Methodology for Measuring Environmental Efficiency in Aquaculture

Abstract: This paper attempts to provide a scientifically sound methodology to measure environmental efficiency in aquaculture. The aquaculture technologies are classified as extensive, semi-intensive and intensive technologies. The blue revolution has witnessed adoption of intensive technologies specially in coastal region of India. The development of coastal aquaculture is characterized by intensive feeding accompanied by application of organic manure and fertilizers, use of chemicals to check diseases and pests besides aeration and water exchange. The excess accumulation of organic matters and decomposition of the same leads to algal blooms, oxygen depletion, formation of toxicant gasses. Theses chemicals causes stress on the fish affecting productivity and release of the same in fragile ecosystem becomes toxic to eggs, larvae and juveniles of aquatic fauna detrimental to biodiversity and finally to development of aquaculture. The story of environmental damages proceeds to the conversion of wetlands and mangrove forests into aquaculture. Wetlands and mangroves are a rich source of biodiversity of aquatic species, fin and shellfishes and its destruction resulted in decline of post larvae in natural water finally affecting the aquaculture production. The coastal aquaculture development, summarizing, resulted in decline in social output because of environmental damages outside the production system and also inside the production system. The recent eco-friendly technologies in aquaculture like bio-fertilizers, biological pest control, and balanced manuring are some of the strategies for correcting the impact of environmental degradation required for sustained productivity. The first type of environmental parameters are named as environmentally detrimental inputs and second type are named as environmentally recuperative inputs. Conventionally, the inputs like land, labor and capital essentially required for any production process are named as basic inputs. The phenomena of shifting to new cropping strategy affected the efficiency of the farms as a unit and also the inefficiency of the above three inputs. The aim of this new methodology is to provide estimates of farm efficiencies due to adverse impact of environmentally detrimental inputs, positive (eco-friendly) impact of environmentally recuperative inputs and impact of basic inputs along with multiple output matrix (VIZ; production of fish and loss of biodiversity). The methodology will also provide a unique and best combination of all three types of inputs yielding enhanced productivity and sustainability of modern aquaculture in India. This will ultimately provide a sustainable farming strategy to farmers and policy makers. The methodology may also proved to be a turning point to theorists for future research in environmental modeling. In conventional specification of production function models single output is function of only variable inputs (basic inputs VIZ; land, labor and capital) and the response of inputs are measured by single input matrix specifying linear or non linear single equation model. The function were usually estimated by OLS technique. Contrary to above,
the model in new methodology provides specification of vector of output as a function of input matrix. The input matrix is partitioned into three components- reflecting the response of basic inputs, environmentally detrimental inputs and environmentally recuperative inputs, respectively. The function thus specified is proposed to be modeled considering all the three inputs together using single equation model or simultaneous equation model. The model will be estimated by using stochastic frontier production technique. Single equation stochastic frontier production function model may be written as

\[ TE_{it} = \mathbb{E}\left[ \exp(-U_i)/(V_i - U_{it}) \right] \]

Where for all farms are indexed with a subscript \( i \) and all years are indexed with a subscript \( t \); \( Y_{it} \) is the vector output; \( X_{it} \) is the vector of basic inputs; \( Z_{it} \) is a vector of environmentally detrimental inputs and \( F_{it} \) is vector of environmentally recuperative inputs. \( b, g, x \) are parameters to be estimated. 

Environmental efficiency for detrimental input is defined as the ratio of minimum feasible use to observed use of environmentally detrimental inputs, conditional on observed levels of the desirable social output (high fish productivity and low loss in biodiversity) and the conventional inputs. So defined, environmental efficiency is a non-radial input-oriented measure of technical efficiency that allows for a radial reduction of the environmentally detrimental inputs and/or reduction in detrimental output (damage to biodiversity). Similarly, the environmental efficiency for recuperative inputs is defined as the ratio of maximum feasible use to observed use of environmentally recuperative inputs, conditional on observed levels of the desirable social output and the conventional inputs. So defined, environmental efficiency for recuperative inputs is a non-radial input-oriented measure of technical efficiency that allows for a radial increase of the environmentally recuperative inputs and desired output (biodiversity). Isoquant function in \( En \) space for the three inputs can be derived from estimated production function. The environmental efficiency for each types of inputs along with unique combination of inputs in multi-input partitioned matrix can be derived representing an eco-friendly optimal cropping strategy.

Key words: Environmental efficiency, detrimental inputs, sustainability, biodiversity.