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The dissertation was submitted in partial fulfillment of the requirements for the Doctor of Philosophy (Ph.D.) degree in Agrotechnology

Monitoring and accounting of ecological health of Goharkoh Agro-industrial Complex, Taftan using thermodynamic indicators

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September 2024

Abstract

Today, the increase in energy input to agricultural systems has led to a significant increase in the production process of these systems. However, this has led to a decrease in the sustainability of systems and environmental degradation. Therefore, evaluating the durability and well-being of production systems is a crucial and inherent aspect of ecosystem management. This study utilized emergy and economic analysis approaches and an assessment of entropy overproduction to evaluate the sustainability, productivity, and ecological health of production systems in the Goharkuh agro-industrial complex in Taftan County, Sistan and Baluchestan Province. The systems examined in this complex include wheat, barley, alfalfa, cotton, and pistachio. The data used in this study is obtained from the statistical records provided by the managers of the agricultural and industrial complex from 2020 to 2021. All inputs and outputs required for the analyses of this study were calculated at the level of one hectare of the complex's production systems. Statistical analyses included the non-parametric Kruskal-Wallis test and Spearman's rank correlation and Kendall's tau analysis to examine the relationship among five emergy analysis and economic indicators, including emergy efficiency, Emergy Sustainability Index (ESI), Emergy Index for Sustainable Development (EISD), Net Return (NR), and Benefit-to-Cost ratio (B to C). Then, sensitivity analysis was conducted to demonstrate how the results are influenced by changes in variables and to offer valuable insights for future management decisions. Based on the combined analysis of emergy and economic analysis, the pistachio production system exhibited the highest levels of gross return (1200 million Rials/ha), NR (850 million Rials/ha), B to C (3.43 million Rials/ha), Renewability Index (%R) (15.12%), Modified Emergy Yield Ratio (EYR*) (1.397), Modified Emergy Sustainability Index (ESI*) (0.207), Standard Emergy Investment Ratio (EIR) (6.136) and the lowest value of Modified Environmental Loading Ratio (5.61) compared to other products within the complex. The ELR (143.16), ESI (0.0081), EISD (0.0028), and Emergy Index of Agricultural Product Safety (EIPS, indicate the safety of the product in terms of using chemical inputs) (0.437) of this product were found to be favorable. In contrast, cotton showed the least desirable performance across several emergy measures, such as the %R (4.66%), EIR (3.79), ELR (344.13), ESI (00.37), EISD (0.0021), and EIPS (0.198), within the specified context. Among the various systems within the complex, the alfalfa product, with the highest EIPS (0.554) and the lowest transformity (1.34E+05 sej/J), exhibited the most negative economic indicators. The emergy indicators of wheat and barley showed certain similarities, although both crops demonstrated lower economic profitability compared to pistachio and cotton. While the Kruskal-Wallis test did not show a significant difference among the five emergy indicators, the results of Spearman's rank correlation and Kendall's tau analysis revealed a significant negative correlation (at the 5% probability level) between emergy efficiency and

the two indicators of NR and B to C. These findings may suggest that production systems focused on minimizing environmental impacts by reducing resource dependence might experience lower economic profits. The sensitivity analysis conducted on the emergy section revealed that the emergy indicators improved when production systems reduced their reliance on non-renewable resources, such as chemical fertilizers, soil erosion, and fossil fuels. Conversely, the emergy indicators experienced a significant decline as production systems became more dependent on these inputs. In terms of economic sensitivity analysis, the economic indicators of production systems improved as expenses related to land, labor, seed, and machinery decreased. The entropy analysis indicated that the industrial systems under study have positive entropy production, suggesting their current state of instability. Among all the products, alfalfa had the lowest entropy overproduction (0.311 GJ ha^{-1}°k^{-1}), while pistachio had the highest (1.01 GJ ha^{-1}°k^{-1}). The three agricultural systems, namely wheat, barley, and cotton, are situated at a point equidistant from the two opposite ends. The alfalfa production system demonstrated enhanced energy efficiency compared to other integrated production systems, resulting in a higher maximum crop yield for sustainable agriculture and a smaller deviation from sustainable agriculture. The differences in energy flow intensity and the structural characteristics of the integrated production systems accounted for the variation in the values of the examined components. However, all of these solutions are not sustainable in the long run. Sensitivity analysis of entropy production in the input energy and harvest index sections revealed that it is crucial to implement management techniques that reduce the intensity of energy flows into these systems and increase the harvest index to achieve a sustainable condition. Utilizing more renewable energy sources will also ensure the long-term sustainability of production systems.
Keywords: Deviation from sustainability, Economic analysis, Ecosystems, Emergy assessment, Overproduction of entropy