APPRAISING EXTERNALITIES OF THE SWISS AGRICULTURE — A COMPREHENSIVE VIEW* —

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INTRODUCTION

The purpose of the study is to quantitatively evaluate externalities of the Swiss agriculture.

From the perspective of economic accounting, the size of agriculture is conceptually defined to include only goods (food and fibre) and services ("agri-tourism") that are bought and sold in market transactions (with few exceptions). Economic accounts generally "record and measure activities that pass through the marketplace, while most of the activities that raise environmental concerns—from air pollution to appreciation of pristine wildernesses—take place outside the market" (Nordhaus and Kokkelenberg, 1999:19). This is also true of societal concerns. As a consequence, an important part of the very picture of agriculture is missing if natural inputs to agriculture and effects of agriculture on society and the environment are omitted in retaining conventional market-based accounts for agriculture—and, more generally, for our national accounts.

These omissions impact on policies in as much as by underestimating valuable nonmarket components in decision making processes, they overstate the role of market goods and services in economic welfare, providing misleading measures with respect to the overall performance of agriculture, especially in relation with sustainability concerns. Expanding conventional accounts by expanding their boundaries to include measures of these "missing residuals" would provide a better estimate of the seize, functions, and growth of agriculture in relation with society and the environment[1].

This work on assessing externalities of the Swiss agriculture is motivated by the idea that appraising the missing residuals in the latter would provide better estimates as a guiding principle in setting further policy, regulatory, and business decisions at the interface of agriculture with society and the environment.

Externalities of agriculture—that is, its missing residuals from the perspective of conventional economic accounts—are constituted of a large number of economically significant nonmarketed inputs and outputs. In the environmental area, nonmarketed inputs include the free goods and services provided by natural assets such as ecosystems and their components while nonmarketed outputs include spillovers such as water pollution, soil erosion, NO_2 emissions or societal benefits such as landscape upkeep, recreation, or informal education.

Externalities are broadly defined as spillovers—effects outside of commercially measurable parts of economic activities. In this appraisal, externalities are defined as situations where actions of agricultural business affect the state of the environment, the societal and spatial structures of a region or country, and the welfare of people who are external to those decisions. This includes all agents in the business of cultivating the soil, producing crops and raising livestock. Externalities identify either positive (recreational areas, pleasant landscape, sustainable societal and spatial structures), negative (soil eroded, water polluted, …) or conflicting aspects (multiple-use of water, space, biodiversity, …).

Basically, externalities are a component of welfare economics. Meade (1973: 16) defines these as situations where actions of agents affect the production possibilities of the economy and the welfare of people, who are not fully consenting parties in reaching production decisions, as they are in sales and purchases. No compensation is made for welfare losses and gains. In addition, true externalities (which remain uncompensated and are called technological externalities) are distinguished from pecuniary externalities (which are income-related effects that

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* Original study in French by Ecosys®: *Appréciation quantitative des externalités de l'agriculture suisse*, final report, Swiss Federal Office of Agriculture, Berne (Switzerland), 2000, 227 pp.

[1] The proper extension of agriculture economic accounts for Switzerland is reviewed elsewhere. See Swiss Federal Statistical Office, forthcoming.

can be captured within the market economy). Other types of externalities, such as societal and spatial effects as well as purely environmental contributions, are not included in current economic analysis. In short, the economic definition of externalities is stringent, limiting expert judgement to narrow and specific limits.

Externalities of agriculture include economic externalities, but should extend beyond the basic definition to include environmental inflows and outflows, as well as societal and spatial dimensions of agriculture. Tactically, two alternatives arise. On the one hand, one might assume the basic definition of externalities as unerring, valuing established external effects by means of market mimicking tools, and reassigning rights over "untrue" externalities by means of some other form of organization.[2] On the other hand, one might choose to quantitatively estimate all types of externalities by "releasing" the basic economic definition and adopting different valuation methods under differing circumstances. Because of the purpose of the study, the second alternative is given preference. In addition, evaluating all externalities of agriculture might prove useful for a future *mise en valeur* of ecological and societal functions of agriculture and the ensuing reassignment of property rights (OECD, 1994).

Because externalities of agriculture all relate to different bases, different gauges are involved in establishing results of different scope. Established external costs and benefits of agriculture will be assessed with economic analysis. Statistics and other social sciences-related tools will be utilized to account for externalities related to society and space. EMergy synthesis will quantify incoming environmental contributions and costs to agriculture.[3]

Externalities of agriculture are numerous. Those reported in international literature were grouped according to their economic, societal or ecological pertinence and prevailing cost/benefit attributes.

Table I shows examples of externalities of agriculture, while Table II shows examples of externalities according to type.

Table I: Examples of External Effects of Agriculture

Effect of agriculture on…	Details	Cost	Benefit
Amenities	Landscape upkeep		✓
	Landscape structuring		
	Recreational areas		✓
Costs	Pollution	✓	
	Correction	✓	
Natural patrimony	Fauna and flora	✓	✓
	Diversity	✓	✓
Climate	CO_2 production/absorption	✓	✓
	Avalanches	✓	✓

As a consequence, results of the study will be consolidated from several sources, assembling economic (shadow) prices, societal (and spatial) indicators, and values related to systems ecology. Synthesis will not provide a single final number. Instead, some composite valuation of the societal and ecological functions inherent in agriculture will be obtained. Agriculture will be evaluated for effects beyond its "food and fiber" primary economic function.

The economic analysis of externalities of the Swiss agriculture is presented in Section 1. In Section 2, societal externalities are considered. In Section 3, emternalities of the Swiss agriculture are assessed. Section 4 is devoted to bridging together the three complementary approaches and interpreting the composite result of the study. This synthesis is then closed with a discussion.

Table II: Examples of Agriculture-related Externalities

[2] Externalities arise in a context of imperfectly delineated rights. While economic externalities can be internalized with the help of bargaining processes, the policing of untrue externalities requires a reorganization of property rights for capturing ownership functions and attached wealth and costs (see e.g., Barzel, 1989).

[3] These inflowing environmental effects have come to be known as "emternalities" (Pillet *et al.*, 1998, 2000; Ecosys®, 2000).

Type of externality	Effects on ...		Details
External costs and benefits	landscape, image		landscape upkeep
			landscape structuring
			...
	recreation		rural sightseeing
			recreation, sports
	education		education (values)
	well-being, health		noise
			...
	animal well-being		detention condition
	human environment		infrastructures damages (roads, railways, ...)
	resources	*soil*	landslide
			erosion
			...
		water	pollution (nitrates, phosphates, ...)
			eutrophication
			...
		air	pollution, contamination (ammoniac, methane, $CO_{2,...}$)
			...
	natural patrimony	*fauna, flora, habitats*	habitats
			fauna and flora
			...
		diversity	genetic diversity
			...
		environmental domains	soil (protection)
			water (protection)
			...
	climate		micro-climate
			CO_2
			...
	natural hazards		avalanches
			...
Societal externalities	socio-cultural patrimony	*societal struct.*	employment
			conservation of villages
			customs, traditions
			...
		spatial struct.	minimum population density
			balance between rural and urban zones
			...
	societal values	*societal choices*	contribution to food for the world
			...
		security, national defense	potential of auto-subsistence
			...
		market resources	conservation of traditional working methods, know-how)
			...
Emternalities			sun
			precipitation
			soils (organic matters)

1 Economic Analysis of External Costs and Benefits: Results for the Swiss Agriculture

Economic Analysis

The economic analysis of external costs and benefits stringently relies on the theory of externalities. External costs and benefits are technically defined as interdependencies between utility functions of consumers and cost functions of producers, be it within themselves or between themselves, and without leading to any trade of any sort on any market. These do not translate into pecuniary parameters. In other words, individuals may notice that they benefit from advantages they did not buy such as environmental qualities (pure air, clear water, and enjoyable landscape), while others feel adversely submitted to smoke, noise or traffic congestion without being indemnified for those effects. These increases or decreases in the welfare of people are not compensated for in any way.

External economic costs and benefits are preference-oriented values. Evaluation procedures, therefore, consist in revealing individual preferences for incremental improvements in the effects of agriculture on the environment. Analysis includes, among other things, willingness-to-pay, willingness-to-accept, hedonic price or travel cost methods, both direct and indirect inquiries and within either real or hypothetical market conditions.

Table III shows how main economic techniques used to assess external costs and benefits within a market economy are related to different types of inquiry and associated market conditions. According to the scope and attributes of these techniques, external costs and benefits of the Swiss agriculture were estimated.

Table III: Economic Valuation Techniques

	Direct inquiries	Indirect inquiries

Preferences revealed with respect to true market conditions	• consumer suplus and willingness to pay
	• replacement cost method (RCM)
	• dose-response method (DRM)
		• hedonic pricing method (HPM) (house price method, wage risk method)
		• household production function:
		  • travel cost method
		  • avertive expenditure method

Preferences deduced with respect to hypothetical market conditions	• contingent valuation method (willingness to pay–WTP; willingness to accept–WTA) • contingent ranking method	• allocating probable expenditures and income

Sources: after Hoevenhagel (1991), Pillet (1993)

First, economic values were ranked according to the concept of Total Economic Value of the environment (TEV). TEV expands established economic value along usage and time axes relative to possible uses of the natural environment, now and in the future (Pearce and Turner, 1990, and others). On the one hand, environmental use is either direct or indirect (present use), or optional (probable future use). On the other hand, the non-usage of the environment leads to inheritance (bequest) and existence values. Figure 1 shows this TEV-tree, with examples related to agriculture. The more direct the use of the environment, the more quantitative the valuation. The more distant the non-use of the environment, the more qualitative the appraisal. Table IV shows how economic externalities are distributed according to TEV.

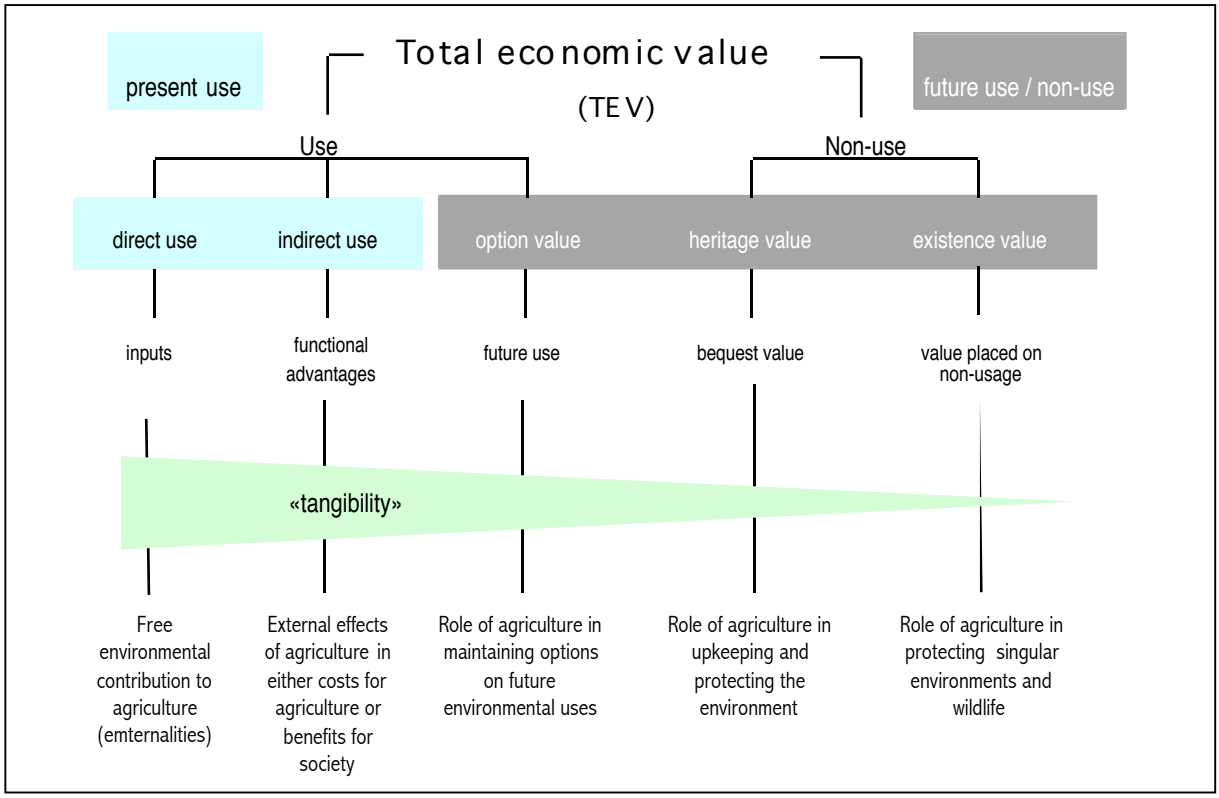

Figure 1: Total Economic Value
Source: after Pearce & Turner (1990), and others

Table IV: Matching Economic Externalities with Components of TEV (Examples)

Themes	Total economic value (TEV)			
	indirect use	option value	heritage value	existence value
landscape	✔	✔	✔	
recreation	✔	✔		
education	✔		✔	
animal detention	✔			
natural resources (soil, water, air)	✔			
natural patrimony (soil, water, air)			✔	
natural patrimony (habitats, fauna, flora, ecosystems, diversity)			✔	✔
climate, microclimate	✔			
hazards		✔		
health	✔			

Source: Ecosys® (2000)

Second, values from the literature were chosen, both Swiss and foreign results.

Individual, preference-related external benefits were estimated using values found in the literature, and then transferred to the account of the Swiss agriculture (a benefit transfer protocol was created to allow Swiss specific features to be taken into account).

External costs for agriculture (pollution costs such as environmental damages and corrective costs necessary to reach or maintain environmental standards) were calculated according to Swiss data on damage and de-contamination costs.

Table V gives examples and sources of pre-transferred values that were used for assessing external costs and benefits of the Swiss agriculture.

Table V: Examples of Values Used for Appraising External Costs and Benefits of Agriculture

	Domain	Original Value	Source
Benefits	Landscape (use)	14 DEM / household/month	WTP in Germany for landscape upkeep
	Recreation (use)	7 Ecu /visit/yr	TCM estimating relation between recreation and agriculture in Italy
	Soil protection (heritage)	25 CHF /ha/yr	Expenses in CH to maintain soil fertility
	Diversity	35 CHF /pers/month	WTP for biodiversity in Swiss Jura Mountains
Costs	Nitrates	12 CHF /kg N	Cost to equip STEPs° for denitrification
	Phosphates	4 CHF /kg P	Cost of chemicals used to precipitate P in STEPs°

° Wastewater treatment facilities

RESULTS

Economic results were obtained from superposing benefits and costs evaluated by transferring both foreign and home values to the Swiss case study (benefit transfer) and from calculating costs with Swiss single costs and other damage assessments (Figure 2).

The following assumptions and a time horizon in 2008 were retained for superposing external costs and benefits (a 2% discount rate was used in the calculations—Arrow, 1994):

- pollution costs level as environmental programs are implemented—these costs become insignificant beyond 2008, and are due only to inherited pollution;[4]
- corrective costs (costs required to meet environmental standards) decrease and become insignificant after 2005 (ecological goals are supposed to be attained by then);
- Management costs appear when an achieved goal or an achieved environmental standard must be kept. They are not evaluated because they don't belong to external effects.

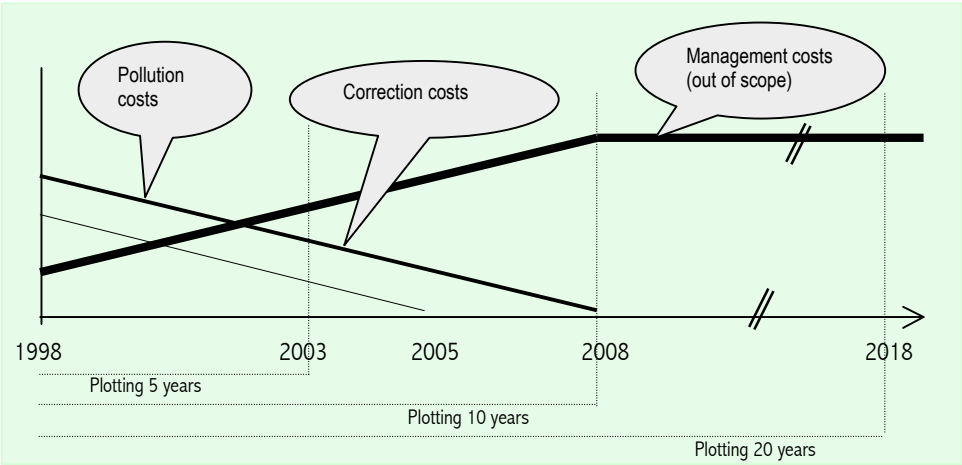

Figure 2 : Costs distribution in time
Based on environmental programs for the Swiss agriculture

[4] This does not mean that all pollution forms will vanish; this means that economic costs associated to such forms of pollution leave off.

Table VI provides results for external benefits and costs for the years 1998, 2003, 2005 and 2008.

In 1998, costs are larger than benefits; positive external effects are due to amenities only.

In 2003, costs will have deeply decreased (negative effects on natural patrimony and climate become insignificant).

In 2005, only pollution costs remain; corrective costs will vanish; effect of agriculture on natural patrimony and climate will turn beneficiary.

In 2008, pollution costs will become insignificant; external effects of the Swiss agriculture will prove globally positive.

Table VI: External Costs and Benefits for the Swiss Agriculture 1998-2008: results

Discounted/annualized CHF1998 10^6

External Costs and Benefits	1998		2003		2005		2008	
	Benefits	Costs	Benefits	Costs	Benefits	Costs	Benefits	Costs
Amenities	1,400.0	0	1,221.0	0	1,189.1	0	1,120.5	0
Costs (pollution, correction)	-	995.9	-	360.8	-	138.8	-	0
Natural patrimony	0	783.9	0	142.0	965.9	0	910.3	0
Climate, health, hazards	0	44.5	0	8.02	38.8	0	36.6	0
Total	1,400.0	1,824.4	1,221.0	510.9	2,193.9	138.8	2,067.4	0
Net external benefits	**- 400.0**		**700.0**		**2,000.0**		**2,000.0**	

Source: adapted from Ecosys® (2000)

2 Appraising Societal Externalities: Results for the Swiss Agriculture

Societal Approach

Societal externalities are closely related to societal norms and values; they go beyond the economic definition of external costs and benefits. They thus embrace those externalities that do not match the basic definition of external effects (for example, pecuniary, structural and socio-cultural externalities). Appraising societal externalities of agriculture means to some extent assessing the societal function of agriculture.

Examples were compiled from the literature to assess societal externalities associated with Swiss agriculture. Table VII presents such examples.

Table VII: Examples of Societal Externalities

Effect of agriculture on…	Designation
Societal structures	Village conservation
	Customs, local traditions
Spatial structures	Decentralised habitat
	Rural-urban spatial equilibrium
Societal values	Contribution to security (food)
	Hereditary know-how

Society relies on societal norms to make choices. Such a norm can be, for example, that agriculture should play a role in the conservation of open spaces or of scattered settlements. The question is: does agriculture fulfil the roles and functions society has entrusted to it? As a consequence, convergence and divergence between agricultural evolution and the fulfilment of such norms should allow assessment of many societal externalities.

Indicators given in the literature were applied to Swiss agriculture by using the most recent local data. Indicators tell if agriculture moves in the direction of the norm (approaching the societal norm) or if it moves away (departing from the societal norm).

Table VIII shows indicators that were considered for the Swiss agriculture case study.

Table VIII: Examples of Socio-cultural Indicators

Societal externality	Indicator
Education	Evolution of visits (and expenses) to a state farm
Village conservation	Evolution of population (rural, agricultural, …)
Socio-economic structures	Evolution of disparities

RESULTS

Evolution of the Swiss agriculture with respect to societal norms and values (approaching or departing from a societal norm or remaining unchanged) was assessed by means of a core set of appropriate indicators. Trends were associated with each type of societal externality as those presented in Table IX and were globally assessed for the same time horizon as the economic analysis. In total, the effects of agriculture on societal structures "come slightly close to the norm". Externalities related to spatial structures tend to keep away from the norm. A few societal values and choices approach satisfaction in the "societal values and choices" domain.

Table IX: Societal Externalities: results

Societal externalities	Distance to the norm
Societal structures	Remaining unchanged – approaching
Spatial structures	Departing – remaining unchanged
Societal values and choices	Approaching – satisfaction

Source: adapted from Ecosys® (2000)

3 EMTERNALITIES: RESULTS FOR THE SWISS AGRICULTURE

DEFINITION

This section addresses the environmental resource fraction that is used in agricultural production without being priced or accounted for commercially. This environmental fraction is called "*emternality*", and its dimension is defined by the measurement of nonmarket environmental inputs into economic processes. Analysis of the agricultural sector is a significant issue because the free environmental fraction embodied in agro-products might prove significant, and the environmental pressure of the sector is particularly obvious.

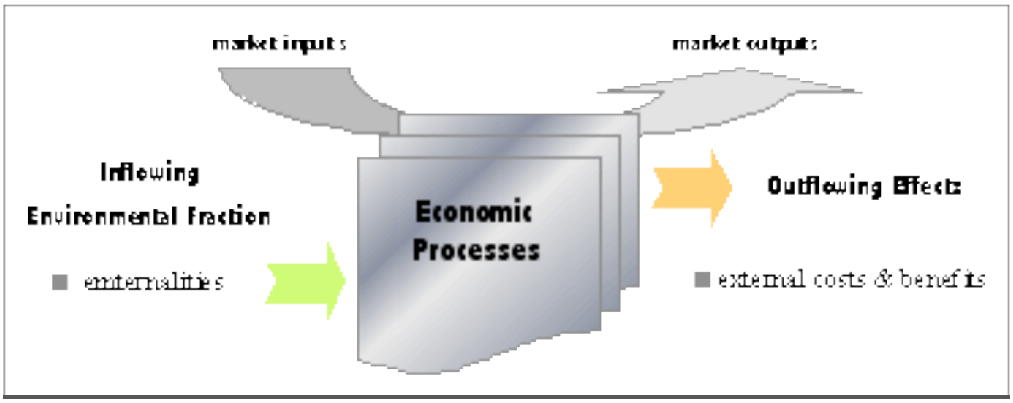

Figure 3 — Emternalities Vs. externalities
Emternalities come into view as the counterpart of economic externalities.

Because commercial markets do not capture emternalities, neither prices nor economic values are available. In theory, *emternalities* can be viewed as the counterpart of established economic *externalities*, except that they designate unassessed inflowing environmental contributions instead of unpriced outflowing impacts of economic processes on the environment (see Fig. 3). The particular prefix aims at emphasizing this "into" attribute (as a variant of "en-", *em-* refers to "put into").

Emternalities are evaluated in eMergy and GDP$-value terms, the former being a quantitative tool for valuing natural ecosystems interacting with economic systems. The economic system itself is considered an ecosystem using free environmental flows as nonmarket inputs into agricultural production and use.

EMERGY SYNTHESIS

Emternalities inflowing into agricultural processes and products first need to be environmentally dimensioned (with respect to eMergy synthesis), and then appraised in relative pecuniary terms.

EMergy synthesis is the metric used for assessing components of agroecosystems and other systems so that emternalities can be expressed in absolute as well as in relative terms. It allows all system parameters, both economic and environmental, to be appraised on a common energy basis using embodied solar joules, or *emjoules* (abbreviated seJ or emJ). The eMergy metric evolved from H.T. Odum's energy hierarchy theory, which relates both environmental and economic work to energy flows of different quality (energy is more or less concentrated). In order to compare different energy forms and concentrations, such as environmental inflows and market inputs, all energy flows are translated into the solar flows that were "embodied" in their creation. This conversion is done by computing transformity ratios that indicate the total amount of energy (environmental energy and purchased) necessary to produce more concentrated energy flows. All energy inputs are calculated as solar energy equivalents. In other words, transformity ratios tell us how many solar joules (emjoules) are

equivalent to one joule of a more concentrated form. *Transformities,* which increase with each energy transformation in a given process, are used to assess quality differences between different energy forms.

EMergy accounting allows evaluation of all work done or needed to produce agricultural outputs. All incoming flows (nonmarket inputs such as sun, land, wind, as well as market inputs like seeds, pesticides, fuel, services, etc.) that contribute to agricultural products, including the final products (e.g., crops or livestock), can therefore be evaluated in emjoules.

Accordingly, the Swiss agriculture was considered a process, as shown in Figure 4. The process combined renewable environmental inputs (R) and nonrenewable environmental inputs (N) with market inputs (F). Environmental recycle (I') is sometimes added.

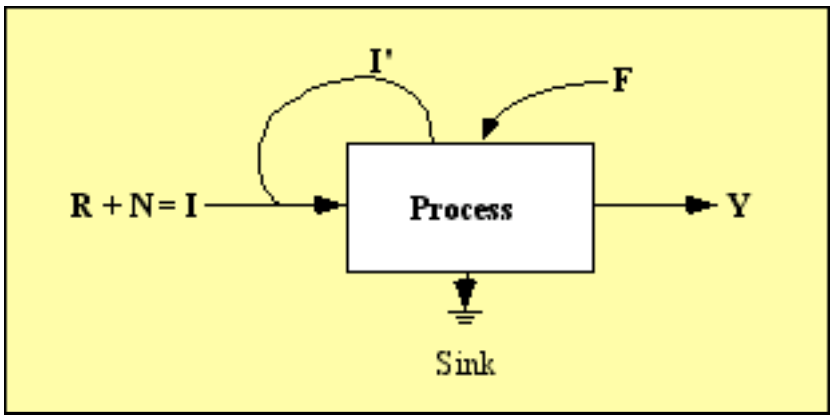

Figure 4: Three-arm diagram

Abbreviations: R: renewable environmental fraction, N: nonrenewable environmental fraction, I: total environmental input, I': recycled environmental fraction, F: inputs fed back by markets; Y: Yield

Three successive protocol-based steps were involved in assessing the environmental fraction in final products of the Swiss agriculture. First, all the inputs of the Swiss agricultural sector were inventoried and classified according to their environmental (renewable or nonrenewable) and market characteristics. Table X shows this categorizing.

Table X: Inputs to Agriculture

Environmental Inputs		Market Inputs
Renewable	**Nonrenewable**	
Sun, rain chemical potential, rain and snow geopotential, earth cycle	Net loss of topsoil	Electricity, lubricant, diesel, gasoline, labor, fertilizers, pesticides, mechanical equipment, seeds, assets, industrial fodder, forages

Second, actual data had to be collected with respect to the different inputs (area, weight, masses, energy, and so on) and translated into energy terms (joules). This second step in the methodology also involved the calculation of eMergy flows.

The eMergy of each item was calculated by multiplying actual energy flows by the corresponding solar transformity ratios (emJ/J) obtained from previous studies. Table XI shows the eMergy values for solar energy and diesel for livestock production in the Swiss agriculture.

Table XI: EMergy Content of Solar and Diesel Flows with respect to their Solar Transformity

Inputs	Energy	Transformity Ratio	EMergy
Solar energy	1.52E+20 J	1 emJ/J	1.52E+20 emJ
Diesel	7.89E+14 J	6.60E+04 emJ/J	0.52E+20 emJ

The third and last methodological stage consisted of computing composite results and system ratios allowing further interpretation and simplification of international comparisons. The emternality ratio [I/(I+F), see Figure 3] was calculated for the Swiss agriculture as a whole. Other ratios such as the eMergy investment ratio [F/(R+N)] and the environmental pressure ratio were also calculated [(F+N)/R] as a basis for the formulation of judgements concerning the efficiency and ecological impacts of the Swiss agroecosystem (production side).

RESULTS

Emternalities are primarily made of renewable environmental flows (2.28 E21 emJ, see Table XII). Nonrenewable flows (soil used up; i.e., 1.61 E20 emJ/year) are negligible.

Analysis shows that 4.1 emJ of market inputs are invested per joule of emternality (eMergy investment ratio). Furthermore, analysis shows that emternalities of the Swiss agriculture amount to 2.44 E21 emJ per year. In other words, the *free part of nature in the Swiss agriculture is of about 20% of all inputs.*

Tab. XII: Assessment of Emternalities relative to the Swiss Agroecosystem

#	EMergy flows, values and ratios	Expression	Swiss Agroecosystem
EMergy flows			
Emternalities			
1	**Renewable inputs**	emJ/yr	2.28E+21
2	**Nonrenewable inputs**	emJ/yr	1.61E+20
3	**Total environmental fraction**	emJ/yr	2.44E+21
Market inputs			
4	**Labor and energy**	emJ/yr	6.56E+21
5	**Goods an assets used in crops production**	emJ/yr	3.07E+21
6	**Goods an assets used in livestock production**	emJ/yr	3.52E+20
7	**Total market fraction**	emJ/yr	9.98E+21
EMergy use ratios			
8	**Emternality ratio**	(R+N)/ (R+N+F)	19.6%
Environmental pressure ratios			
9	**Environmental pressure ratio**	(F+N)/R	4.5
10	**Sustainability ratio**	(Y/F)/ [(F+N)/R]	0.28

Source: Ecosys® (2000)

To provide a comparative ranking, Swiss, Italian and Chinese agroecosystems are presented. Table XIII shows the results. A comparative analysis reveals that Chinese agriculture uses twice more emternalities than either the Italian or the Swiss agroecosystems.

Tab. XIII: Emternalities: Values and Ratios in Selected Agroecosystems

	Emternalities		Emternality Ratios	
	E+21 emJ/yr	**E+15 emJ/ha/yr**	**Emternality Ratio (free environmental fraction)**	**Renewable Fraction Ratio**
Swiss Agriculture (1996)	2.4	1.5	**19.6%**	18.3%
Italian Agriculture (1989)	18.7	1.1	**16.5%**	15.4%
Chinese Agriculture (1988)	341.0	3.4	n.d.	n.d.

Sources: Ulgiati *et al.* (1992), Lan *et al.* (1998), adapted from Ecosys® (2000)

A more detailed outlook (see Table XIV) presents the renewable and nonrenewable dimensions of emternalities. It appears that Chinese agriculture uses more nonrenewable environmental inputs than renewable ones. This is not the case for Switzerland and Italy. Nonrenewable emternalities have a negative sign because use of soils in these areas constitutes some unsustainable environmental pressure.

Table XIV: Renewable and Nonrenewable Environmental Fractions in Selected Agroecosystems

	Emternalities	
	Renewable E+15 emJ/ha/yr	Non-renewable E+15 emJ/ha/yr
Swiss Agriculture (1996)	1.4	0.1
Italian Agriculture (1989)	1.0	0.1
Chinese Agriculture (1988)	1.3	2.1

Sources: Ulgiati *et al.* (1992), Lan *et al.* (1998), adapted from Ecosys® (2000)

4 Composite Total Value for the Swiss Agriculture

The appraisal of externalities of the Swiss agriculture relates three different analyses and gauges: economic external effects (implicit prices), societal indicators (indices), and GDP-$ values (monergy ratios). These three different results cannot logically be aggregated. Sources, actual data, and dimensional units differ. However, these three values, together with the market value of agriculture, constitute a possible assessment of the Total Value of Agriculture in Switzerland. The composite presentation in Figure 5 illustrates the multi-functional role of agriculture by pointing out differences in scopes, values, valuation techniques and gauges. For each category of externality, a different type of result is obtained: Swiss francs, indices, or embodied joules.

Overviewing these results poses the following challenge. All three perspectives shed light on the quantitative valuation of ecological services and societal functions of agriculture. Why not combine these results without aggregating them, in order to get an overall, though composite, outcome which might show the complimentary character of all three assessments?

Single results of the study were brought together to provide a synthesized perspective of their individual contribution to diverse aspects of sustainable agriculture. The two main conditions to sustainable development beyond the economic one (which is out of the scope of the study) are socio-cultural acceptance and environmental conservation. The "rosette" diagram in Figure 6 shows how dissimilar externalities relate to sustainability.

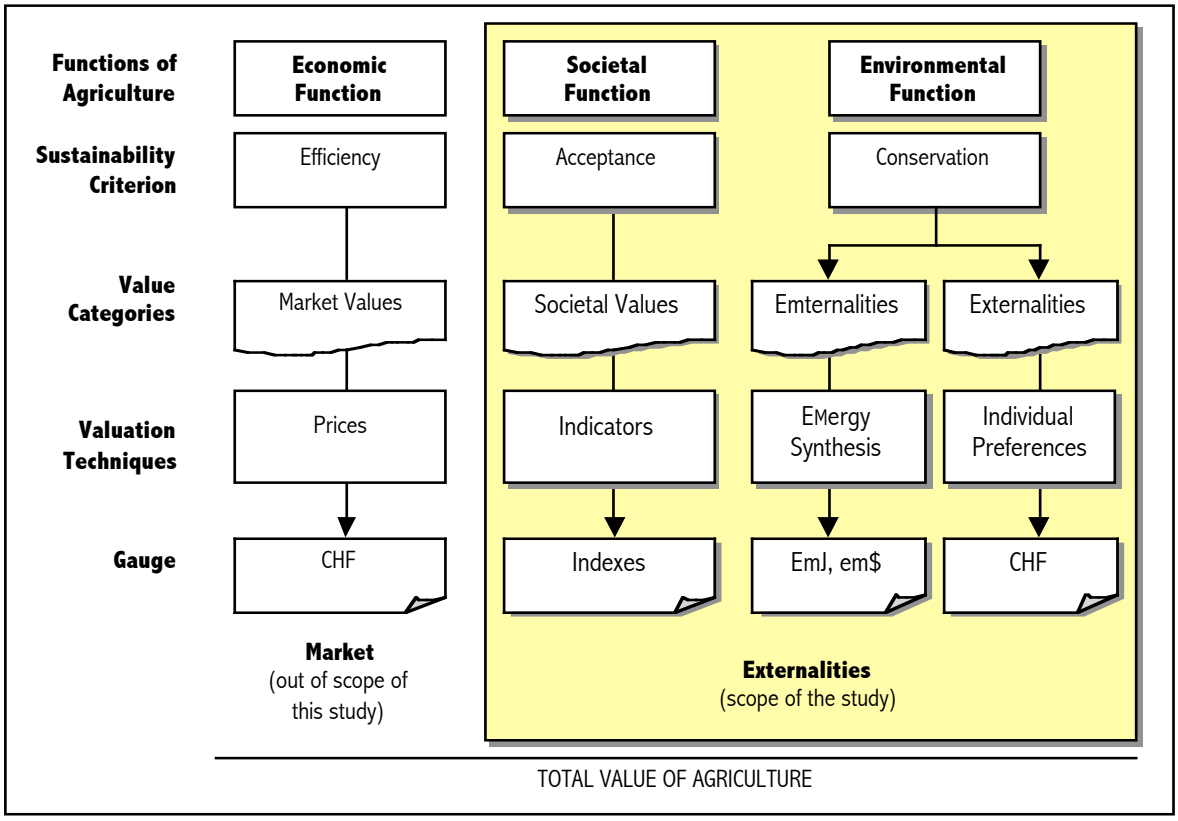

Figure 5: Illustrating Total Value of Agriculture
Source: Ecosys® (2000), adapted

The following criteria were used for building the «rosette» diagram (Fig. 6):

- external costs and benefits (amenities, calculated costs, natural patrimony and climate/health/natural hazards categories) : a systematic internalization of external costs and "mise en valeur" of the benefits would correspond to a maximum contribution to the environmental dimension of sustainability (specifically external costs and benefits);
- societal externalities (social structures, choices, and values, spatial structures) : approaching the norm (or satisfying the norm) would coincide with a maximum contribution to the socio-cultural dimension of sustainability;
- emternalities : a high ratio of emternalities (environmental fraction), a low ratio of environmental pressure and a high sustainability index would show a maximum contribution to sustainability with respect to direct environmental use.

Accordingly, the rosette perimeter characterizes a maximum contribution to sustainability whereas the very center of the rosette indicates a minimum contribution to sustainability. Shaded areas have no mathematical significance.

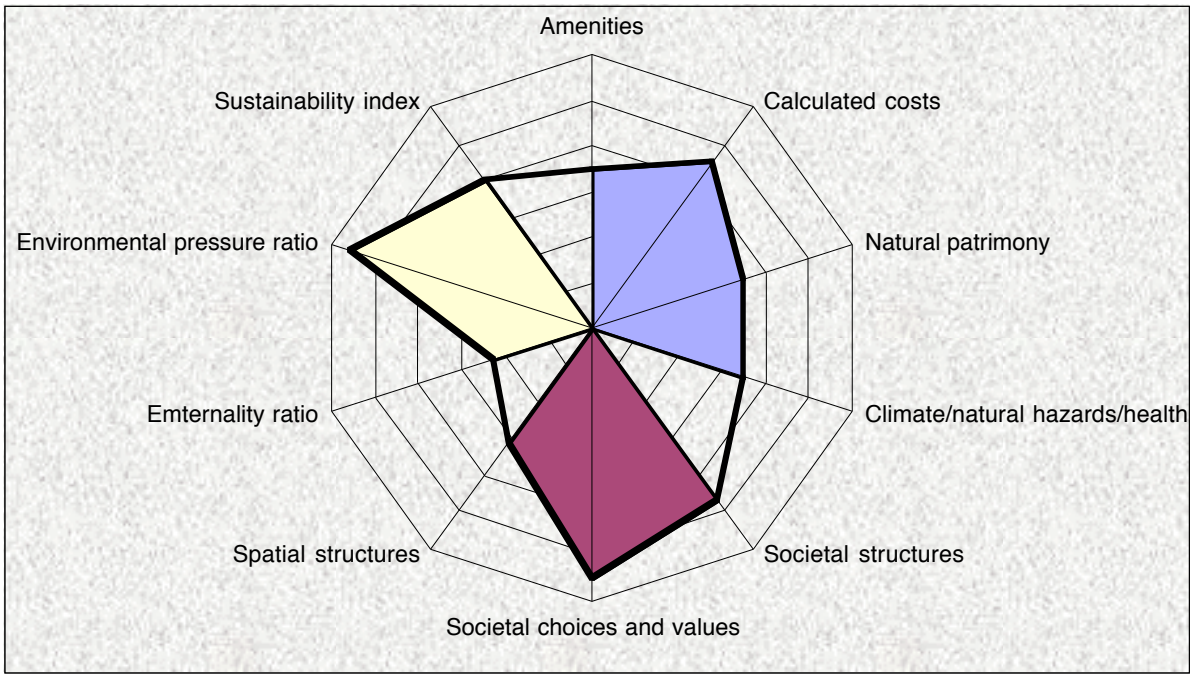

Figure 6: Sustainability Rosette for the Swiss Agriculture
Based on annuities, ratios and trends. Source: Ecosys® (2000)

Legend. Light grey area: ecological contribution (environmental fraction — eMergy synthesis) to sustainability ;
Middle grey area: environmental contribution (external costs and benefits) to sustainability ;
Dark grey area: societal contribution to sustainability.

This last step of the study points out that, beyond the quantitative assessment of each of the three categories of externalities of the Swiss agriculture, a composite result can be obtained. This «overall result» is not a simple aggregation of the externalities, changing everything into Swiss francs. It is the result of an agricultural system in which not only the economic efficiency is considered, but also socio-cultural acceptance and environmental conservation.

This composite result establishes one important step towards the «re-valuation» of the importance of agriculture as a multi-functional economic sector, with social and ecological value added.

Discussion

Once the decision to broaden the boundaries of economic accounts in order to include nonmarketed goods and services associated to society and the environment is taken, the next issue is how to proceed, and how far. The purpose of this study was to experiment and provide an overall estimation of the externalities of Swiss agriculture, applying economic as well as alternative approaches and methodologies.

- Economic externalities, or nonmarketed effects of agriculture on the environment such as water pollution or soil erosion were dealt with using economic values from the literature. These values—obtained by applying economic valuation methods such as contingent valuation, travel-cost valuation or hedonic pricing— were then transferred to the Swiss case study by means of an ad hoc transfer protocol.

- Societal externalities—comprising untrue externalities and responses of agriculture to societal norms and values—where dealt with using social sciences related methods and statistics. Statistical indicators were used and trends were assessed as a measure of how far agriculture was fulfilling societal norms and values at stake.
- Emternalities—or nonmarketed environmental inputs to agriculture as both renewable and nonrenewable free goods and services provided by environmental assets and flows—were dealt with using the eMergy synthesis method. They amount to about 20% of all inputs.

Methodological issues are worth to be mentioned. "The paucity of data and difficulties of valuation for most environmentally related activities make constructing economic measures much more difficult than is the case for market-related activities" (Nordhaus and Kokkelenberg, 1999:19).

- First, benefit transfers were made to place dollar values on economic externalities. There is no one and only such protocol in the literature. An ad hoc transfer protocol was elaborated and used. Further research as well as direct applications of economic valuation methods to Swiss agriculture are needed.
- Second, many societal externalities do not respond to a dollar value perspective though their assessment is needed to add light to the societal performance of agriculture. They need to be assessed a more synthetic way by means of indicators and ratios.
- Third, of special interest—well beyond controversies that still accompany the method used in this work—is the assessment of emternalities in agriculture. Some natural assets—such as stocks of underground water, soils or flows of river water—are limited in supply, and thus have economic scarcity value. However, components of the natural system that are flowing into agricultural processes as free goods and services are less economically tangible assets or flows. As a consequence, these usually hide behind physical data and values. The goal of this study was to unveil these values. The economic valuation of the environmental fraction inflowing into Swiss agriculture was indirectly obtained.

  Last, while eMergy synthesis is recognized as a form of environmental accounting (Odum, 1996), the use of monergies raises further open questions. For example, international trade and economic development theories might bring considerable explanation to cross-national and cross-sectorial variations in the value of emternalities in different agroecosystems (Pillet *et al.*, 2000).

Further steps are obviously concerned with more detailed assessments of externalities of Swiss agriculture (applying economic valuations methods instead of transferring foreign values, assessing externalities according to the type of agriculture—e.g., bio-agriculture, alpine agriculture, …), with further assessing implications to sound policy, regulatory and business decisions, and with expanding conventional economic accounts in agriculture.[5]

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[5] Satellite accounts for agriculture—as supplemental accounts to the conventional market-based (core) accounts and the European sectorial accounts for agriculture—are in the experimentation phase in Switzerland (see Swiss Federal Statistical Office, with Ecosys®, Inc. Geneva, forthcoming).

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