International Journal of Advanced Trends in Multidisciplinary Research
ISSN: 3139-0986, Volume 2 Issue 8
Aug 2026, PP 1-4

Economic Valuation of Carbon Fixation and Climate-Adaptation Services of Sugarcane Agroecosystems in Bangladesh

Mohammad Nazmul Huda
Bangladesh

***Abstract* – Agricultural landscapes provide economic outputs as well as environmental services that are frequently omitted from conventional economic accounting. Sugarcane is a high-biomass C4 crop capable of substantial atmospheric CO_2 fixation and evapotranspiration. This study develops an indicative economic valuation of these services for six sugar-mill-associated sugarcane systems in Bangladesh and compares the potential value of maintaining existing vegetation with two hypothetical alternatives: (i) recreating an equivalent carbon-fixation service through tree plantation and (ii) increased dependence on imported mechanical cooling and related appliances under hypothetical additional thermal-stress scenarios. The underlying assessment estimates approximately 24,412 ha of reconstructed sugarcane-associated land and approximately 1.195 million tonnes of cane-equivalent production per crop cycle. Applying a biomass-based conversion factor of 0.802 tonnes CO_2 per tonne of fresh cane gives an estimated 958,347 tonnes of gross CO_2 fixation per crop cycle. Using illustrative carbon valuations of US\$20, US\$60, US\$88 and US\$180 per tonne CO_2, the gross CO_2-fixation service is valued at approximately US\$19.2–172.5 million, equivalent to approximately BDT 232–2,087 crore at BDT 121/US\$. A separate scenario analysis indicates that a hypothetical 10%, 25% and 50% increase in selected cooling and refrigeration imports would correspond to approximately BDT 201 crore, 503 crore and 1,007 crore, respectively. The analysis does not claim direct causation between vegetation loss and appliance imports; rather, it illustrates the economic magnitude of alternative adaptation pathways.**

***Keywords* – sugarcane; CO_2 fixation; ecosystem services; carbon valuation; climate adaptation; air conditioning; refrigeration; fans; tree plantation; Bangladesh; Rooppur,**

I. INTRODUCTION

Climate change and rapid infrastructure development are increasing the importance of incorporating environmental services into economic decision-making. Conventional agricultural accounting generally emphasizes crop yield, farm income, employment and industrial output. However, vegetated agricultural landscapes also perform ecological functions, including atmospheric carbon fixation, evapotranspiration, soil protection and surface-energy regulation.

Sugarcane (Saccharum spp.) is particularly important because it is a high-biomass C4 crop. Research demonstrates substantial carbon accumulation and carbon-fixation capacity across sugarcane developmental stages, although the magnitude varies with cultivar, environmental conditions and plant development (Wu et al., 2026).

The present study develops a comparative economic assessment for six sugar-mill-associated sugarcane systems in Bangladesh. The central question is: What is the indicative economic value of the CO_2-fixation service provided by the sugarcane landscape, and how does this compare with the potential cost of recreating the service through tree plantation or relying more heavily on imported cooling technologies under hypothetical climate-adaptation scenarios?

II. STUDY BASIS

The assessment covers Natore Sugar Mills Ltd., North Bengal Sugar Mills Ltd., Pabna Sugar Mills Ltd., Rajshahi Sugar Mills Ltd., Kushtia Sugar Mills Ltd., and Faridpur Sugar Mills Ltd. The reconstructed reference area is approximately 24,412 ha, with approximately 1.195 million tonnes of cane-equivalent production per crop cycle. The underlying source describes this as a reconstructed six-mill reference area rather than a verified 2026 cultivated area. The production estimate uses a reference yield of approximately 48.95 t/ha.

III. GROSS CO_2 FIXATION

The underlying assessment applies a conversion factor of approximately 0.802 tonnes CO_2 per tonne fresh cane. Thus, 1,194,946 tonnes cane × 0.802 = 958,347 tonnes CO_2. The six sugarcane systems therefore represent approximately 958,347 tonnes of gross atmospheric CO_2 fixation per crop cycle. This is gross biological fixation, not permanent net ecosystem carbon sequestration.

Table 1. Mill-wise production and gross CO_2 fixation
Natore: 198,094 t cane; 158,871 t CO_2.
North Bengal: 200,000 t cane; 160,400 t CO_2.
Pabna: 293,700 t cane; 235,547 t CO_2.
Rajshahi: 197,562 t cane; 158,445 t CO_2.
Kushtia: 100,000 t cane; 80,200 t CO_2.
Faridpur: 205,590 t cane; 164,883 t CO_2.
Total: 1,194,946 t cane; 958,347 t CO_2.

IV. ECONOMIC VALUATION OF CO_2 FIXATION

Because there is no single universally applicable monetary value for a tonne of CO_2, a scenario approach is used. Illustrative carbon values of US\$20, US\$60, US\$88 and

US$180/t$CO_2$ are applied to 958,347 tonnes. At BDT 121/US$, the resulting indicative values are approximately BDT 232 crore, 696 crore, 1,020 crore and 2,087 crore, respectively. These are ecosystem-service valuations, not actual carbon-credit income.

Table 2. Indicative economic value of gross CO_2 fixation
US$20/t$CO_2$ → US$19.17 million → BDT 232 crore.
US$60/t$CO_2$ → US$57.50 million → BDT 696 crore.
US$88/t$CO_2$ → US$84.33 million → BDT 1,020 crore.
US$180/t$CO_2$ → US$172.50 million → BDT 2,087 crore.

V. SUGARCANE AS A MULTIFUNCTIONAL ENVIRONMENTAL ASSET

The underlying assessment estimates approximately 351 million m³ of evapotranspirative water transfer from the reconstructed sugarcane landscape and approximately 860,000 TJ of latent-energy transfer under the benchmark scenario. These values indicate that the landscape functions as a large vegetated environmental system. However, evapotranspiration should not be interpreted as direct absorption or cancellation of RNPP waste heat; the driving energy is primarily solar and meteorological.

VI. COUNTERFACTUAL I: TREE-PLANTATION REPLACEMENT

For illustration, assuming 20.1 kg CO_2/tree/year, approximately 47.7 million tree-years would be required to provide a numerically comparable annual carbon-removal service. This is a mathematical comparison, not ecological equivalence. Using an indicative plantation-cost sensitivity of BDT 300–700 per tree-equivalent gives an establishment-cost range of approximately BDT 143–334 crore. This excludes land acquisition, opportunity cost, long-term maintenance, irrigation, protection and monitoring.

Table 3. Indicative plantation replacement cost
BDT 300/tree → approximately 47.7 million tree-equivalents → BDT 143 crore.
BDT 500/tree → approximately 47.7 million tree-equivalents → BDT 239 crore.
BDT 700/tree → approximately 47.7 million tree-equivalents → BDT 334 crore.

VII. COUNTERFACTUAL II: POTENTIAL COOLING-EQUIPMENT IMPORT BURDEN

International trade data provide an observable baseline. For 2024, selected exports to Bangladesh included approximately US$94.7 million of window/wall-type air conditioners, US$59.5 million of selected electric fans, and US$12.2 million of refrigerator-freezers from major listed suppliers. Together these selected categories represent an indicative baseline of approximately US$166.4 million, or about BDT 2,014 crore at BDT 121/US$.

This is a trade-value baseline, not a climate-induced expenditure estimate. Therefore, hypothetical 10%, 25% and 50% additional-demand scenarios are used rather than a causal claim.

Table 4. Additional-import sensitivity scenarios
10% additional demand → US$16.64 million → BDT 201 crore.
25% additional demand → US$41.60 million → BDT 503 crore.
50% additional demand → US$83.20 million → BDT 1,007 crore.

Rechargeable Fans
Rechargeable fans are relevant to climate adaptation because they provide cooling during electricity interruptions and peak-demand periods. However, they do not map cleanly to a single national HS-6 category and may overlap with broader fan classifications. They should therefore be treated as an adaptation subcategory rather than simply added to the national fan-import total, avoiding double counting.

VIII. COMPARATIVE ECONOMIC ANALYSIS

The conservative carbon-fixation value is approximately BDT 232 crore. The illustrative tree-based replacement establishment cost is approximately BDT 143–334 crore. The hypothetical additional import burden is approximately BDT 201 crore at 10%, BDT 503 crore at 25%, and BDT 1,007 crore at 50% additional demand.

These are different economic concepts and should not be added together as though they were independent cash flows. The comparison instead illustrates the relative scale of ecosystem-based environmental services and technology-dependent adaptation pathways.

Table 5. Comparative economic magnitude
Carbon-fixation value @ US$20/t$CO_2$ → BDT 232 crore.
Tree-based replacement → BDT 143–334 crore.
Additional imports, 10% scenario → BDT 201 crore.
Additional imports, 25% scenario → BDT 503 crore.
Additional imports, 50% scenario → BDT 1,007 crore.
Carbon-fixation value @ US$88/t$CO_2$ → BDT 1,020 crore.

Rooppur Regional Context
The underlying study places the agricultural environmental-service analysis in the wider context of the Rooppur Nuclear Power Plant. The two-unit facility has a combined design thermal-output scale of approximately 6.4 GWth. The scientifically appropriate interpretation is not that sugarcane neutralizes RNPP waste heat. Rather, surrounding vegetation may provide regional environmental buffering through carbon fixation, evapotranspiration and modification of the surface-energy

balance. The source recommends direct field measurement, GIS-based catchment delineation and multi-season microclimate monitoring.

IX. DISCUSSION

The results indicate that agricultural green infrastructure has an economic significance that is not captured by crop-market prices alone. The gross carbon-fixation service is large enough to warrant explicit consideration in environmental-economic planning. The tree-plantation comparison demonstrates the potential cost of recreating a numerically comparable carbon-removal service through a separate intervention. The import comparison illustrates the possible economic scale of shifting toward technology-dependent thermal adaptation.

The study does not claim that sugarcane directly prevents air-conditioner imports. The defensible interpretation is that maintaining extensive vegetated agricultural landscapes may provide environmental buffering that could reduce the magnitude of future dependence on energy-intensive thermal adaptation, although the size of this effect requires empirical verification.

Limitations

The 958,347-tonne estimate is gross biological fixation rather than permanent net sequestration. The six-mill area is reconstructed from mixed direct, derived and historical data. Carbon valuation is scenario-dependent. Tree equivalence is a numerical comparison rather than ecological equivalence. Appliance-demand scenarios are hypothetical and cannot be attributed directly to temperature change without household-level and regional climate data. Refrigerator demand is also influenced by income, food-storage behavior, electrification and consumer preferences.

Recommendations

Future research should establish paired monitoring sites and measure air temperature, relative humidity, canopy temperature, land-surface temperature, soil moisture, wind speed, net radiation, evapotranspiration and vegetation indices. Agricultural measurements should include sugarcane area, biomass, yield, crop age, variety, irrigation and soil organic carbon. Household-economic surveys should measure fan, rechargeable-fan, AC and refrigerator ownership, operating hours, electricity consumption and appliance expenditure. A future econometric model can then test the relationship between vegetation cover, temperature, cooling demand and energy expenditure rather than assuming causation.

X. CONCLUSION

The six sugar-mill-associated sugarcane systems represent approximately 24,412 ha of reconstructed reference area, approximately 1.195 million tonnes of cane-equivalent production and approximately 958,347 tonnes of gross atmospheric CO_2 fixation per crop cycle. At an illustrative US\$20/tCO_2, this biological service corresponds to approximately BDT 232 crore; higher valuation scenarios reach approximately BDT 696–2,087 crore.

A tree-plantation counterfactual indicates approximately 47.7 million tree-years under the selected sequestration assumption, with indicative establishment expenditure of approximately BDT 143–334 crore. A separate import sensitivity analysis shows that a hypothetical 10%, 25% and 50% increase in selected cooling and refrigeration demand would correspond to approximately BDT 201 crore, 503 crore and 1,007 crore, respectively.

The central conclusion is that existing sugarcane landscapes represent a substantial natural environmental asset whose carbon-fixation and evapotranspirative services have measurable economic value. Maintaining these services may reduce the need to rely exclusively on costly technological and energy-intensive adaptation pathways as thermal stress increases. Future empirical work should verify current cultivated areas, directly measure biomass carbon and quantify the relationship between vegetation cover, temperature, cooling demand and household energy expenditure.

REFERENCES

1. Bangladesh Customs. (2024–2025). Bangladesh Customs tariff schedule: Chapter 84—Machinery and mechanical appliances. Government of Bangladesh.
2. Bangladesh Water Development Board. (2018). Initial Environmental Examination: Southwest Area Integrated Water Resources Planning and Management Project. Government of Bangladesh.
3. Cardoso, T. F., Watanabe, M. D. B., Souza, A., Chagas, M. F., Dale, B. E., & Bonomi, A. (2015). A regional approach to determine economic, environmental and social impacts of different sugarcane production systems in Brazil. Biomass and Bioenergy, 78, 168–180.
4. Huda, M. N. (2026). Quantifying the carbon-sequestration and evaporative-cooling services of sugarcane agroecosystems in six sugar-mill catchments of Bangladesh: Implications for environmental buffering in the Rooppur nuclear power region. International Journal of Scientific Research and Technology, 3(8), 711–723. https://doi.org/10.5281/zenodo.21990217
5. Silva, F. C., Diaz-Ambrona, C. G. H., Buckeridge, M., Souza, A., Barbieri, V., & Dourado Neto, D. (2008). Sugarcane and climate change: Effects of CO_2 on potential growth and development. Acta Horticulturae, 802, 331–336.
6. United States Environmental Protection Agency. (2024). Interim estimates of the social cost of greenhouse gases. U.S. Environmental Protection Agency.

7. Wu, Y., Mehdi, F., Chen, Y., Zhang, S., Jiang, S., Cao, Z., Gan, Y., Zan, L., & Yang, B. (2026). Carbon sequestration efficiency of sugarcane across developmental stages. Frontiers in Sustainable Food Systems, 10, 1775208. https://doi.org/10.3389/fsufs.2026.1775208
8. World Bank. (2026). World Integrated Trade Solution (WITS): Bangladesh trade data, HS 841451, 841510 and 841810, 2024. World Bank/UN Comtrade.