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THE HARMONIZED TOOLS FOR ENVIRONMENTAL IMPACT ASSESSMENT OF THE GLOBAL AGRO-FOOD CHAINS IN GREENING MODELS

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The present paper research propose a science-based model of Ecological Footprint Assessment for agro-food chains environmental impact evaluation using key- markers useful in optimal harmonized greening strategies. The energy, transports and foods are the capital components of the total ecological impact in the integrated agricultural and food production chains. The global sustainable greening policies in agro-food industry need to use adequate and harmonized assessment tools and equivalent methodologies in order to have relevant environmental impact control and equivalent global models for unitary evaluation.

Keywords: Key Eco-indicators, Ecological Footprint Analysis (EFA), Carbon Footprint Analysis (CFA), harmonization.

INTRODUCTION

In nowadays world, the drastically limitations of natural resources is the critical global issue which need to be addressed by science and technological developments in order to optimize the per capita natural resources using and for their efficient preservation considering the nature regeneration cycle.

The human needs and demands progress exponentially but the natural resources given by the generous Mother Nature has the same production and bio-regeneration cycle, situation which impose sobriety in consummation and alternative equivalent sources to be considered. In this regards, with the increasing of global population on Earth, the agro-food chains need to respond at this imperative inquiries of agricultural yield increasing, better valorisation of in-goods and optimal distribution of global resources.

In nowadays, the agro-food chain actors are concerned about the environmental and sustainability issues, including the origin and alternative production methods, wasting management in circular economy, optimal energy and water consumption.

Meanwhile, a single science-based and global harmonized greening model need to be developed for global environmental impact assessments of human sectorial activities, including the agro-food chains. The current global assessment models adopted in the greening models are not adequate in using similar and equivalent key ecological indicators of environmental impact assessment which due to different methodologies and non-comparable results at the global, regional, national and local level.

The Ecological Footprint (EF) measure the natural resources demand for all human activities[1,2] and reflect the sustainability degree by the level of resources consumption in individual, local, national and global life living activities[3].

The ecological footprint is a generic tool to estimates the "minimum land necessary to provide the basic energy and material flows required by the economy"[1].

All the natural resources consumption are converted into a single material index, the landscape surface area required to sustain all the life living activities, including the feeding agro-chains, among global human consummations. The surface area of land, forest and sea available to serve for human life living use is called biocapacity and represents the Earth natural disponible resources to meet human life living demands.

The degree of human consummation unsustainability is calculated as the difference between the current biocapacity and the required equivalent land needed to cover the human population needs and demands.

In the original ecological footprints model created by Wackernagel and Rees[1] and reformulated by Chambers *et al*.[4], the land areas considered were weighted with equivalence and local yield factors, in order to calculate appropriated bio productivity in world-average terms[2].

The Ecological Footprint and Carbon Footprint are commonly accepted as key indicators in the environmental impact assessment of human social and economic activities.

The ecological footprint assessing models consider that the materials and energetically sources used in all human activities consumption and wasting recycling are based on current finite natural resources, generated automatically and bio-recycled. Six natural productive surfaces (arable land, pasture, forest, sea space, built-up land and fossil energy land) are considered in the Ecological Footprint calculations and assessment of ecological biocapacity[2].

The Ecological Footprint Analysis (EFA) methodology was based on Wackernagel and Rees procedure[5]. In the calculation of specific EF were taking into account all the quality-controlled life cycle information including energy, materials, transportation and wastes. To calculate EF, the inputs of different kinds are first converted to the corresponding actual area of equivalent land/water ecosystems needed to produce the resources or assimilate the emissions. The EFA results were expressed as units of EF in global hectare with world average biological productivity, for the purposes of adding areas together and comparing results across land types.

The Carbon Footprint Analysis (CFA) was based on the calculation of carbon footprint for materials and processes with known quantity of fuel, energy or raw material multiplied by an conversion factor, which is a rate of tons CO2e emitted per quantity unit of the material consumed[6,7]. Greenhouse gases emitted through transport and the production of food, energy, utilities (electricity, gas, coal, water) are expressed in terms of the amount of CO2e emitted, in tones units.

Also, in the original ecological footprint assessing model were not considered the CO2 emissions from agricultural and industrial production and wasting.

Since the formulation of the ecological footprint analysis, a number of researchers have criticised the originally model. As consequence, different models for assessing the environmental impact are being commonly used such as Life Cycle Assessment (LCA), Input-Output Analysis (I-OA), Ecological Footprint Analysis (EFA) and Carbon Footprint Analysis (CFA)[8,9].

A science-based, harmonised, standardised and global equivalent procedure for ecological footprint assessment still does not exist, despite of global wide using of similar indicators in common apreciation of human activities environmental impact.

The present paper research propose a science-based model of Ecological Footprint Assessment using key-markers for optimal harmonized evaluation of agro-food chain environmental impact**.**

MATERIALS AND METHODS

The proposed harmonized model for Ecological Footprint Assessment (EFA) of agro-food chain environmental impact use the calculation of EF considering the main tree basic stages of the agro-food life cycles:

1. the agriculture EF;
2. the food processing EF;
3. the distribution and commercialization EF of food products stocks (Figure 1).

The EFA and CFA were conducted by grouping the raw foods under the variables of nature and types of agro-production system.

In the calculation of food groups EF were considered all the quality-controlled life cycle data including energy, materials, transportation and wastes.

The harmonization model were applied based on the equivalence principles to calculate the foods EF considering the inputs origins and the specific industrial yield, as key indicators in accurate assessment of overall natural resources (land/water/energy from ecosystems) needed to produce or to neutralize the emissions. The final agro-foods EF was expressed in global hectare (*g*ha) by means of yield and equivalence factors. The equivalence factor were used to differentiate the productivity of main land-use types[10,11].

The agro-food chain flow resources were considered, both from materials and energetically balance account. The food categories EF were considered by equivalent land used, related with the total CO2 emissions from fossil energy associated with agro-industrial processing and transportation[12].

The ecological footprint of the raw agro- foods were considered using Empreinte Ecologique Ouverte provided by www.ee.angenius.org[13], compared with Wackernagel cited in: A technical Report, Stockholm Environment Institute[10].

The environmental impact generated by the transportation system was considered 0.915 gha/MWh, as indicated "Empreinte Ecologique Ouverte" provided by www.ee.angenius.org[13].

The water supply ecological footprint was considered 0.00522 gha/mc, as indicated "Empreinte Ecologique Ouverte" provided by www.ee.angenius.org[13].

The harmonized ecological footprint model were applied for the comparative evaluation of processed foods and beverages in home-made auto consummation system versus industrial production systems, with the EF expressed in g m^2/kg in case of foods, transport system (Table 3) and wastes (Table 4).

RESULTS AND DISCUSSIONS

The animal origin commodities and the intensive industrial processed foods have the leading impact on the total agro-foods EF and CF, respectively. In meat cases, the poultry commodities present the lowest ecological and emissive impact, in average with tree times less than the beef items (Table 1).

The ecological footprint of processed foods, calculated taking into account the two key indicators-the raw agro- foods ecological footprint and the industrial yield depending on the quality characteristic of the food item (fat content in case of dairy product such butter and cream, the flour extraction in case of bread, the alcoholic content in case of wine) are presented in Table 2.

The food commodities created by an intensive processing such refining (oils, sugar), dry substance concentration (cream, cheese, pasta, cans) or extraction (flour) multiply the EF value of the raw material proportional with the degree of concentration /extraction level (Table 2). This is the main scientific finding of the present research, giving a strong reason for limiting the production in large quantities of industrialized foods and to re-valorise the raw, unprocessed and fresh local/traditional agro-foods in food industry and foodservices.

The total costs are doubled in daily home-made production via domestic cooking due to the non-efficient investment in kitchen features and labor, a non-visible cost in case of one family person involved in the daily menu scheduling (Table 5).

CONCLUSIONS

The harmonized assessment model for agro-food chains environmental impact using key performance eco-indicators and the equivalence principles conduct to the followings main conclusions[14]:

– the energy consummation for food processing is in average 10% from total energy involved in the agro-food chains activities;

– the primary agricultural products show the lowest EF value;

– meat commodities are the greatest emissive food items involved in the agro-food chains and the potential environmental impact were estimated at 74.56% from the total foods EF;

– a greater industrialization of foods due to a proportionally increasing of foodprint value (in case of refined foods as oils, sugar or food derivates such as cream butter or cheese);

– as a general rule formulated as original thesis in the present article, the degree of dry substance concentration in the industrialization process represent the factor of multiplying the EF value of the primary raw food;

– the intensive industrial processing, such deep fat frying, and the complex food formulations due to more than double ecological footprint impact;

– the auto consummation in home-made via domestic cooking multiply the ecological footprint impact and the production costs considering the non-efficient investments in domestic equipment and labor, lower productivity and partial-ecological waste management.

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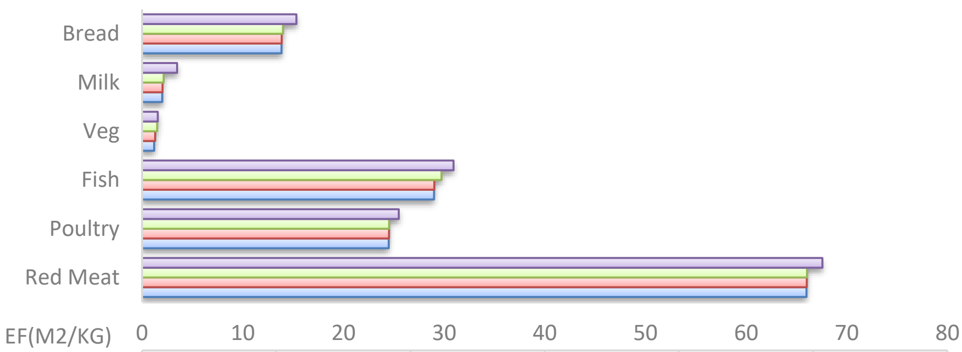

	Red Meat	Poultry	Fish	Veg	Milk	Bread
EU	67.58	25.5	30.94	1.56	3.48	15.33
National	66.05	24.54	29.74	1.5	2.14	14
Regional	66.03	24.53	29.03	1.3	2.03	13.87
Local	66	24.5	29	1.2	2	13.85

EU National Regional Local

Figure 1. The ecological fooprint of the local,regional, national and EU foods[14].

Table 1

Ecological footprint of raw agrifoods

Food item	Ecological Footprint (gm^2/kg)[13]	Ecological Footprint (gm^2/kg)[10]	Ecological Footprint (gm^2/kg)[1]
Beef and veal	65.14	228.9	229
Chicken	24.01	134.6	79
Egg	50.54	74.2	76
Butter 85%fat	32.81	174.2	174
Cream 65%fat	25.09	36.1	99
Oil	42.47	84	84
Sugar	3.17	15.5	16
Salt	1	nd	nd
Pepper	30.5	nd	nd
Rice	5.78	nd	Nd
Mushrooms	0.03	nd	nd
Orange	0.97	14.2	14
Salad	4.2	8.3	8
Wheat	8.31	nd	nd
Flour	16.62	15.9	16
Milk	1.93	23.5	24
Coffee	28.76	92	92
Chocolate	46.38	86.7	87
Bread	13.30	11.1	11
Breadcrumbs	13.31	nd	nd
Wine	3.82	51.6	52

nd-non determinate

Table 2

The ecological footprint of processed foods

Raw agro-food	Ecological Footprint of raw agro-food gm^2/kg	Industrial Yield	Processed food	Ecological Footprint of processed food gm^2/kg
Wheat	8.31	0.5	Whole Flour	16.62
Milk	1.93	0.058823	Butter 85%fat	32.81
Milk	1.93	0.076923	Cream, 65%fat	25.09
Orange	0.97	0.666666	Orange juice	1.455
Whole flour	16.62	0.80024	Bread	13.30

Table 3

The ecological and carbon footprint for the food transportation systems[13]

Transport system	Ecological Footprint (gha/t)	Carbon Footprint (Eq gCO_2/t, km)[13]
Car diesel	0.079	168-186
Truck	0.031	210-1430
Maritime	0.005	15-30
Aerian	0.357	570-1580

Table 4

The ecological footprint of food wastes[13]

Category of food wastes	Ecological Footprint(gha/t)
Paper	0.134
Plastic	1.245
Glass	2.11
Food wastes	0.103
Compost	0.331

Table 5

The estimated costs for auto consummation home-made (AC) and industrial food (IC) production systems

In Good Transport	AC: Domestic transport: 6 l/100 km or electric car (best eco-friendly 2017/11 kWh for 130km autonomy)[15]; proximity purchasing:10 km	IC: Truck: 10 l/100 km (10-13 l/100 km)[16]; local purchasing: 50 km	AC Costs: -car (best eco-friendly 2017)[15] and taxes: 30. 394 euro, 5 years of turnover):17.07 euro/day -fuel:0.66 euro/day(1.1 euro/l) or -electricity:0.211 euro (0.846 kW)	IC Costs: -truck and taxes:54.79 euro/day (5 years of turnover, 100.000 euro [17]) -fuel:5.5 euro/day
Storage	AC: 3 days of cold storage at 4ºC, model: FFTR1814TW Capacity 14.1 cu ft Energy consummation: 1.1 kW/day[18]	IC: 3 days of cold storage at 4ºC, model RS25J500DSG/AA Capacity 24.5 cu ft Energy consummation:1.9 kW/day[19]	AC Costs: - refrigerator :8.01 euro/day (investment: 433 euro, turnover: 1 year, 54 days/year) -electric energy: 0.275 euro/day	IC Costs: - refrigerator: 3.07 euro/day (investment: 996 euro, turnover:1year,324 days/year) -electric energy:0.475 euro/day
Wastes management	AC: 1 euro/person, month	IC: 50 costumers capacity, 500 euro/month	AC Costs: 0.133 euro/day (4 euro/month)	IC Costs: 16.66 euro/day (500 euro/month)
Dishes Washing	AC:2cycles/day Domestic washing machine: 6 sets capacity, 8l water/cycle, 0.62 kWh, 1.5 hours/cycle, price:170 euro	OC: 6cycles/day for two washing machines: 12 sets capacity, 9.5 l water/cycle, 0.90 kWh, 2.5 hours/cycle, total price:380 euro/unit	AC Costs -machine: 3.14 euro/day (investment: 415euro, turnover:1 year) -water:0.0324 euro (2 euro/mc)/day -energy: 0.93euro (0.5 euro/kW)/day[20]	OC Costs -machine:1.17 euro/day (investment: 747euro, turnover: 1 year) -water:0.285euro (2 euro/mc)/day -energy: 6.75euro (0.5 euro/kW)/day[20]
Kitchen investment	AC Domestic kitchen: 10000 Euro[21]	IC:50.000 euro (robotic kitchen for 100 meals)[22]	AC Costs: 37.03 euro/day (investment: 10.000 euro, turnover: 5 years, 54 days /year)	IC Costs: 47.13 euro/day (investment:76.360 euro, turnover: 5 years, 324 days/year)
Labor	AC :2.5 hours/day 1.5 hours/ Purchasing, transportation, storage, regeneration, wastes management.	8 hours/day 10 employees Labor costs: 7 euro/hour	AC Costs: 28 euro/day 7euro/day	IC Costs: 560 euro/day 11.2euro/serving whole daily menu
Total Costs, euro/day (Without food costs)			114.76	717.14
Total Costs, euro/serving (Without food costs)			28.69	14.34
Total Costs, euro/serving (Including 30% food costs)			37.29	18.64