SOCIAL LIFE CYCLE ASSESSMENT FOR WILD HARVESTING AND CULTIVATION OF *F. LUMBRICALIS* RED MACROALGAE

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Abstract – The sustainable development of macroalgae production in Europe, particularly in the Baltic Sea Region, presents significant socio-economic opportunities and challenges. While global seaweed production is dominated by Asian countries, European efforts are growing, with increasing interest in both wild harvesting and offshore cultivation. This study conducts an Explorative Social Life Cycle Assessment (SLCA) of *Furcellaria lumbricalis*, comparing wild harvesting (WH) and offshore cultivation (OC) scenarios to evaluate their social impacts. Using the Social Hotspot Database (SHDB) and following UNEP/SETAC 2020 guidelines, we assess key social risk indicators, including labor rights, community impacts, and governance structures. Results indicate that WH carries lower social risks than OC, with total impact scores of 432.85 Pt for WH and 719.51 Pt for OC. The WH scenario identifies seaweed harvesting as the most socially impactful stage, with high-risk indicators such as injuries & fatalities, forced labor, and discrimination. While WH supports traditional economic activities and fosters community engagement, occupational safety and fair labor practices remain areas for improvement. Furthermore, the SHDB hotspot analysis reveals that many social impacts of WH extend beyond Estonia, particularly in supply chain regions such as Ivory Coast and China. Conversely, the OC scenario demonstrates higher social risks, primarily due to extended maintenance activities required during the three-month cultivation period. Boat maintenance emerges as the most socially impactful stage, contributing significantly to labor rights risks, occupational hazards, and governance-related issues. Although OC presents scalability potential, the associated social burdens highlight the need for enhanced worker protections and improved governance frameworks before large-scale adoption. To refine these findings, Monte Carlo simulations (5 000 iterations) were conducted, confirming that WH consistently outperforms OC in social sustainability. The absence of overlap between the impact ranges reinforces the conclusion that wild harvesting is the more socially sustainable option under current conditions. However, the long-term viability of WH requires improvements in labor conditions and sustainability policies to ensure equitable benefits for coastal communities. This study underscores the need for a balanced approach in macroalgae production, integrating environmental, economic, and social considerations. Future research should incorporate localized, stakeholder-driven data to improve the granularity of S-LCA applications. Additionally, refining OC technologies and governance structures could mitigate social risks, potentially making it a more sustainable alternative in the future. These findings contribute to ongoing discussions on social sustainability in the blue bioeconomy, supporting informed policymaking for European macroalgae industries.

Keywords – Blue bioeconomy; Life Cycle Thinking; macroalgae production; Social Hotspot Database; Social Life Cycle Assessment