17th European Symposium on Computer Aided Process Engineering – ESCAPE17
V. Plesu and P.S. Agachi (Editors)

Environmental Impact Assessment of the Vegetable Cultivations using the Pimentel-Euleistein Model. Case Study Arges Lower Watershed

Cristian Ioja [a], Maria Pătroescu [a], Marius Matache [a], Gabriela Pavelescu [b], Radu Damian [c]

[a] *University of Bucharest, Centre for Environmental Research and Impact Studies, 1, Nicolae Balcescu Avenue, Bucharest, 010400, Romania, ccmesi@yahoo.com*
[b] *National Institute on Optoelectronics - INOE,1, Atomiştilor Str, Măgurele, 76900, Romania, gpavel@inoe.inoe.ro*
[c] *Tehnical University of Civil Engeneering, 124 Lacul Tei Avenue, Bucharest, 020396, Romania, damian@instal.utcb.ro*

Abstract

The culture of vegetables is characterized by a high level of energy inputs required for high production. For this reason the effects upon the environment are complex and diverse. The lower watershed of Arges River is characterized by a large area of vegetables cultivations and the presence of an important sale market (Bucharest City). For the assessment of environmental impact caused by the above mentioned factors, the Pimentel-Euleistein Energetic Model was used. We evaluated the amount of energy that is entering the agroecosystem (pesticides, seeds, electricity, etc.) and we calculated the energetic efficiency η as a relation between the energy amount yielded by the agroecosystem (Qo) and the amount provided by human intervention (Qi). Based on η, we calculated the entropy amount, the critical energetic limit (the maximum value of Qi for which the agroecosystem remains sustainable) and the sustainable production (the maximum amount extracted from the agroecosystem without causing unbalance).

Keywords: environmental impact assessment, sustainable development, vegetable yield, Pimentel-Euleistein model, Arges, Romania

1. Introduction

The new trend in what concerns the vegetables cultivations (excessive use of fertilizers, greenhouse cultivations, high water consumption etc.) has determined an increase in the interest to identify new methods for environmental impact assessment [1], [2], [3], [4]. Their development in regions neighbouring important human communities enhanced the adjustment of vegetables cultivations depending on the market dynamics and emphasised the energetic unbalance with a direct consequence in the environmental quality.

2. Problem Statement, background

The lower sector of the Arges River encounters the highest anthropogenic influence within this Romanian region – Bucharest urban agglomeration, its main environmental issues being reflected in the southern and south-eastern part of Bucharest. The Arges-Sabar floodplain, located in the southern part of Bucharest, represents the most important vegetables cultivations area from Romania, due to its productivity. Also, it is characterised by very important environmental issues (water, groundwater and soil degradation, wrong management of waste and hazardous compounds, improvement works, etc.).

3. Paper approach

3.1. Methodology

The environmental impact assessment of the vegetables cultivations within the Arges Lower Watershed was achieved using the Pimentel energetic model (assessment of the energetic efficiency) [1] and the Euleistein energetic model (determination of entropy, the critical energetic level and the sustainable production) [3]. The assessment of the energy amount induced into the system uses the energetic equivalents resulting from the information provided by the Giurgiu Agricultural and Rural Development Department (Fig. 1).

3.2. Experimental arrangement

Energetic efficiency (η) is $\eta = Qo * 100 / Qi$, where *Qo* is the agroecosystem energetic production (vegetable yield in kcal), and *Qi* is the anthropogenic energy inputs (kcal). Using energetic efficiency, we calculated the entropy level, which is important in order to assess the agroecosystems importance for the environmental quality degradation [3].

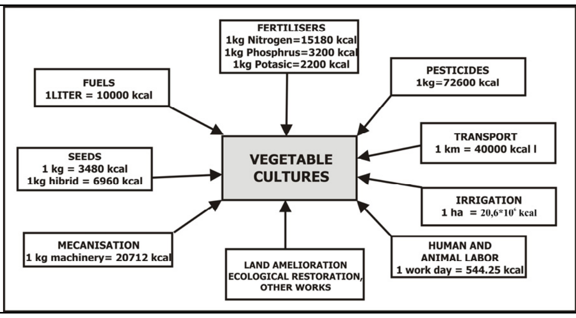

Fig. 1 – Human energetic inputs in agroecosystems for vegetable yield

For the entropy assessment, we considered the biomass production (entropy decrease) and the anthropogenic inputs energy (entropy increase). The natural ecosystem, used as reference, shows natural conditions similar with the agroecosystem (solar radiation, evapotranspiration, soil types, etc.). This is necessary in order to assess the agroecosystems changes.

The entropy was evaluated using the following formula (Euleistein et al., 2003):

$$\sigma = \frac{1}{T} * \left[W * (1 - \eta + \frac{\eta}{s}) - Po \right]$$

, where T is the average air temperature in the vegetation season (Kelvin degree), P_0 is net primary yield of the ecosystem, s = k*(1-r), k – caloric constant, r – respiration coefficient. If entropy budget $\sigma > 0$, then there is an entropy increase (agroecosystem degradation). In the Arges Lower Watershed the *critical energetic level* (W_{cr}) and *sustainable yield* (y_{cr}) were calculated, thus emphasizing the ecosystem degradation.

$$Wcr = \frac{Po}{1 - \eta + \frac{\eta}{s}} \quad \text{and} \quad ycr = \frac{Po}{\frac{1}{\eta} + \frac{1}{s} - 1}$$

For their calculation in the Lower Arges Watershed, we established the following values: T = 294.12 K, k = 0.5, r = 0.4, s = 0.3 and Po = $11{,}8 \cdot 10^6$ J/m^2. The agroecosystem is sustainable if s = 0, $W_{cr} > W$ and $y_{cr} > y$ [3].

3.3. Case study

For the analysis, we considered two different areas from the point of view of the vegetable cultivations proportion out of the arable land (south-west of Bucharest city with 1-3 % of arable land occupied by vegetables and Bucharest south and south-east with 10-25 % of arable land occupied by vegetables), which allowed the territory classification and the assessment of the environmental synergetic effect for the vegetable cultivations [5].

3.4. Results & discussions

The energetic efficiency of the vegetable cultivations is correlated with the dominant economic profile. As a rule, the energetic efficiency is higher when anthropogenic inputs are elevated.

Table 1

Sustainability indicators due to the vegetable cultivations in the Arges Lower Watershed (2004)

Settlements	Input energy W	Yield y	Energetic efficiency	Critical energetic level Wcr	Sustainable yield ycr	W/W_{cr}	y/y_{cr}	Entrop
	kJ/m^2	kJ/m^2		kJ/m^2	kJ/m^2			J/K
Ad. Copaceni	12091	47304	3,91	1166	4558	4,34	10,38	134004
Bolintin Deal	10892	19074	1,75	2321	4062	1,96	4,70	38642
Bolintin Vale	6616	15201	2,3	1853	4263	1,49	3,57	19801
Bucsani	9788	43152	4,41	1045	4609	3,92	9,36	117087
Bulbucata	8737	33227	3,8	1196	4545	3,06	7,31	82507
Calugareni	9198	21854	2,37	1807	4283	2,13	5,10	45323
Clejani	8430	43399	5,15	907	4669	3,89	9,30	115971
Colibasi	37508	99420	2,65	1643	4353	9,55	22,84	343168
Comana	8370	41036	4,9	949	4650	3,69	8,82	107922
Crevedia Mare	6836	10443	1,52	2595	3945	1,10	2,65	4092
Fl. Stoenesti	16455	9720	0,59	4965	2929	1,39	3,32	15513
Gaiseni	9847	21750	2,21	1917	4236	2,15	5,13	46123
Gostinari	10601	41958	3,96	1152	4563	3,85	9,19	114302
Gradinari	9523	37647	3,95	1155	4562	3,45	8,25	98287
Greaca	12008	9831	0,82	4050	3321	1,24	2,96	9645
Hotarele	8636	19920	2,31	1847	4266	1,96	4,67	38382
Iepuresti	7946	31671	3,99	1145	4567	2,90	6,94	76419
Joita	9967	21416	2,15	1961	4217	2,13	5,08	45189
Letca Noua	7540	25185	3,34	1342	4482	2,35	5,62	54194
Mihai Bravu	6627	20772	3,13	1421	4448	1,95	4,67	38163
Ogrezeni	7385	31494	4,26	1079	4595	2,86	6,85	74809
Singureni	12614	46566	3,69	1228	4531	4,30	10,28	132324
Ulmi	6320	20622	3,26	1371	4470	1,93	4,61	37259
Valea Dragului	9011	18583	2,06	2032	4186	1,86	4,44	34312
Varasti	14949	107139	7,17	666	4772	9,40	22,45	336912

In the areas with low percentage of the vegetable cultivations, the energetic efficiency is low (Floresti-Stoenesti – 0.59, Greaca – 0.82), whereas inside of the area with higher proportion of vegetable cultivations there is a significant increase (Varasti 7.17). In the area with more vegetable cultivations, most of the values vary between 2 and 4, emphasising the pressure on the environment (very high production and energetic inputs) (Table 1).

The information related to the vegetable cultivations entropy budget is very important in order to reduce the energy losses, to assess their profitability and the environmental quality. The analysis of the Arges Lower Watershed revealed the following categories: *areas with very strong energetic unbalance* (Colibaşi, Vărăşti), *areas with strong energetic unbalance* (Adunati-Copaceni, Singureni, Comana, etc.), *areas with medium energetic unbalance* (Hotarele, Ulmi, Ogrezeni) and *areas with relative energetic balance* (Crevedia Mare, Floreşti-Stoeneşti, etc.) (Fig. 2).

The unbalance determined by the vegetable cultivations can be emphasised by the W/W_{cr} and y/y_{cr} ratio, where the critical energetic level (Colibasi, Varasti – over 9) and the sustainable yield (Colibasi, Varasti – over 22) have been significantly higher (Fig. 3). We predict an increase of environmental problems, because of the trend of return to intensive vegetable cultivation [5].

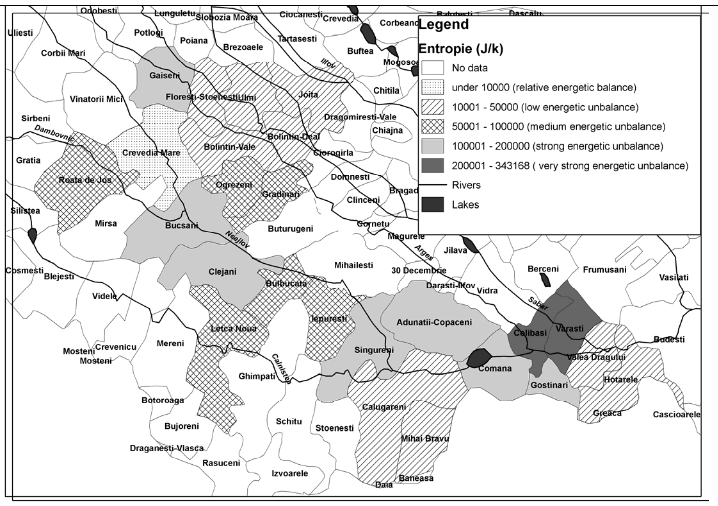

Fig. 2
Entropy values dynamic in vegetable agroecosystems from Lower Arges Watershed

4. Conclusions

The unusually high values of the sustainability indicators (W/W_{cr}, y/y_{cr}, σ) lead to an increase in the environmental degradation (especially of the soils), mainly when several natural risks (deflation, raindrop erosion) are being active.

The vegetable yield determines an energy extraction from the agroecosystem. Associated with pollution (especially with pesticides), erosions and acidification processes put an emphasis on the environmental degradation problems (Euleistein et al., 2003). The entropy overproduction gives a measure of the agroecosystem degradation level. Their tendency provides information on the trends of environmental quality evolution, and also to identify and to set the priorities in order to enforce the measures that will reduce the unbalances.

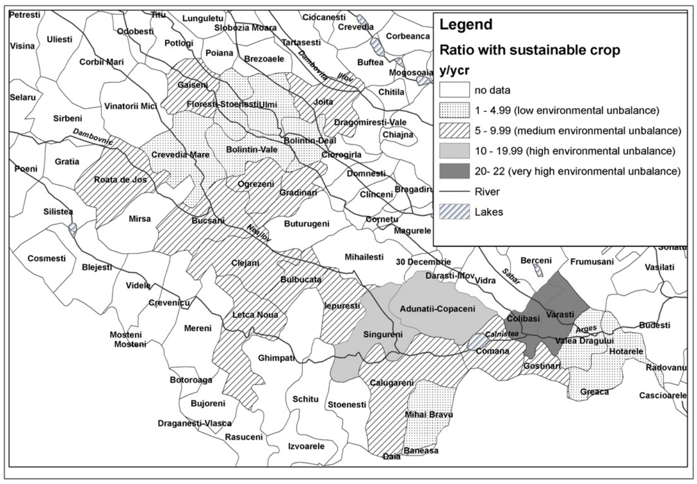

Fig. 3 Variation of y/y_{cr} ratio in Lower Arges Watershed

Acknowledgements

We would like thank Giurgiu Agricultural and Rural Development Department for providing rapid access to the required information.

References

1. Pimentel, D., Energy and food, Annual Reviews of Energy, 2, pg. 177-195. 1977.
2. Pimentel, D., L. Hurd, A. Bellotti, M. Forster, I. Oka, I. Sholes, R. Whitman, Food production and energy crisis. Science, 182, pg. 443-449. 1973.
3. Eulenstein, F., W. Haberstock, W. Steinborn, Y. Svirezhev, J. Olejnik, S.L. Schlindwein, V. Pomaz, Perspectives from Energetic-Thermodynamic analysis of land use Systems. Archive of Agronomical and Soil Science, 49, pg. 663-674. 2003.
4. Torbjörn Rydberg, Andrew C. Haden, Energy evaluations of Denmark and Danish agriculture: Assessing the influence of changing resource availability on the organization of agriculture and society. Agriculture, Ecosystems & Environment, Volume 117, Issues 2-3, pg. 145-158. 2006.
5. Ioja, C., Methods and techniques for environmental quality assessment in Bucharest metropolitan area. PhD. thesis, University of Bucharest. 2006.