 Chemicals	1.75E+11 g	3.80E+08	0.67	0.02
26Wood,Paper,Textiles	1.54E+16J	3.49E+04	5.36	0.15
27 Mech.& Trans Eqp.	2.13E+11 g	g 6.70E+09	14.29	0.41
28 Service in imports	1.24E+10\$	6.00E+12	2 742.44	21.38

Expor	ts:				
29 Agı	ricultural Crops	2.08E+16J	1.00E+05	20.75	0.60
30 Live	estock	2.05E+15J	1.00E+06	20.51	0.59
31 For	est Products	2.03E+15J	3.49E+04	0.71	0.02
32 Met	tals	4.25E+11g	1.80E+09	7.65	0.22
33 Pan	er & Wood Products	4.30E+15J	3.49E+04	1.50	0.04
_	emicals	1.30E+11g	3.80E+08	0.49	0.01
	vice in exports	1.24E+10\$	3.47E+12	429.06	12.37
	<u> </u>	·			
	otes to Table C.7				
	vable resources:				
1	Solar energy:	0.71E+11 ma	at 200 m damth	(1	2,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
	Cont Shelf Area = Land Area = 2.78E-		at 200 m depth	,	Brown, 1998) NDEC, 2000)
	this figure excludes l		and the Argentin	`	,
	Insolation = 1.57E-		•		rown, 1998)
	Albedo = 30%	02 Real, elli2,	J	(2	* estimate
	Energy (J) = (area i	ncluding shelf)*(average insolat	ion)*(1-albedo)	
	(4186 J	/kcal)	_		
		+22 J/y			
2	Rain, chemical poten	0,			
	Land Area = 2.78E-				
	Cont Shelf Area = 8		(0) (1 T., 1 1 1	A71 -1 - A +1 \
	Rain (land) = 0.94 r		,	d Encyclopedic V estimated as 45%	,
	Rain (shelf) = 0.42 Energy (land) (J) =			esimaleu as 45 /	of total faili
	.	, , ,	os free energy nun	nber= 4940 I/kø	
	= 1.29E+19	•	so free energy num	1) 10)/ 16	
	Energy (shelf) (J)=		f)(rainfall)(G)(100	0 kg/m3)	
	=	1.82E+18	J/y		
	Total energy $(J) =$	1.47E+19	J/y		
3	Rain, geopotential er	0,5			
	Land Area = 2.78E-				
	Rain (land) =	0.94 m			
	Evapotranspiration		m/y	estimated from I	VIDEC 2000)
	Average Elevation = Runoff rate = 31%	- 009.07 111	(6	estimated from II	Brown, 1998)
	Energy $(J) = (area)$	(%runoff)(wat	er density)(rainfal	,	,
	= 7.03E	, , ,		/(-/(8)/
4	Wind energy:	2, 3			
	Energy $(J) = 2.07E$	+19 J/y		(I	Brown, 1998)
5	Wave energy:				_
	Energy $(J) =$	8.05E+17	J/y	(I	Brown, 1998)

```
6
       Tidal energy:
       Continental Shelf Area =
                                   8.71E+11
                                                 m2
                                                                       (Brown, 1998)
       Average Tide Range =
                                   1.00
                                          m
                                                                       (Brown, 1998)
       Tides/year = 7.30E+02
                                                             Estimated as 2 tides/day
       Energy (J) =
                     (shelf)(0.5)(tides/y)(mean tidal range)2(den. seawater)(gravity)
                                                                        (Odum 1996)
                     3.19E+18
                                   J/y
7
       Earth cycle
       Land Area = 2.78E+12
                                   m2
       Heat flow = 1.00E+06
                                   J/m2
                                                                        (Odum 1996)
       Energy (J) = (area)(heat flow)
                     2.78E+18
                                   J/y
Indigenous renewable energy
       Hydroelectricity:
8
       Production = 1.26E+09
                                   kwh/v
                                                                  (BAC, 1982)
       Energy (J) = (kwh/y)*(3.6 E+06 J/kwh)
                     4.54E+15
                                   J/y
9
       Agricultural production:
       Production = 2.81E+07
                                                    (Díaz Alejandro, 1970; FAO, 1998)
                                   ton/v
                     (ton)*(1E06 g/ton)*(20%)*(4.0 kcal/g)*(4186 J/kcal)
       Energy (J) =
                     9.39E+16
                                   J/y
10
       Livestock production:
        Production =7.54E+06 ton/y
                                        (Díaz Alejandro, 1970; BCA, 1982; FAO, 1998)
                             (ton)*(1.00 E+06 g/ton)*(20%)*(5 kcal/g)*(4186 J/Cal)
           Energy (J) =
                     3.16E+16
                                   J/y
11
       Fisheries production:
        Fish Catch = 1.35E+05
                                   ton/y
                                                                         (BAC, 1982)
        Energy(J) = (ton)*(1E+06 g/ton)*(5 kcal/g)*(20\%)*(4186 J/kcal)
                     5.65E+14
                                   J/y
12
       Fuelwood production
       Production = 5.38E+06
                                   ton/y
                                                                         (FAO, 1998)
       Energy (J) =
                     (ton)(1E+06g/ton)(80%)(2.625 kcal/g)(4186 J/kcal)
                     4.73E+16
                                   J/y
13
       Forest extraction
       Harvest =
                     3.61E+06
                                   ton/y
                                                                         (FAO, 1998)
                      (ton)(1E+06g/ton)(80%)(3.8 kcal/g)(4186 J/kcal)
        Energy(J) =
                     4.59E+16
                                   J/y
Nonrenewable resources from within
14
       Natural gas
        Production
                            4.00E+09
                                                                         (BAC, 1982)
                                          m3/y
        Energy (J) = (m3/y)(3.9 E+17 J/m3)
                     1.56E+17
                                   J/y
15
       Oil
        Production =
                            1.13E+07
                                          m3/v
                                                                         (BAC, 1982)
                            (m3/y)(0.87ton/m3)(4.2 E+10 J/ton)
           Energy(J) =
                     4.74E+17
                                   J/y
```

```
16
       Coal
        Production =
                            2.34E+05
                                          MT/v
                                                                         (CTI, 1986)
          Energy(J) =
                            (3.8 E+05 Mt/y)*(2.9E+10 J/Mt)
                     6.79E+15
                                  J/y
17
       Minerals non metallic/ rocks
        Production =
                            2.36E+07
                                          ton/y
                                                                         (BAC, 1982)
          Mass(g) = (ton)*(1E6 g/ton)
                     2.36E+13
18
       Metals
                                                                         (BAC, 1982)
        Production =
                            2.66E+05
                                          ton/y
          Mass(g) = (ton)*(1E6 g/ton)
                     2.66E+11
                                   g/y
19
       Topsoil:
                                                    (Díaz Alejandro, 1970; FAO, 1998)
       Arable Land = 2.00E+07
                                   ha
       Rate of Loss = 1.00E+07
                                   g/ha
        Soil loss = 2.00E+14
                                   g/y
                            (2.22 E14 g/y)*(0.03 OM)*(5.4 kcal/g)(4186 J/kcal)
          Energy (J) =
                     1.36E+17
                                  J/y
Imports of outside energy sources:
20
       Crude oil and derivative products
        Imports =
                    4.27E+06
                                                                        (Azar, 1977)
                                   ton
          Energy (J) =
                            (ton/y)*(4.20 E10 J/ton)
                     1.79E+17
                                   J/y
21
       Metals
        Imports =
                    8.43E+05
                                   ton/v
                                                                        (Azar, 1977)
          Mass (g) = (ton/y)*(1.00E+06 g/ton)
                     8.43E+11
                                   g/y
22
       Minerals non metallic/ rocks
        Imports = 1.23E+06
                                   ton/v
                                                                      (INDEC, 1982)
          Mass (g) = (ton/y)*(1.00E+06 g/ton)
                     1.23E+12
                                   g/y
23
       Food and agricultural products
        Imports =
                    4.40E+04
                                   ton/v
                                                                        (Azar, 1977)
          Energy (J) =
                            (ton/y)*(1E+06g/ton)*(3.5 kcal/g)*(4186 J/kcal)
                     6.45E+14
                                  J/y
24
       Coal
        Imports =
                     1.08E+06
                                   ton/v
                                                                        (Azar, 1977)
          Energy (J) =
                            (ton/y)*(2.9 E10 J/MT)
                     3.12E+16
                                  J/y
25
       Chemicals
                                                                        (Azar, 1977)
        Imports =
                     1.75E+05
                                   ton/y
          Mass (g) = (ton/y)*(1E+06g/ton)
                    1.75E+11
                                   g/y
```

```
26
       Wood, paper, textiles, leather
        Imports = 1.02E+06
                                   ton/v
                                                                       (Azar, 1977)
                            (ton/y)*(1E+06g/ton)*(15E+3J/g)
           Energy(J) =
                     1.54E+16
                                   J/v
27
       Machinery, transportation, equipment
                                                                       (Azar, 1977)
       Imports =
                     2.13E+05
                                   ton/y
                      (ton/y)*(1E+06g/ton)
        Mass(g) =
                     2.13E+11
                                   g/y
28
       Imported services:
                                          $US
        Dollar Value =
                            1.24E+10
                                                                       (BAC, 1982)
Exports of energy, materials and services
29
       Food and agricultural products
                     7.08E+06
        Exports:
                                                                       (Azar, 1977)
           Energy (J) =
                             (ton)*(1E+06 g/ton)*(20%)*(3.5 kcal/g)*(4186 J/kcal)
                     2.08E+16
                                   J/y
30
       Livestock
       Meat =
                     4.90E+05
                                   ton/y
                                                                       (Azar, 1977)
                             (ton)*(1.00 E+06 g/ton)*(20%)*(5 kcal/g)*(4186 J/Cal)
           Energy (J) =
                     2.05E+15
                                   J/y
31
       Forestry products
        Exports =
                     1.68E+05
                                                  (Comercio Exterior Argentino, 1982)
                                   ton/v
                             (ton)(1.0E+06 g/ton)(80%)(3.6 kcal/g)(4186 J/kcal)
           Energy (J) =
                     2.03E+15
                                   J/y
32
       Metals/ minerals/ rocks
        Exports =
                     4.25E+05
                                   MT/v
                                                                       (Azar, 1977)
                     (1.41 E+06 MT)*(1E+06 g/MT)
        Mass(g) =
                     4.25E+11
                                   g/y
33
       Paper, textile, leather products
        Exports =
                     2.57E+05
                                   ton/v
                                                                       (Azar, 1977)
           Energy (J) =
                             (ton)(1.0E+06 g/ton)(4.0 kcal/g)(4186 J/kcal)
                     4.30E+15
34
       Chemicals:
                                                                       (Azar, 1977)
        Exports =
                     1.30E+05
                                   ton/y
        Energy (g) = (ton)*(1E+06 g/ton)
                     1.30E+11
35
       Services in exports:
         Dollar Value =
                                            $US
                              1.24E+10
                                                                         (BAC, 1982)
```

Table C.8. Summary of annual major emergy and monetary flows for Argentina during the 1944-1975 period.

Variable	Item	Solar Emergy (E20 sej/y)	Dollars
R	Renewable sources (rain chemical) Rain Chemical, item 2	2680.46	
N	Nonrenewable resources from within Argentin $N_0 + N_1 + N_2$	a 696.16	
N_0	Dispersed Rural Source Items 11, 12, 13, and 19 less item 31	122.87	
N_1	Concentrated Use Sum of items 14, 15, 16, 17 and 18 less item 32	564.93	
N_2	Exported without Use Items 31 and 32	8.35	
F	Imported Fuels and Minerals Items 20, 21, 22 and 24	158.21	
G	Imported Goods Items 23, 25, 26 and 27	21.61	
I	Dollars Paid for Imports Item 28		1.24E+10
P ₂ I	Emergy of Services in Imported Goods & Fuels Item 28	742.44	
E	Dollars Received for Exports Item 35		1.24E+10
P ₁ E	Emergy Value of Goods and Service Exports Item 35	429.06	
X	Gross Domestic Product (1990 dollars)		1.24E+11
P_2	World emergy/\$ ratio, used in imports	6.00E+12	
P ₁	Argentina Emergy/\$ ratio (total emergy used/GDP)	3.47E+12	

Table C.9. Overview indices of annual solar emergy use for Argentina during the 1944-1975 period.

Item	Name of Index	Expression	Quantity	Unit
1	Renewable emergy flow	R	2.68E+23	sej/y
2	Flow from indigenous nonrene	ewable		
	reserves	N	6.96E+22	sej/y
3	Flow of imported emergy	F+G+P ₂ I	9.22E+22	sej/y
4	Total emergy inflows	$R+N+F+G+P_2I$	4.30E+23	sej/y
5	Total emergy used, U	$N_0+N_1+R+F+G+P_2I$	4.29E+23	sej/y
6	Total exported emergy	P_1E	4.29E+22	sej/y
7	Fraction emergy use derived			
	from home sources	$(N_O+N_1+R)/U$	0.79	
8	Imports minus exports	$(F+G+P_2I)-(N_2+P_1E)$	4.85E+22	sej/y
9	Export to Imports	$(N_2+P_1E)/(F+G+P_2I)$	0.47	
10	Fraction used,			
	locally renewable	R/U	0.62	
11	Fraction of use purchased	$(F+G+P_2I)/U$	0.21	
12	Fraction imported service	P_2I/U	0.17	
13	Fraction of use that is free	$(R+N_0)/U$ $(F+G+P_2I+N_1)/(R+N_0)$	0.65	
14	Ratio of concentrated to rural)	0.53	
15	Use per unit area	U/(area)	1.54E+11	sej/m²
16	Use per person	U/population	2.10E+16	sej/person
17	Renewable carrying capacity			
	at present living standard	(R/U) (population)	1.28E+07	people
18	Developed carrying capacity			
	at same living standard	8(R/U)(population)	1.02E+08	people
19	Ratio of use to GDP,			
	emergy/dollar ratio	$P_1=U/GDP$	3.47E+12	sej/\$
20	Ratio of electricity to use	(el)/U	0.02	
21	Fuel use per person	fuel/population	2.28E+15	sej/person

Table C.10. Annual emergy flows supporting the Argentine economy during the 1976-1989 period.

Note	Item	Raw Unit	Emergy/unit (sej/unit)	Solar Emergy (E20 sej)	EmDollars (E9 1990 US\$)
Renew	able resources:				
1S	unlight	1.68E+22J	1.00E+00	167.99	7.71
2 R	lain, chemical	1.47E+19J	1.82E+04	2680.46	123.05
3 R	lain, geopotential	7.03E+18J	2.79E+04	1958.65	89.91
4 V	Vind, kinetic energy	2.07E+19J	1.50E+03	309.67	14.22
5 V	Vaves	8.05E+17J	3.06E+04	245.93	11.29
6T	ide	3.19E+18J	1.68E+04	538.03	24.70
7E	arth Cycle	2.78E+18J	3.44E+04	955.82	43.88
Indige	nous renewable energy	7:			
8F	Iydroelectricity	6.09E+16J	1.65E+05	100.50	4.63
9 <i>A</i>	Agriculture Production	1.37E+17J	1.00E+05	136.50	6.29
10 L	ivestock Production	4.29E+16J	1.00E+06	428.70	19.75
11 F	isheries Production	1.81E+15J	1.00E+06	18.10	0.83
12F	uelwood Production	4.54E+10J	1.87E+04	0.00	0.00
13 F	orest Extraction	3.67E+16J	1.87E+04	6.87	0.32
Nonre	newable sources from	within system:			
141	Natural Gas	6.41E+17J	4.80E+04	307.64	14.12
150	Oil	1.11E+18J	5.40E+04	602.01	27.64
160	Coal	1.20E+16J	4.00E+04	4.81	0.22
17 N	Minerals and rocks	5.62E+13g	1.00E+09	561.95	25.80
18 N	Metals	1.20E+12g	1.00E+09	11.95	0.55
197	Top Soil	3.21E+17J	7.40E+04	237.30	10.89
Impor	ts and outside sources:				
20Oil	Derived Products	1.30E+17J	6.60E+04	85.78	3.94
21 Me	tals	9.31E+11 g	1.80E+09	16.77	0.77
22 Mir	nerals and rocks	7.64E+12g	1.00E+09	76.40	3.51
23 Foo	d & Agric. Products	4.71E+15J	2.00E+05	9.41	0.43
24 Coa		2.12E+16J			
	stics & Rubber	5.07E+15J			
	emicals	9.90E+11g			
27 W o	od,Paper,Textiles	7.64E+15J	3.49E+04	2.67	0.12

28 Mech.& Trans Eqp.	2.78E+11 g	6.70E+09	18.60	0.85
29 Service in imports	1.99E+10\$	2.00E+12	397.64	18.25
Exports:				
30 Agricultural Crops	6.70E+16 J	1.00E+05	67.03	3.09
31 Fishery Products	1.37E+14 J	1.00E+06	1.37	0.06
32 Forest Products	1.56E+15 J	3.49E+04	0.54	0.03
33 Crude Oil	4.35E+17 J	5.30E+04	230.33	10.61
34 Metals / Minerals	2.84E+12 g	1.00E+09	28.36	1.31
35 Paper & Wood Products	5.49E+15 J	3.49E+04	1.92	0.09
36 Chemicals	4.92E+11 g	3.80E+08	1.87	0.09
37 Service in exports	2.65E+10\$	2.17E+12	575.30	26.51
38 Service external debt	1.19E+10\$	2.17E+12	258.88	11.93

```
Footnotes to Table C10
Renewable resources:
1
       Solar energy:
        Cont Shelf Area =
                             8.71E+11 m2 at 200 m depth
                                                                            (Brown, 1998)
        Land Area = 2.78E+12 m2
                                                                           (INDEC, 2000)
       this figure excludes Islas Malvinas and the Argentinean Antarctic territory
        Insolation = 1.57E+02 \text{ kcal/cm2/y}
                                                                           (Brown, 1998)
        Albedo =
                                                                               * estimate
                      30%
        Energy (J) = (area including shelf)*(average insolation)*(1-albedo) (4186 J/kcal)
                      1.68E+22 J/v
2
       Rain, chemical potential energy:
        Land Area = 2.78E+12 m2
        Cont Shelf Area = 8.71E+11 m<sup>2</sup>
        Rain (land) = 0.94 \text{ m/y}
                                                     (Oxford Encyclopedic World Atlas)
                                                            estimated as 45% of total rain
        Rain (shelf) = 0.42 m/y
        Energy (land) (J) = (area)(rainfall)(G)(1000 kg/m3)
```

where G corresponds to Gibbs free energy number= 4940 J/kg

= 1.29E+19 J/v(area of shelf)(rainfall)(G)(1000 kg/m3) Energy (shelf) (J)=

m2

m

1.82E+18 J/y Total energy (J) =1.47E+19 J/y

3 Rain, geopotential energy:

Land Area = 2.78E+12

Rain (land) = Evapotranspiration rate= 0.65 m/y

0.94

Average Elevation = 889.87 m (estimated from INDEC, 2000) Runoff rate = 31%(Brown, 1998)

(area)(%runoff)(water density)(rainfall)(aver. elevation)(gravity) Energy (J) =7.03E+18 J/y

```
Wind energy:
4
       Energy (J) = 2.07E+19
                                                                       (Brown, 1998)
                                   J/y
5
       Wave energy:
           Energy (J) =
                            8.05E+17
                                          J/y
                                                                       (Brown, 1998)
6
       Tidal energy:
       Continental Shelf Area =
                                                                       (Brown, 1998)
                                   8.71E+11
                                                 m2
       Average Tide Range =
                                   1.00
                                                                       (Brown, 1998)
                                          m
       Tides/year = 7.30E+02
                                                             Estimated as 2 tides/day
                     (shelf)(0.5)(tides/y)(mean tidal range)2(den. seawater)(gravity)
       Energy (J) =
                     3.19E+18
                                                                       (Odum 1996)
                                   J/y
7
       Earth cycle
       Land Area = 2.78E+12
                                   m2
       Heat flow = 1.00E+06
                                                                       (Odum 1996)
                                   J/m2
       Energy (I) = (area)(heat flow)
                     2.78E+18
                                   J/y
Indigenous renewable energy
8
       Hydroelectricity:
       Kilowatt Hrs/v =
                                          KwH/v
                            1.69E+10
                                                              (BAC, 1982; EIA, 2000b)
                            (KwH/y)*(3.6 E+06 J/KwH)
           Energy(J) =
                     6.09E+16
                                   J/y
9
       Agricultural production:
        Production =
                            4.08E+07
                                                                         (FAO, 1998)
                                          ton/y
           Energy (J) =
                            (ton)*(1E06 g/ton)*(20\%)*(4.0 kcal/g)*(4186 J/kcal)
                 = 1.37E+17
                                   J/y
10
       Livestock production:
        Production =
                            1.02E+07
                                          MT/y
                                                                         (FAO, 1998)
                             (ton)*(1.00 E+06 g/ton)*(20%)*(5 kcal/g)*(4186 J/Cal)
           Energy (J) =
                     4.29E+16
                                   J/y
11
       Fisheries production:
        Fish Catch = 4.32E+05
                                   ton/v
                                                                         (FAO, 1998)
           Energy(J) =
                             (ton)*(1E+06 g/ton)*(5 kcal/g)*(20%)*(4186 J/kcal)
                     1.81E+15
                                   J/y
12
       Fuelwood production
                                                                         (FAO, 1998)
        Production =
                            3.76E+06
                                          m3
                            (m3)(0.5E+06 g/m3)(80\%)(3.6 Cal/g)(4186 J/Cal)
           Energy(J) =
                     4.54E+10
                                   J/y
13
       Forest extraction
        Harvest =
                     6.10E+06
                                                                         (FAO, 1998)
                                   m3
                             (m3)(0.5E+06 g/m3)(80%)(3.6 Cal/g)(4186 J/Cal)
           Energy(J) =
                     3.67E+16
                                   J/y
Nonrenewable resources from within
       Natural gas
14
        Production =
                            1.64E+10
                                          m3/v
                                                               (BAC, 1982; CTI, 1996)
                            (m3/y)(3.9 E+17 J/m3)
           Energy (J) =
                     6.41E+17
                                  J/y
```

```
15
       Oil
        Production =
                            2.65E+07
                                          m3/v
                                                              (BAC, 1982; CTI, 1996)
                            (m3/y)(0.87ton/m3)(4.2 E+10 J/ton)
          Energy(J) =
                    1.11E+18
                                  J/y
16
       Coal
        Production =
                            4.15E+05
                                                                         (CTI, 1996)
                                          ton/y
                            (ton/y)*(2.9E+10 J/ton)
          Energy(J) =
                     1.20E+16
                                  J/y
17
       Minerals non metallic/ rocks
                            5.62E+07
                                                                         (BAC, 1982)
        Production =
                                          ton/y
          Mass(g) = (ton)*(1E6 g/ton)
                    5.62E+13
                                   g/y
18
       Metals
        Production =
                            1.20E+06
                                          ton/v
                                                                         (BAC, 1982)
          Mass(g) = (ton)*(1E6 g/ton)
                    1.20E+12
                                   g/y
19
       Topsoil:
       Arable Land = 2.36E+07
                                                                         (FAO, 1998)
                                   ha
                                   g/ha
       Rate of Loss = 2.00E+07
        Soil loss = 4.73E+14
                                   g/y
          Energy (J) =
                            (2.22 E14 g/y)*(0.03 OM)*(5.4 kcal/g)(4186 J/kcal)
                     3.21E+17
                                   J/y
Imports of outside energy sources:
20
       Oil derived products:
        Imports =
                    3.09E+06
                                                                      (INDEC, 1996)
                                   ton
          Energy (J) =
                            (ton/y)*(4.20 E10 J/ton)
                    1.30E+17
                                   J/y
21
       Metals
        Imports =
                    9.31E+05
                                                                      (INDEC, 1996)
                                   ton
          Mass (g) = (ton/y)*(1.00E+06 g/ton)
                     9.31E+11
                                   g/y
22
       Minerals non metallic/ rocks
        Imports =
                    7.64E+06
                                                                      (INDEC, 1996)
                                   ton
          Mass (g) = (ton/y)*(1.00E+06 g/ton)
                     7.64E+12
                                   g/y
23
       Food and agricultural products
                                                                      (INDEC, 1996)
        Imports =
                    3.21E+05
                                   ton
          Energy (J) =
                            (ton/y)*(1E+06g/ton)*(3.5 Kcal/g)*(4186 J/Kcal)
                     4.71E+15
                                  J/y
24
       Coal
        Imports =
                    2.01E+13
                                   btu/y
                                                                        (EIA, 2000b)
          Energy (J) =
                            (btu/y)*(1,055 J/btu)
                     2.12E+16
                                  J/v
```

```
25
       Plastics & rubber
        Imports =
                     1.69E+05
                                                                       (INDEC, 1996)
                                    ton
           Energy(J) =
                            (ton/y)*(1000 \text{ Kg/MT})*(30.0E+06J/kg)
                     5.07E+15
26
       Chemicals
        Imports =
                     9.90E+05
                                    ton
                                                                       (INDEC, 1996)
           Mass (g) = (ton/y)*(1E+06g/ton)
                     9.90E+11
                                    g/y
       Wood, paper, textiles, leather
27
        Imports =
                     5.09E+05
                                                                       (INDEC, 1996)
                                    ton
           Energy(J) =
                            (ton/y)*(1E+06g/ton)*(15E+3J/g)
                     7.64E+15
                                   J/y
28
       Machinery, transportation, equipment
       Imports =
                     2.78E+05
                                    ton
                                                                       (INDEC, 1996)
        Mass(g) =
                      (ton/y)*(1E+06g/ton)
                     2.78E+11
                                    g/y
29
       Imported services:
        Dollar Value =
                            1.99E+10
                                           $US
                                                                (BAC, 1982; CTI, 1996)
Exports of energy, materials and services
30
       Agricultural crops
        Exports:
                     2.29E+07
                                                  (Comercio Exterior Argentino, 1996)
                                    ton/v
                             (ton)*(1E+06 g/ton)*(20%)*(3.5 kcal/g)*(4186 J/kcal)
           Energy(J) =
                     6.70E+16
                                   J/y
31
       Fishery production:
       Exported =
                     2.98E+04
                                    ton/v
                                                                          (FAO, 1998)
                            (ton)(1E+06 g/ton)(5 kcal/g)(4187 J/kcal)(0.22 prot)
           Energy (J) =
                     1.37E+14
                                   J/y
32
       Forestry products
        Exports =
                     1.72E+05
                                    ton/v
                                                                       (INDEC, 1996)
           Energy (J) =
                             (ton/y)(1.0E+06 g/ton)(80\%)(3.6 kcal/g)(4186 J/kcal)
                     1.56E+15
                                   J/y
33
       Petroleum products:
        Exports =
                     1.03E+07
                                    ton/y
                                                                       (INDEC, 1996)
        Energy (J) = (ton/y)*(4.2 E+10 J/ton)
                     4.35E+17
34
       Metals/minerals
        Exports =
                     2.84E+06
                                    ton/v
                                                                       (INDEC, 1996)
        Mass(g) =
                     (ton/y)*(1E+06 g/ton)
                     2.84E+12
                                    g/y
35
       Paper, textile, leather products
                     3.28E+05
       Exports =
                                    ton/v
                                                                       (INDEC, 1996)
            Energy (J) =
                             (ton/y)(1.0E+06 g/ton)(4.0 kcal/g)(4186 J/kcal)
                     5.49E+15
```

36 Chemicals:

Exports = 4.92E+05 ton/y Energy (g) = (ton)*(1E+06 g/ton)= 4.92E+11 g

37 Services in exports:

Dollar Value = 2.65E+10 \$US (BAC, 1982; CTI, 1996)

38 Service external debt

Debt service ratio = 45 % (Conesa, 1988)

Exports = 2.65E+10 \$US

Service dollar value = 11928933000 \$US

Table C.11. Summary of annual major emergy and monetary flows for Argentina during the 1976-1989 period.

Variable Item		Solar Emergy (E20 sej/y)	Dollars	
R	Renewable sources (rain chemical) Rain Chemical, item 2 Nonrenewable resources from within	2680.46		
N	Argentina	1750.64		
	$N_0 + N_1 + N_2$			
N_0	Dispersed Rural Source	261.73		
	Items 11, 12, 13, and 19 less item 33			
N_1	Concentrated Use	1229.13		
	Sum of items 14, 15, 16, 17, and 18 less 33, 34 ar	nd 35		
N_2	Exported without Use	259.23		
	Items 33, 34 and 35			
F	Imported Fuels and Minerals	187.41		
	Items 20, 21, 22, and 24			
G	Imported Goods	37.78		
	Items 23, 25, 26, 27, and 28			
I	Dollars Paid for Imports		1.99E+10	
	Item 29			
P ₂ I	Emergy of Services in Imported Goods & Fuels Item 29	397.64		
E	Dollars Received for Exports Item 37		2.65E+10	
P ₁ E	Emergy Value of Goods and Service Exports Item 37	575.30		
x	Gross Domestic Product		2.21E+11	
	(1990 dollars)			
P_2	World emergy/\$ ratio, used in imports	2.00E+12		
P ₁	Argentina Emergy/\$ ratio (total emergy used/GDP)	2.17E+12		

Table C.12. Overview indices of annual solar emergy use for Argentina during the 1976-1989 period.

Item	Name of Index	Expression	Quantity	Unit		
1	Renewable emergy flow	R	2.68E+23	sej/y		
2	Flow from indigenous nonrenewable					
	reserves	N	1.75E+23	sej/y		
3	Flow of imported emergy	F+G+P ₂ I	6.23E+22	sej/y		
4	Total emergy inflows	R+N+F+G+P ₂ I	5.05E+23	sej/y		
5	Total emergy used, U	$N_0+N_1+R+F+G+P_2I$	4.79E+23	sej/y		
6	Total exported emergy	P_1E	5.75E+22	sej/y		
7	Fraction emergy use derived					
	from home sources	$(N_O+N_1+R)/U$	0.87			
8	Imports minus exports	$(F+G+P_2I)-(N_2+P_1E)$	-2.12E+22	sej/y		
9	Export to Imports	$(N_2+P_1E)/(F+G+P_2I)$	1.34			
10	Fraction used,					
	locally renewable	R/U	0.56			
11	Fraction of use purchased	$(F+G+P_2I)/U$	0.13			
12	Fraction imported service	P_2I/U	0.08			
13	Fraction of use that is free	$(R+N_0)/U$	0.61			
14	Ratio of concentrated to rural	$(F+G+P_2I+N_1)/(R+N_0)$	0.63			
15	Use per unit area	U/(area)	1.72E+11	sej/m²		
16	Use per person	U/population	1.64E+16	sej/person		
17	Renewable carrying capacity					
	at present living standard	(R/U) (population)	1.63E+07	people		
18	Developed carrying capacity					
	at same living standard	8(R/U)(population)	1.31E+08	people		
19	Ratio of use to GDP,					
	emergy/dollar ratio	$P_1=U/GDP$	2.17E+12	sej/\$		
20	Ratio of electricity to use	(el)/U	0.06	. ,		
21	Fuel use per person	fuel/population	2.66E+15	sej/person		

Table C.13. Footnotes for the emergy evaluation of the Argentine economy during the 1990-1995 period.

```
Renewable resources:
1
       Solar energy:
        Cont Shelf Area =
                             8.71E+11 m2 at 200 m depth
                                                                         (Brown, 1998)
        Land Area = 2.78E+12 m2
                                                                         (INDEC, 2000)
       this figure excludes Islas Malvinas and the Argentinean Antarctic territory
        Insolation = 1.57E+02 \text{ kcal/cm2/y}
                                                                         (Brown, 1998)
        Albedo =
                                                                             * estimate
                      30%
        Energy (J) = (area including shelf)*(average insolation)*(1-albedo)
                     (4186 J/kcal)
                      1.68E+22 J/v
       Rain, chemical potential energy:
2
        Land Area = 2.78E+12 \text{ m}2
        Cont Shelf Area = 8.71E+11 m2
        Rain (land) = 0.94 \text{ m/y}
                                                    (Oxford Encyclopedic World Atlas)
        Rain (shelf) = 0.42 m/y
                                                          estimated as 45% of total rain
        Energy (land) (J) = (area)(rainfall)(G)(1000 kg/m3)
             where G corresponds to Gibbs free energy number= 4940 J/kg
                 = 1.29E + 19 J/v
       Energy (shelf) (J)=
                             (area of shelf)(rainfall)(G)(1000 kg/m3)
                             1.82E+18
                                           J/y
                                           J/y
       Total energy (J) =
                             1.47E+19
3
       Rain, geopotential energy:
        Land Area = 2.78E+12
                                    m2
        Rain (land) =
                             0.94
                                    m
        Evapotranspiration rate=
                                    0.65
                                           m/y
       Average Elevation = 889.87 m
                                                         (estimated from INDEC, 2000)
       Runoff rate = 31\%
                                                                         (Brown, 1998)
       Energy (J) = (area)(%runoff)(water density)(rainfall)(aver. elevation)(gravity)
                      7.03E+18
                                    J/y
4
       Wind energy:
        Energy (J) = 2.07E+19
                                    J/y
                                                                         (Brown, 1998)
5
       Wave energy:
           Energy (J) =
                             8.05E+17
                                                                         (Brown, 1998)
                                           J/y
       Tidal energy:
6
       Continental Shelf Area =
                                    8.71E+11
                                                   m2
                                                                         (Brown, 1998)
       Average Tide Range =
                                    1.00
                                                                         (Brown, 1998)
                                           m
       Tides/year = 7.30E+02
                                                               Estimated as 2 tides/day
       Energy (J) =
                      (shelf)(0.5)(tides/y)(mean tidal range)2(den. seawater)(gravity)
                                                                          (Odum 1996)
                      3.19E+18
                                    J/y
7
       Earth cycle
       Land Area = 2.78E+12
                                    m2
       Heat flow = 1.00E+06
                                    J/m2
                                                                          (Odum 1996)
       Energy (J) =
                     (area)(heat flow)
                      2.78E+18
                                    J/y
```

```
Indigenous renewable energy
       Hydroelectricity:
       Kilowatt Hrs/y =
                             2.69E+10
                                           KwH/y
                                                                           (EIA, 2000b)
           Energy(J) =
                             (KwH/y)*(3.6 E+06 J/KwH)
                     9.67E+16
                                    J/y
9
       Agricultural production:
        Production =
                             4.14E+07
                                                                           (FAO, 1998)
                                           ton/y
                             (ton)*(1E06 g/ton)*(20%)*(4.0 kcal/g)*(4186 J/kcal)
           Energy (J) =
                             1.39E+17
                                           J/y
10
       Livestock production:
        Production =
                            1.11E+07
                                           MT/v
                                                                           (FAO, 1998)
                             (ton)*(1.00 E+06 g/ton)*(20%)*(5 kcal/g)*(4186 J/Cal)
           Energy (J) =
                     4.65E+16
                                    J/y
11
       Fisheries production:
        Fish Catch = 8.22E+05
                                    ton/y
                                                                           (FAO, 1998)
                             (ton)*(1E+06 g/ton)*(5 kcal/g)*(20%)*(4186 J/kcal)
           Energy(J) =
                     3.44E+15
12
       Fuelwood production:
       Production = 3.63E+06
                                                                           (FAO, 1998)
                                    m3
                             (m3)(0.5E+06 g/m3)(80\%)(3.6 Cal/g)(4186 J/Cal)
           Energy(J) =
                     4.38E+10
                                    J/y
13
       Forest extraction
        Harvest = 7.88E+06
                                    m3
                                                                           (FAO, 1998)
          Energy(J) = (6.86 \text{ E}+06 \text{ m}3)(0.5\text{E}+06 \text{ g/m}3)(80\%)(3.6 \text{ Cal/g})(4186 \text{ J/Cal})
                     4.75E+16
                                    J/y
Nonrenewable resources from within
       Natural gas
14
        Production =
                             2.63E+10
                                           m3/y
                                                                            (CTI, 1996)
                             (m3/y)(3.9 E+17 J/m3)
           Energy (J) =
                     1.02E+18
                                    J/y
15
       Oil
                             3.40E+07
        Production =
                                           m3/v
                                                                            (CTI, 1996)
           Energy(J) =
                             (m3/v)(0.87ton/m3)(4.2 E+10 J/ton)
                     1.43E+18
                                    J/y
16
       Coal
        Production =
                             2.64E+05
                                           MT/y
                                                                            (CTI, 1996)
                             (3.8 E+05 Mt/v)*(2.9E+10 J/Mt)
           Energy(J) =
                     7.65E+15
                                    J/y
17
       Minerals non metallic
        Production =
                             4.82E+07
                                           ton/y
                                                                          (SUIM, 2000)
           Mass(g) = (ton)*(1E6 g/ton)
                     4.82E+13
                                    g/y
18
       Metals
        Production
                             2.02E+05
                                           ton/y
                                                                          (SUIM, 2000)
                     2.02E+11
                                    g/y
```

```
19
       Topsoil:
       Arable Land = 2.50E+07
                                   ha
                                                                          (FAO, 1998)
       Rate of Loss = 1.00E+07
                                   g/ha
        Soil loss =
                     2.50E+14
                                   g/y
                            (2.22 E14 g/y)*(0.03 OM)*(5.4 kcal/g)(4186 J/kcal)
           Energy (J) =
                     1.70E+17
                                   J/y
Imports of outside energy sources:
20
       Oil derived products:
        Imports =
                     2.53E+06
                                   ton
                                                                       (INDEC, 1996)
           Energy (J) =
                            (ton/y)*(4.20 E10 J/ton)
                     1.06E+17
                                   J/y
21
       Metals
        Imports =
                     9.91E+05
                                                                       (INDEC, 1996)
                                   ton
           Mass (g) = (ton/y)*(1.00E+06 g/ton)
                     9.91E+11
                                   g/y
22
       Minerals non metallic
        Imports =
                     4.41E+06
                                                                       (INDEC, 1996)
                                   ton
           Mass (g) = (ton/y)*(1.00E+06 g/ton)
                     4.41E+12
                                   g/y
23
       Food and agricultural products
        Imports =
                     9.11E+05
                                   ton
                                                                       (INDEC, 1996)
                            (ton/y)*(1E+06g/ton)*(3.5 Kcal/g)*(4186 J/Kcal)
           Energy (J) =
                     1.34E+16
                                   J/y
24
       Coal
        Imports =
                     1.25E+06
                                   ton/v
                                                                          (EIA, 2000b)
                            (1.16 E+06 ton/y)*(2.9 E+10 J/ton)
           Energy (J) =
                     3.63E+16
                                   J/y
25
       Plastics & rubber
        Imports =
                     4.02E+05
                                                                       (INDEC, 1996)
                                   ton
           Energy(J) =
                            (ton/y)*(1000 \text{ Kg/MT})*(30.0E+06J/kg)
                     1.21E+16
26
       Chemicals
        Imports =
                     1.88E+06
                                                                       (INDEC, 1996)
                                   ton
           Mass (g) = (ton/y)*(1E+06g/ton)
                     1.88E+12
                                   g/y
27
       Wood, paper, textiles, leather
                                                                       (INDEC, 1996)
        Imports =
                     8.58E+05
                                   ton
           Energy(J) =
                            (ton/y)*(1E+06g/ton)*(15E+3J/g)
                     1.29E+16
                                   J/y
28
       Machinery, transportation, equipment
       Imports =
                     7.40E+05
                                   ton
                                                                       (INDEC, 1996)
        Mass(g) =
                      (ton/y)*(1E+06g/ton)
                     7.40E+11
                                   g/y
29
       Imported services:
        Dollar Value =
                            3.23E+10
                                          $US
                                                                           (CTI, 1996)
```

```
Exports of energy, materials and services
30
       Agricultural crops
        Exports:
                     2.98E+07
                                    ton/y
                                                                        (INDEC, 1996)
           Energy(J) =
                             (ton)*(1E+06 g/ton)*(20%)*(3.5 kcal/g)*(4186 J/kcal)
                     8.72E+16
                                   J/y
       Fishery production:
31
       Exported =
                     1.07E+04
                                    ton/y
                                                                        (INDEC, 1996)
                            (ton)(1E+06 g/ton)(5 kcal/g)(4187 J/kcal)(0.22 prot)
           Energy (J) =
                     4.95E+13
                                   J/y
32
       Forestry products
        Exports =
                     7.42E+05
                                    ton/y
                                                                        (INDEC, 1996)
                             (ton/y)(1.0E+06 g/ton)(80\%)(3.6 kcal/g)(4186 J/kcal)
           Energy (J) =
                     6.71E+15
                                   J/y
33
       Petroleum products:
                     1.14E+07
                                                                        (INDEC, 1996)
        Exports =
                                    ton/y
        Energy (J) = (ton/y)*(4.2 E+10 J/ton)
                     4.78E+17
34
       Metals/minerals
        Exports =
                     1.57E+07
                                    ton/y
                                                                        (INDEC, 1996)
        Mass(g) =
                     (ton/y)*(1E+06 g/ton)
                     1.57E+13
                                    g/y
35
       Paper, textile, leather products
        Exports =
                     5.48E+05
                                    ton/y
                                                                        (INDEC, 1996)
           Energy (J) =
                             (ton/y)(1.0E+06 g/ton)(4.0 kcal/g)(4186 J/kcal)
                     9.17E+15
36
       Chemicals:
        Exports =
                     5.93E+05
                                    ton/y
                                                                        (INDEC, 1996)
        Energy (g) = (ton)*(1E+06 g/ton)
                     5.93E+11
                                    g
37
       Services in exports:
                                           $US
        Dollar Value =
                            2.74E+10
                                                                           (CTI, 1996)
38
       Service external debt
                                    %
                                                           (European Parliament, 1999)
       Debt service ratio =
                            34
       Exports =
                     2.74E+10
                                    $US
       Service dollar value = 9306092400
                                           $US
```

APPENDIX D EMERGY EVALUATION TABLES AND FOOTNOTES FOR THE ROLLING PAMPAS

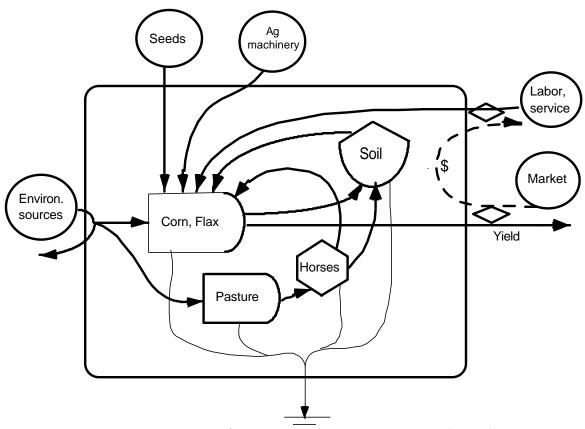


Figure D.1. Low energy tenant farming production system in the Rolling Pampas.

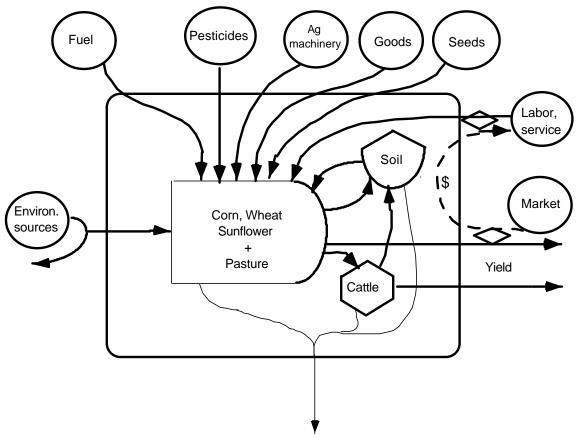


Figure D.2. Mixed grain and livestock production system in the Rolling Pampas.

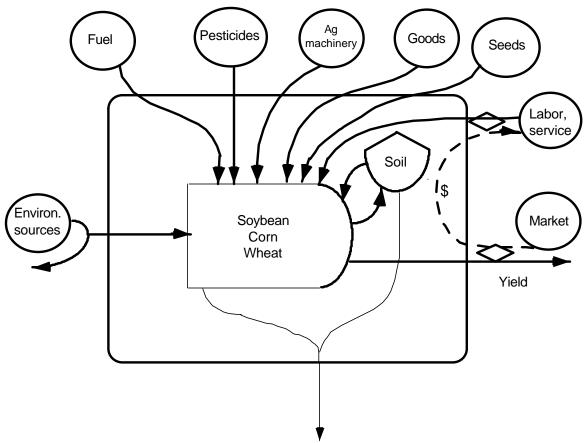


Figure D.3. Agricultural industrialization production system in the Rolling Pampas.

Table D.1. Emergy evaluation of 1 ha of low energy tenant farming production in the Rolling Pampas.

Note Item	Unit	Data (unit/ha/y)	Transformity (sej/unit)	Solar E (E+13 sej/y)	Em\$ Value (1990 US\$)	
Renewable resources:						
1Rain, chemical	J	4.28E+10	1.82E+04	77.9	55.3	
Nonrenewable resources	s use fi	om within syst	em:			
2Net Top Soil Loss	J	1.45E+09	7.40E+04	10.7	7.6	
Sum of free inputs				88.7	62.9	
Purchased resources:						
3horses	J	3.14E+07	4.64E+04	0.1	0.1	
4seeds (energy)	J	5.77E+08	5.46E+04	3.2	2.2	
5Human labor	hr	7.50E+01	5.79E+12	43.4	30.8	
6Machinery	g	8.00E+03	6.70E+09	5.4	3.8	
7Goods	g	1.00E+03	2.27E+09	0.2	0.2	
Sum of purchased inputs 52.1				37.0		
Products of the agricultural phase						
8Yield (dry)	g	2.13E+06	6.63E+08	3 140.8	99.9	
			4.58E+08	97.4	69.1	
	j	3.19E+10	4.42E+04	140.8	99.9	
	,		3.06E+04	97.4	69.1	

Footnotes to Table D.1

Renewable resources:

1 Rain, chemical potential energy:

Land Area =	$10000\mathrm{m}^2$				
Rain (average) =	$1.02\mathrm{m/y}$	D'Elia et al. (1999)			
Runoff =	15 %	D'Elia et al. (1999)			
Gibbs free energy water =	4.94j/g	Odum (1995)			
Energy on land = (area)(rainfall)(runoff)(water density)(Gibbs no.)					
=4.28E+10 J/y					

2 Net loss of top soil

Land Area =
$$8000 \,\mathrm{m}^2$$
 MABA (1929)
Erosion rate = $200 \,\mathrm{g/m}^2/\mathrm{y}$
Net loss of top soil = $1.60 \mathrm{E} + 06 \,\mathrm{g/y}$
% OM in soil = $4 \,\%$ Moscatelli (1991)

OM in top soil eroded = (total mass of top soil)(%OM)

= 6.40E + 04 g/y

Energy loss = (OM eroded)(energy content of OM)

= 1.45E + 09J/y

Only the surface under crop cultivation was considered for erosion purposes (80 ha= 50 ha corn + 25 ha flaxseed + 5 ha grazing)

3 Horses

Annual consumption =
$$7.50E+00 \text{ kg/y}$$

Energy (J) = $(\text{kg})*(1000 \text{ g/kg})*(20\%)*(5 \text{ kcal/g})*(4186 \text{ J/kcal})$
= $3.14E+07 \text{ J/ha}$

(20 creole horses for 80 ha, working for 10 years, each one weighs 300 kg)

4 Seeds

Corn

Energy per unit mass= 3.50E+00j/g

Energy (j) =
$$(g \text{ of seeds})(energy content/g)(1000 g/kg)$$

= 1.90E + 08 J/ha

Flaxseed

Energy per unit mass= 4.20E+00j/g

Energy (j) =
$$(g \text{ of seeds})(energy content/g)(1000 g/kg)$$

= 3.87E + 08 J/ha

Total =
$$5.77E+08J/ha$$

5 Human labor

6 MachinerY

Total applied goods. =
$$8.00E+03g/y$$
 MABA (1929)

(weight= approximately 100 kg each machine, duration= 5 years)

7 Goods

Total applied goods. =
$$1.00E+03g/y$$
 MABA (1929)

8 Yield (dry weight)

$$corn = 1.88E + 06 g/ha$$
 MABA (1929)
flaxseed = $2.50E + 05 g/ha$ MABA (1929)

Total mass = 2.13E+06g/ha

Total energy = 3.19E+10j/ha

Table D.2. Emergy evaluation of 1 ha of mixed grain and livestock farming production in the Rolling Pampas.

Note	Item	Unit	Data (unit/ha/y)	Transformity (sej/unit)	Solar E (E+13 sej/y)	Em\$ Value (1990 US\$)
Renewable resources:						
1	Rain, chemical	J	4.28E+10	1.82E+04	77.9	399.7
Nonre	enewable resources	use from	m within syste	em:		
2	Net Top Soil Loss	J	3.70E+09	7.40E+04	27.3	140.3
Sum o	of free inputs				105.3	540.0
Purch	ased resources:					
3	Fuel	J	1.27E+09	6.60E+04	8.4	43.0
4	seeds (energy)	J	3.69E+08	7.72E+04	2.9	14.6
5	livestock	J	12.09E+06	5.69E+04	0.0	0.1
6	Herbicides	g	5.00E+02	1.48E+10	0.7	3.8
7	Human labor	h	5.20E+00	2.40E+12	1.2	6.4
8	Machinery	g	5.00E+03	6.70E+09	3.4	17.2
9	Goods	US \$	5 1.50E+01	3.47E+12	5.2	26.7
Sum of purchased inputs 21.8 113						111.7
Products of the agricultural phase						
10 Yie	eld (dry)	g	2.36E+06	5.38E+08	127.1	651.7
				5.32E+08	125.8	651.7
		j	2.36E+10	5.39E+04	127.1	651.7
				5.33E+04	125.8	645.3

Footnotes to Table D.2

Renewable resources:

1 Rain, chemical potential energy:

Land Area = $10000 \,\mathrm{m}^2$ Rain (average) = $1.02 \,\mathrm{m/y}$ D'Elia et al. (1999) Runoff = $15 \,\%$ D'Elia et al. (1999) Gibbs free energy water = $4.94 \,\mathrm{j/g}$ Odum (1995) Energy on land = (area)(rainfall)(runoff)(water density)(Gibbs no.) = $4.28\mathrm{E} + 10 \,\mathrm{J/y}$

2 Net loss of top soil

Land Area = $10000 \,\mathrm{m}^2$

Erosion rate = $545 \,\mathrm{g/m^2/y}$

(10 ton of erosion per ha during 6 agricultural years assigned to the 11 years of the whole rotation)

```
Table D.2 (continued)
```

Total applied goods. =

Net loss of top soil = 5.45E+06 g/v3 % % OM in soil = OM in top soil eroded = (total mass of top soil)(%OM) = 1.64E + 05 g/yEnergy loss = (OM eroded)(energy content of OM) = 3.70E + 09 J/y3 Fuel Annual consumption = 3.50E+011/yPereya and Tricco (1968) Lower heating value = 4.45E+07j/kgEnergy (j) = $(l ext{ of fuel})(fuel ext{ density})(energy ext{ content/kg})$ = 1.27E + 09j/y4 Seeds (Hybrid, variety) Cereals and grass Annual consumption = 24 kg/yPereyra and Tricco (1968) Energy per unit mass= 1.47E+04j/gEnergy (j) = (g of seeds)(energy content/g)(1000 g/kg)= 3.52E + 08i/gOleaginous (sunflower) Annual consumption = Pereyra and Tricco (1968) 1 kg/yEnergy per unit mass= 1.76E+04j/gEnergy (j) = (g of seeds)(energy content/g)(1000 g/kg)= 1.76E + 07i/gTotal = 3.69E + 08j/g5 Livestock Annual consumption = 500 Kugler and Nocetti (1969) g (35 cows, 1 bull and a young bull in 36 ha during 5 years of the rotation) Energy (J) = (g)*(20%)*(5 kcal/g)*(4186 J/Cal)Energy = 2.09E+06J/ha8 Pesticides Annual consumption = 5.00E + 02g/yPereyra and Tricco (1968) 9 Human labor Total applied labor = 5.20E+00hr Pereyra and Tricco (1968) 10 Machinery Total applied goods. = 5.00E+03 g/yPereyra and Tricco (1968) 11 Goods

1.50E+01US \$/y

Pereyra and Tricco (1968)

12 Yield (dry weight)

cereals, oleaginous = 1.36E+06g/ha Pereyra and Tricco (1968)

Energy (J) = (g)*(85%)*(4.0 kcal/g)*(4186 J/kcal)

Energy = 1.94E+10J/ha

livestock = 1.00E+06 g/ha Kugler and Nocetti (1969)

Energy (J) = (g)*(20%)*(5 kcal/g)*(4186 J/Cal)

Energy = 4.19E+09J/ha

Total mass = 2.36E+06

Total energy = 2.36E+10J/ha

Table D.3. Emergy evaluation of 1 ha of industrialized agricultural production in the Rolling Pampas.

Note	Item	Unit	Data (unit/ha/y)	Transformity (sej/unit)	Solar E (E+13 sej/y)	Em\$ Value (1990 US\$)
Renewable resources:						
1 I	Rain, chemical	J	4.28E+10	1.82E+	-04 77.9	357.6
Nonrer	Nonrenewable resources use from within system:					
21	Net Top Soil Loss	J	1.70E+10	7.40E+	-04 125.5	575.5
Sum of	free inputs				203.4	933.0
Purchased resources:						
31	Fuel	J	4.94E+09	6.60E+	-04 32.6	149.5
$4\mathrm{s}$	seeds (energy)	J	1.74E+09	5.01E+	-04 8.7	40.1
5 s	seeds (info)	US\$	0.00E+00	1.95E+	-12 0.0	0.0
81	Herbicides	g	3.25E+03	1.48E+	-10 4.8	22.1
91	Human labor	h	1.20E+01	1.88E+	-12 2.3	10.4
10 N	Machinery	g	5.00E+03	6.70E+	-09 3.4	15.4
110	Goods	US\$	1.50E+01	2.18E+	-12 3.3	15.0
Sum of purchased inputs					55.0	252.3
Products of the agricultural phase						
12 Y	ield (dry)	g	4.50E+06	5.74E+	-08 258.4	1185.4
				5.69E+	-08 256.2	2 1175.0
		j	5.30E+10	4.88E+	-04 258.4	1185.4
				4.84E+	-04 256.2	2 1175.0

Footnotes to Table D.3

Renewable resources:

1 Rain, chemical potential energy:

Land Area	$10000 \mathrm{m}^2$	
Rain (average) =	$1.02\mathrm{m/y}$	D'Elia et al. (1999)
Runoff =	15 %	D'Elia et al. (1999)
Gibbs free energy water =	4.94 j/g	Odum (1995)
Energy on land =	(area)(rainfall)(ru	noff)(water density)(Gibbs no.)
= 4	.28E+10 J/y	

2 Net loss of top soil

Land Area = $10000 \,\mathrm{m}^2$ Erosion rate = $2500 \,\mathrm{g/m}^2/\mathrm{y}$ Marelli (1998) Net loss of top soil = $2.50\mathrm{E}+07 \,\mathrm{g/y}$ % OM in soil = 3 % EEA Pergamino (1998)

```
Table D.3 (continued)
```

```
OM eroded = (total mass of top soil)(%OM)
                            =7.50E+05 g/y
               Energy loss = (OM eroded)(energy content of OM)
                            =1.70E+10 J/y
  Fuel
3
         Annual consump. = 1.36E+02 l/y
                                                        Pizarro and Cacciamani (1980);
         Lower heating value = 4.45E+07 j/kg
                                                            Basail and Ravazzoli (1981)
                  Energy (j) = (l of fuel)(fuel density)(energy content/kg)
                            =4.94E+09 i/v
4 Seeds (Hybrid, variety)
    Cereals (wheat, corn)
      Annual consumption =
                                       71 \text{kg/y}
                                                        Pizarro and Cacciamani (1980);
       Energy per unit mass= 1.47E+04j/g
                                                            Basail and Ravazzoli (1981)
                  Energy (j) = (g \text{ of seeds})(\text{energy content/}g)(1000 \text{ g/kg})
                                    1.04E + 09j/g
    Oleaginous (soybean)
      Annual consumption =
                                       40 \text{kg/y}
                                                         Pizarro and Cacciamani (1980)
       Energy per unit mass= 1.76E+04j/g
                  Energy (j) = (g \text{ of seeds})(\text{energy content/}g)(1000 \text{ g/kg})
                            = 7.03E + 08i/g
                      Total = 1.74E + 09j/g
  Seeds (info)
                                                          Pizarro and Cacciamani (1980);
    Annual consumption =
                                     0\$/y
                                                              Basail and Ravazzoli (1981)
  (calculated as the difference between the price of the seeds and the price of the yield)
  Pesticides
    Annual consumption =
                                                          Pizarro and Cacciamani (1980);
                                3.25E+03g/y
                                                              Basail and Ravazzoli (1981)
  Human labor
    Total applied labor =
                                1.20E+01hr
                                                          Pizarro and Cacciamani (1980);
                                                              Basail and Ravazzoli (1981)
10 Machinery
    Total applied goods. =
                                5.00E + 03 g/y
                                                          Pizarro and Cacciamani (1980);
                                                              Basail and Ravazzoli (1981)
11 Goods
    Total applied goods. =
                                1.50E+01US $/y
                                                          Pizarro and Cacciamani (1980);
                                                              Basail and Ravazzoli (1981)
```

Table D.3 (continued)

12 Yield (dry weight) corn, soybean, wheat = 4.50E+06g/haEnergy = 5.30E+10J/ha

Pizarro and Cacciamani (1980); Basail and Ravazzoli (1981)

Table D.4. Footnotes for the emergy evaluation table of 1 ha of Rainfed intensive production system in the Rolling Pampas.

Renewable resources:

1 Rain, chemical potential energy:

Land Area =
$$10000 \,\mathrm{m}^2$$

Rain (average) = $1.02 \,\mathrm{m/y}$ D'Elia et al. (1999)
Runoff = $15 \,\%$ D'Elia et al. (1999)
Gibbs free energy water = $4.94 \,\mathrm{j/g}$ Odum (1995)
Energy on land = (area)(rainfall)(runoff)(water density)(Gibbs no.)
= $4.28\mathrm{E} + 10 \,\mathrm{J/y}$

2 Net loss of top soil:

Land Area =
$$10000 \,\mathrm{m}^2$$

Erosion rate = $2000 \,\mathrm{g/m}^2/\mathrm{y}$ EEA Pergamino (1998)
Net loss of top soil = $2.00\mathrm{E}+07 \,\mathrm{g/y}$
% OM in soil = $3 \,\%$ EEA Pergamino (1998)

OM in top soil eroded = (total mass of top soil)(%OM)

3 Fuel

Annual consumption =
$$1.65E+021/y$$
 PROSAP (1997)
Lower heating value = $4.45E+07j/kg$
Energy (j) = (l of fuel)(fuel density)(energy content/kg)
= $5.99E+09j/y$

4 Seeds (Hybrid, variety)

Cereals (wheat, corn)

Annual consumption =
$$70 \text{ kg/y}$$
 PROSAP (1997)
Energy per unit mass= $1.47\text{E}+04 \text{ j/g}$
Energy (j) = (g of seeds)(energy content/g)(1000 g/kg)
= $1.03\text{E}+09 \text{ j/g}$

Oleaginous (soybean)

Annual consumption =
$$38 \text{ kg/y}$$
 PROSAP (1997)
Energy per unit mass= $1.76\text{E}+04\text{ j/g}$
Energy (j) = (g of seeds)(energy content/g)(1000 g/kg)
= $6.68\text{E}+08\text{ j/g}$
Total = $1.69\text{E}+09\text{ j/g}$

Table D.4 (continued)

5	Seeds (info)					
	Annual consumption =	52.7\$/y	PROSAP (1997)			
(ca	(calculated as the difference between the price of the seeds and the price of the yield)					
6	Nitrogen (gN)					
	Annual consumption =	5.75E+04g/y	PROSAP (1997)			
7	Phosphate (gP)					
	Annual consumption =	6.30E+03g/y	PROSAP (1997)			
8	Pesticides					
	Annual consumption =	4.00E+03g/y	PROSAP (1997)			
9	Human labor					
	Total applied labor =	4.35E+00hr	Daza (1998)			
10	Machinery					
	Total applied goods. =	5.33E+03g/y	EEA Pergamino (1998)			
11	Goods					
	Total applied goods. =	1.50E+01US\$/y	EEA Pergamino (1998)			
12	Yield (dry weight)					
	corn, soybean, wheat =	7.00E+06g/ha	PROSAP (1997)			

8.14E+10J/ha

Energy =

Table D.5. Footnotes for the emergy evaluation table of 1 ha of Irrigated intensive production system in the Rolling Pampas.

Renewable resources:

1 Rain, chemical potential energy:

Land Area =
$$10000 \,\text{m}^2$$

Rain (average) = $1.02 \,\text{m/y}$ D'Elia et al. (1999)
Runoff = $15 \,\%$ D'Elia et al. (1999)

Gibbs free energy water =
$$4.94i/g$$
 Odum (1995)

Energy on land = (area)(rainfall)(runoff)(water density)(Gibbs no.)

= 4.28E+10 J/y

2 Groundwater (Irrigation):

Land Area = $10000 \,\mathrm{m}^2$

Complementary irrig. = $0.155 \,\mathrm{m/y}$ PROSAP (1997)

Avg. elevation = $60 \,\mathrm{m}$ PROSAP (1997)

Energy on land = (area)(irrig)(water density)(avg.elevation)(gravity)

= 9.11E + 08 J/y

3 Net loss of top soil

Land Area = $10000 \,\mathrm{m}^2$

Erosion rate = $2000 \text{ g/m}^2/\text{y}$ EEA Pergamino (1998)

Net loss of top soil = 2.00E+07 g/y

% OM in soil = 3 % EEA Pergamino (1998)

OM in top soil eroded = (total mass of top soil)(%OM)

= 6.00E + 05 g/y

Energy loss = (OM eroded)(energy content of OM)

= 1.36E+10 J/v

4 Fuel

Lower heating value = 4.45E+07j/kg

Energy (j) = (l of fuel)(fuel density)(energy content/kg)

= 1.06E + 10i/v

5 Seeds (Hybrid, variety)

Cereals (wheat, corn)

Annual consumption =
$$73 \text{ kg/y}$$
 PROSAP (1997)

Energy per unit mass= 1.47E+04j/g

Energy (j) =
$$(g \text{ of seeds})(energy content/g)(1000 g/kg)$$

= 1.07E + 09j/g

Table D.5 (continued)

Oleaginous (soybean) Annual consumption = 38 kg/yPROSAP (1997) Energy per unit mass= 1.76E+04j/gEnergy (j) = (g of seeds)(energy content/g)(1000 g/kg)= 6.68E + 08j/gTotal = 1.74E + 09j/g6 Seeds (info) Annual consumption = PROSAP (1997) 62\$/y(calculated as the difference between the price of the seeds and the price of the yield) 7 Nitrogen (gN) Annual consumption = 9.66E+04g/yPROSAP (1997) 8 Phosphate (gP) Annual consumption = 9.00E+03g/yPROSAP (1997) 9 Pesticides Annual consumption = 5.00E+03g/yPROSAP (1997) 10 Human labor Total applied labor = 5.15E+00h/yEEA Pergamino (1998) 11 Machinery Total applied goods. = 1.03E+04g/yEEA Pergamino (1998) 12 Goods Total applied goods. = 1.50E+01g/yEEA Pergamino (1998) 13 Yield (dry weight) corn, soybean, wheat = 1.30E+07g/haPROSAP (1997) Energy = 1.34E+11J/ha

Table D.6. Footnotes for the emergy evaluation table of 1 ha of No-tillage intensive production system in the Rolling Pampas.

Renewable resources:

1 Rain, chemical potential energy:

Land Area =
$$10000 \,\mathrm{m}^2$$

Rain (average) = $1.02 \,\mathrm{m/y}$ D'Elia et al. (1999)
Runoff = $15 \,\%$ D'Elia et al. (1999)
Gibbs free energy water = $4.94 \,\mathrm{j/g}$ Odum (1995)
Energy on land = (area)(rainfall)(runoff)(water density)(Gibbs no.)

Energy on land = (area)(rainfall)(runoff)(water density)(Gibbs no.)

= 4.28E+10J/y

2 Net loss of top soil

Land Area =
$$10000 \,\mathrm{m}^2$$

Erosion rate = $1000 \,\mathrm{g/m}^2/\mathrm{y}$ Marelli (1998)
Net loss of top soil = $1.00\mathrm{E} + 07 \,\mathrm{g/y}$

% OM in soil = 1.00E+07 g/y

OM in top soil eroded = (total mass of top soil)(%OM)

= 3.00E + 05 g/y

Energy loss = (OM eroded)(energy content of OM)

= 6.78E + 09J/y

3 Fuel

Lower heating value = 4.45E+07j/kg

Energy (j) = (l of fuel)(fuel density)(energy content/kg)
=
$$3.18E+09j/y$$

Oleaginous (soybean)

Energy per unit mass= 1.76E+04j/g

Energy (j) = (g of seeds)(energy content/g)(1000 g/kg)
=
$$7.47E+08j/g$$

Total = 1.33E + 09j/g

5 Seeds (info)

Annual consumption = 51.5\$/y Daza (1998)

(calculated as the difference between the price of the seeds and the price of the yield)

6 Nitrogen (gN)

Annual consumption = 6.40E+04g/y Daza (1998)

7 Phosphate (gp)

Annual consumption = 2.34E+03 g/y Daza (1998)

Table D.6 (continued)

8	Pesticides		
	Annual consumption =	7.45E+03g/y	Daza (1998)
9	Human labor		
	Total applied labor =	1.50E+00hr/y	Daza (1998)
10	Machinery		
	Total applied goods. =	3.33E+03g/y	Daza (1998)
11	Goods		
	Total applied goods. =	1.50E+01US \$/y	Daza (1998)
12	Yield (dry weight)		
	corn, soybean, wheat =	5.70E+06g/ha	Daza (1998)
	Energy =	7.36E+10J/ha	

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BIOGRAPHICAL SKETCH

Maria Cecilia Ferreyra was born in La Plata, Argentina, on September 6, 1968. She became involved with environmental issues through a part time job assisting a local wildlife researcher during her high school years. This led to her studies at the Universidad Nacional de La Plata, where she graduated with an engineer's degree in agronomy in 1997. Before finishing, she had the opportunity of spending a year in Indonesia, a very enriching experience that confirmed her desires to become involved in conservation. She worked as a research intern in environmental impact assessment at the Institute of Rural Economics and Sociology of the National Institute of Agricultural Technology (INTA) in Buenos Aires (Argentina). After graduation, she was selected by INTA as a senior research scholar and assigned to the Pergamino Agricultural Experimental Station, located at the heart of the Pampean Region of Argentina. Her work was related to assessing the impact of intensive grain production on soil and ground water in the area. She has also been actively involved in communicating current environmental legislation to local farmers and professionals. Before attending the master's program at the University of Florida, she graduated as an Environmental Management Specialist from the Universidad Catolica Argentina in Buenos Aires.