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Original Article

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

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ABSTRACT

Large thermal power facilities release substantial quantities of heat to the environment, while surrounding vegetation can modify the local carbon and surface-energy balance through photosynthesis and evapotranspiration. This study quantitatively evaluates the potential environmental-regulation services of sugarcane agroecosystems associated with six sugar mills in Bangladesh: 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 study is motivated by the development of the Rooppur Nuclear Power Plant (RNPP), a two-unit VVER-1200 facility with a design thermal output of 3,212 MW per unit. A data-synthesis and quantitative estimation approach was adopted using publicly available information from the Bangladesh Sugar and Food Industries Corporation (BSFIC), Bangladesh Sugarcane Research Institute (BSRI), Bangladesh Bureau of Statistics (BBS)-reported crop statistics, government and institutional records, and peer-reviewed literature. Directly reported cultivated-area figures were used where available; otherwise, cultivated area was reconstructed from reported cane-crushing quantities using a national reference yield of 48.95 t ha^{-1} for the 2023–24 cropping season. Gross atmospheric CO_2 fixation was estimated using a published sugarcane conversion factor of approximately 0.802 t CO_2 per tonne of fresh cane. Evaporative-cooling potential was estimated using a published sugarcane crop evapotranspiration benchmark of 1,438.23 mm per crop cycle and a latent heat of vaporization of approximately 2.45 MJ kg^{-1} water. The reconstructed six-mill study area was approximately 24,412 ha under the stated assumptions, corresponding to approximately 1.195 million tonnes of annual cane-equivalent production. The associated gross photosynthetic CO_2 fixation was estimated at approximately 0.958 million tonnes CO_2 per crop cycle. The benchmark evapotranspiration scenario corresponds to approximately 351 million m^3 of water transfer and approximately 860 million GJ of latent-energy flux over the crop cycle. These values demonstrate that extensive sugarcane landscapes possess substantial carbon-uptake and evaporative-energy-transfer capacity. However, the study does not interpret this latent-energy flux as a direct thermodynamic cancellation of RNPP waste heat. The energy driving evapotranspiration is primarily solar and meteorological rather than reactor heat. The results instead support the more scientifically defensible conclusion that sugarcane agroecosystems can provide a substantial **environmental buffering service** through atmospheric CO_2 removal, biomass carbon accumulation and evapotranspirative modification of the surface-energy balance. Direct field measurements, GIS-based catchment delineation and multi-season microclimate monitoring are recommended to determine the actual magnitude of this buffering function in the RNPP region.

Keywords: Rooppur Nuclear Power Plant; sugarcane; CO_2 fixation; carbon sequestration; evapotranspiration; evaporative cooling; surface-energy balance; sugar mills; Bangladesh; environmental buffering.

INTRODUCTION

Bangladesh is simultaneously expanding electricity-generation capacity and facing increasing environmental and climatic pressures. Agricultural landscapes remain particularly important because vegetation provides ecosystem services extending beyond food and industrial production.

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Sugarcane (*Saccharum* spp.) is one of Bangladesh's major industrial crops. The Bangladesh Sugarcane Research Institute identifies Rajshahi, Pabna, Natore, Faridpur and Kushtia among the country's important sugarcane-producing districts.

The crop is particularly relevant to environmental assessment because sugarcane is a high-biomass C4 crop. During active growth, it removes atmospheric CO_2 through photosynthesis, incorporates carbon into biomass and transfers large quantities of water from soil to atmosphere through evapotranspiration.

The latter process is especially important for local thermal regulation. Evapotranspiration converts part of the available surface energy into latent heat, reducing the proportion available for sensible heating of the land surface.

At the same time, Bangladesh is developing the Rooppur Nuclear Power Plant (RNPP) in Ishwardi, Pabna. RNPP consists of two VVER-1200 units. Official project information reports a thermal output of 3,212 MW for each unit. The IAEA's PRIS database reports a thermal capacity of 3,200 MWt for each Rooppur unit.

Thus, the two-unit plant has a design thermal-output scale of approximately:

3,212 × 2 = 6,424 MWth

The existence of a large thermal power facility raises an important environmental question:

Can surrounding agricultural ecosystems provide measurable carbon and surface-energy regulation that contributes to environmental buffering in the broader region?

This study focuses on six sugar-mill-associated sugarcane systems:

1. Natore Sugar Mills Ltd.
2. North Bengal Sugar Mills Ltd.
3. Pabna Sugar Mills Ltd.
4. Rajshahi Sugar Mills Ltd.
5. Kushtia Sugar Mills Ltd.
6. Faridpur Sugar Mills Ltd.

The central objective is not to claim that sugarcane can physically neutralize all heat rejected by RNPP. Rather, the study seeks to quantify the magnitude of two ecosystem functions:

(1) atmospheric CO_2 fixation

and

(2) evapotranspirative energy transfer

and evaluate their relevance to environmental buffering.

2. CONCEPTUAL FRAMEWORK

The proposed environmental interaction can be represented as:

RNPP

→ thermal-energy rejection

→ local atmospheric/surface-energy environment

↓

Agricultural landscape

↓

Sugarcane canopy

↙ ↘

CO_2 fixation **Evapotranspiration**

↓ ↓

Biomass carbon **Latent heat flux**

↘ ↙

Environmental buffering capacity

This framework contains two distinct physical mechanisms.

Carbon mechanism

Atmospheric CO_2 is incorporated into plant biomass through photosynthesis.

Thermal mechanism

Water is transferred from soil and plant tissues to the atmosphere through evapotranspiration, consuming latent heat and thereby modifying the surface-energy balance.

These mechanisms should not be treated as identical.

3. RESEARCH QUESTIONS

Primary question

What is the quantitative carbon-sequestration and evaporative-cooling potential of sugarcane agroecosystems associated with the six selected sugar mills?

Secondary questions

1. How much sugarcane area is associated with each mill?
2. How much cane biomass is produced?
3. How much atmospheric CO_2 is represented by this biomass production?
4. How much water is transferred through crop evapotranspiration?
5. What latent-energy flux is associated with that evapotranspiration?
6. How does this environmental-service magnitude compare with the thermal scale of RNPP?
7. Can these agricultural systems reasonably be characterized as environmental buffers?

4. STUDY AREA AND DATA SOURCES

The study covers six sugar-mill systems distributed across important sugarcane-producing regions of Bangladesh.

BSRI identifies Rajshahi, Pabna, Natore, Faridpur and Kushtia among the significant sugarcane-producing districts.

The six selected mills are:

No.	Sugar mill	Region
1	Natore Sugar Mills Ltd.	Natore
2	North Bengal Sugar Mills Ltd.	Lalpur, Natore
3	Pabna Sugar Mills Ltd.	Ishwardi, Pabna
4	Rajshahi Sugar Mills Ltd.	Rajshahi
5	Kushtia Sugar Mills Ltd.	Kushtia
6	Faridpur Sugar Mills Ltd.	Madhukhali, Faridpur

The study uses the following data hierarchy:

Tier 1: Officially reported cultivated area.

Tier 2: Officially reported cane-crushing quantity.

Tier 3: Published regional production data.

Tier 4: Derived estimates using a verified reference yield.

This hierarchy is important because the six mills do not currently have a single publicly accessible, same-year, mill-by-mill cultivated-area dataset.

5. SUGARCANE PRODUCTION BASELINE

The BSRI Annual Research Programme reports that in the 2023–24 cropping season, sugarcane was cultivated on approximately **40.73 thousand hectares** in Bangladesh, producing approximately **2.016 million tonnes**, corresponding to a national average yield of **48.95 t ha^{-1}**.

This value was adopted as the reference yield for reconstructing area from reported cane quantities where direct area data were unavailable.

The relationship is:

Estimated area = Reported cane quantity / 48.95

6. MILL-LEVEL QUANTITATIVE DATASET

6.1 Natore Sugar Mills Ltd.

For the 2025–26 crushing season, Natore Sugar Mill set a target to crush approximately **110,000 tonnes of sugarcane**. Cane was to be supplied through 48 centres in eight sub-zones.

Using the reference yield:

110,000 / 48.95 = 2,247 ha

However, a 2026 report states that Natore Sugar Mill authorities were working toward a target of **10,000 acres** of sugarcane, equivalent to approximately:

10,000 × 0.404686 = 4,047 ha

The latter is a directly reported cultivation target and is therefore preferred for the land-area estimate.

Adopted area: approximately 4,047 ha.

6.2 North Bengal Sugar Mills Ltd.

North Bengal Sugar Mills in Lalpur, Natore targeted **200,000 tonnes of sugarcane crushing** for the 2025–26 season.

Using the reference yield:

200,000 / 48.95 = 4,086 ha

Thus:

Estimated associated cultivated area = 4,086 ha

This should be regarded as a derived estimate rather than a directly reported field-area measurement.

6.3 Pabna Sugar Mills Ltd.

Pabna Sugar Mills stopped production in 2020 and had not resumed production as of December 2025.

Before closure, approximately **6,000 hectares** of land were reported to have been under sugarcane cultivation in the Pabna mill-associated production area, producing approximately 100,000 tonnes of cane. After closure, production in the district fell dramatically; a 2022 report stated that only 40–50 ha were then under sugarcane cultivation.

For historical mill-catchment assessment:

Adopted reference area = 6,000 ha

This is explicitly treated as a **pre-closure/historical baseline**, not as a 2026 active cultivated area.

6.4 Rajshahi Sugar Mills Ltd.

A published report on Rajshahi Sugar Mills stated that sugarcane was cultivated on approximately **4,036 hectares** in the mill's region during the relevant season.

The mill subsequently reported a 2025–26 target of **75,000 tonnes of cane** for crushing.

For consistency with the available mill-zone cultivation evidence:

Adopted reference area = 4,036 ha

6.5 Kushtia Sugar Mills Ltd.

Kushtia Sugar Mills has been inactive since the 2020 closure programme.

Historical operational records indicate that the mill targeted **100,000 tonnes of sugarcane** during the 2013–14 crushing season.

Using the 48.95 t ha^{-1} reference yield gives:

100,000 / 48.95 = 2,043 ha

Therefore:

Estimated historical reference area = 2,043 ha

This is a reconstructed historical estimate and should not be interpreted as current active cultivation.

6.6 Faridpur Sugar Mills Ltd.

Historical evidence reports approximately **4,200 hectares** of sugarcane under the supervision/catchment of Faridpur Sugar Mills.

The mill serves sugarcane-producing areas of Faridpur and neighbouring districts.

Accordingly:

Adopted reference area = 4,200 ha

Again, this is a historical/reference value requiring current DAE/BSFIC verification before being presented as a 2026 cultivated-area figure.

7. Reconstructed Six-Mill Area

The six reference areas are therefore:

Sugar mill	Reference area (ha)	Data status
Natore	4,047	Reported target
North Bengal	4,086	Derived from 200,000 t
Pabna	6,000	Historical pre-closure
Rajshahi	4,036	Reported mill-zone area
Kushtia	2,043	Derived historical estimate
Faridpur	4,200	Historical mill-associated area
Total	**24,412 ha**	Mixed direct/derived baseline

The total should therefore be described as a:

reconstructed six-mill reference area

rather than a verified 2026 cultivated area.

8. Cane Production Equivalent

Applying the reference yield of 48.95 t ha^{-1} to the reconstructed areas gives:

Sugar mill	Area (ha)	Cane-equivalent production (t/year)
Natore	4,047	198,094
North Bengal	4,086	200,000
Pabna	6,000	293,700
Rajshahi	4,036	197,562
Kushtia	2,043	100,000
Faridpur	4,200	205,590
Total	**24,412**	**1,194,946**

Thus, under the reconstruction assumptions, the six-mill system represents approximately:

1.195 million tonnes of cane-equivalent annual production.

This is an analytical baseline, not a claim that all 1.195 million tonnes were actually crushed by the mills in the same year.

9. CO_2 FIXATION ESTIMATION

A national greenhouse-gas inventory methodology reported a carbon fraction of approximately 0.45 for dry plant matter and estimated that approximately **802 kg CO_2 were fixed per tonne of fresh sugarcane cane** under the relevant biomass-accounting framework.

Accordingly:

Gross CO_2 fixation = Fresh cane production × 0.802

For the six-mill reconstructed production:

1,194,946 × 0.802

=

958,347 tonnes CO_2

Therefore, the reconstructed six-mill sugarcane system represents approximately:

0.96 million tonnes CO_2 of gross biological fixation per crop cycle

This is an important result.

However, it must be described correctly.

It is **gross photosynthetic CO_2 fixation represented by biomass production**, not automatically equivalent to permanent net ecosystem carbon sequestration.

10. MILL-WISE CO_2 FIXATION

Sugar mill	Cane-equivalent production (t)	Gross CO_2 fixation (t CO_2)
Natore	198,094	158,871
North Bengal	200,000	160,400
Pabna	293,700	235,547
Rajshahi	197,562	158,445
Kushtia	100,000	80,200
Faridpur	205,590	164,883
Total	**1,194,946**	**958,347**

Pabna contributes the largest value in this reconstructed scenario because its historical mill-associated cane area is the largest of the six reference areas.

11. EVAPOTRANSPIRATION AND ENVIRONMENTAL COOLING

Sugarcane cooling should be quantified through evapotranspiration rather than by treating the crop as directly absorbing reactor heat.

Published field research reports sugarcane crop evapotranspiration of approximately **1,438.23 mm over a crop cycle**, with a mean daily ET of approximately 4.05 mm in the cited study.

This value is used here as a **benchmark scenario**, not as a Bangladesh-specific measured value.

For one hectare:

1 mm ET = 10 m³ water

Therefore:

1,438.23 mm = 14,382.3 m³ water ha^{-1} $crop^{-1}$

For 24,412 ha:

14,382.3 × 24,412

≈

351 million m³ water per crop cycle

This represents the order of magnitude of water transfer if the benchmark ET rate applies to the reconstructed six-mill area.

12. LATENT-ENERGY FLUX

The latent heat of vaporization of water is approximately:

2.45 MJ kg^{-1}

Since one cubic metre of water has a mass of approximately 1,000 kg:

1 m^3 water ≈ 2.45 GJ latent energy

Therefore:

351 million m^3 × 2.45 GJ

≈

860 million GJ

or approximately:

860,000 TJ

of latent-energy transfer over the assumed crop cycle.

This is a very large number, but it must be interpreted correctly.

It does **not** mean that the sugarcane fields remove 860,000 TJ of RNPP waste heat.

The latent-energy flux is driven predominantly by solar radiation, atmospheric demand and water availability.

It demonstrates the **scale of the crop's evaporative energy-transfer capacity**, not a direct heat-offset mechanism.

13. COMPARISON WITH RNPP THERMAL OUTPUT

RNPP has two units, each with a thermal output of approximately 3,212 MW.

Thus:

Total reactor thermal output = 6,424 MWth

If hypothetically operated continuously at full thermal output for one year:

6,424 MW × 8,760 h

=

56,274,240 MWh thermal

or approximately:

202,587 TJ thermal energy per year

The benchmark sugarcane evapotranspiration estimate is approximately:

860,000 TJ per crop cycle

This is several times larger in numerical energy magnitude than one year's total reactor thermal output.

However, **this does not mean sugarcane thermally neutralizes RNPP.**

The two energy flows have different origins, spatial distributions and physical pathways.

The comparison instead demonstrates that the agricultural landscape has a potentially very large **latent-energy flux capacity**.

14. Why the "Balance" Concept Must Be Defined Carefully

The original research concept can therefore be reformulated scientifically.

The weak statement would be:

"Sugarcane fields absorb the additional heat generated by RNPP."

This is not scientifically defensible without direct energy-balance measurements.

The stronger statement is:

"Extensive sugarcane agroecosystems may provide measurable environmental buffering through carbon sequestration and evapotranspirative modification of the local surface-energy balance."

This distinction substantially improves the publication potential of the research.

15. ENVIRONMENTAL BUFFERING MECHANISM

The environmental-buffering function can be divided into three components.

15.1 Carbon buffering

Approximately:

958,347 t CO_2

of gross atmospheric CO_2 fixation is represented by the reconstructed cane production.

15.2 Evaporative buffering

Approximately:

351 million m^3

of water transfer is represented by the benchmark ET scenario.

15.3 Surface-energy buffering

Approximately:

860 million GJ

of latent-energy transfer is represented by the benchmark scenario.

Together, these mechanisms indicate a substantial ecosystem service.

16. SENSITIVITY ANALYSIS

Because the evapotranspiration value is not Bangladesh-specific, a sensitivity analysis is more appropriate than presenting a single number as fact.

Assuming:

- Low ET = 1,000 mm/cycle
- Central ET = 1,438 mm/cycle
- High ET = 1,800 mm/cycle

the estimated latent-energy transfer would be:

ET scenario	Water transfer	Latent energy
1,000 mm	244 million m^3	~598,000 TJ
1,438 mm	351 million m^3	~860,000 TJ
1,800 mm	439 million m^3	~1,075,000 TJ

This demonstrates that the estimated cooling service is sensitive to actual crop water use.

Consequently, field-based ET measurements should be incorporated in the definitive empirical study.

17. SENSITIVITY OF CO_2 FIXATION

The CO_2 estimate is similarly sensitive to actual cane production.

If the six-mill system produces:

1.0 million tonnes cane

then:

$1{,}000{,}000 \times 0.802 = 802{,}000$ t CO_2

If production reaches:

1.2 million tonnes

then:

$1{,}200{,}000 \times 0.802 = 962{,}400$ t CO_2

Thus, the central estimate of approximately **958,000 t CO_2** is consistent with a cane-equivalent production of approximately 1.195 million tonnes.

18. LIMITATIONS

Several limitations must be explicitly acknowledged.

18.1 Mixed-year data

The six mill estimates do not originate from a single common agricultural year.

18.2 Closed mills

Pabna and Kushtia have not operated normally since the 2020 closure programme.

Therefore, their historical cultivation areas cannot be presented as current 2026 areas.

18.3 Derived areas

North Bengal and Kushtia areas were reconstructed from cane quantities and a reference yield.

18.4 CO_2 fixation versus permanent sequestration

Gross photosynthetic fixation is not equivalent to long-term ecosystem carbon storage.

18.5 ET transfer is not reactor-heat removal

The calculated latent-energy flux cannot be interpreted as direct absorption or neutralization of RNPP waste heat.

18.6 Lack of local field measurements

No continuous meteorological transect, eddy-covariance measurement, lysimeter measurement or field energy-balance campaign has yet been incorporated.

19. RECOMMENDED EMPIRICAL VALIDATION

The next stage should establish permanent measurement sites in representative sugarcane fields.

At least three categories should be monitored:

A. Near-RNPP sugarcane fields

Fields located in the potential influence zone.

B. Intermediate-distance sugarcane fields

Fields at approximately 10–30 km or other scientifically justified distances.

C. Control sugarcane fields

Fields sufficiently distant to represent background agricultural conditions.

Each site should measure:

- Air temperature
- Relative humidity
- Wind speed
- Wind direction
- Soil temperature
- Soil moisture
- Net radiation
- Canopy temperature
- Evapotranspiration
- Crop height
- Leaf-area index
- Biomass
- Cane yield
- Soil organic carbon

20. REMOTE-SENSING VALIDATION

Satellite data should be used to generate:

- Land-surface temperature maps
- NDVI maps
- EVI maps
- Crop-area maps
- Crop phenology
- Vegetation-density maps
- Seasonal thermal anomaly maps

The analysis should compare:

Sugarcane vs non-sugarcane

and:

Near-RNPP vs distant control

rather than assuming that all observed temperature differences originate from RNPP.

21. PROPOSED STATISTICAL FRAMEWORK

The following mixed-effects model is recommended:

$$\mathbf{Y_{ij} = \beta_0 + \beta_1 D_i + \beta_2 ET_{ij} + \beta_3 SM_{ij} + \beta_4 T_{ij} + \beta_5 CropAge_{ij} + u_i + \varepsilon_{ij}}$$

where:

- **Y** = canopy temperature, biomass or yield
- **D** = distance from RNPP
- **ET** = evapotranspiration
- **SM** = soil moisture
- **T** = air temperature
- **CropAge** = crop developmental stage
- **u** = site-level random effect
- **ε** = residual error

This would allow the researchers to distinguish RNPP-associated spatial effects from normal agricultural variability.

22. ENVIRONMENTAL BUFFERING INDEX

A quantitative index can be developed:

Sugarcane Environmental Buffering Index (SEBI)

The index may combine:

Carbon fixation

Evapotranspiration

Land-surface-temperature moderation

Vegetation coverage

Soil-moisture availability

The index should be normalized before combining variables with different units.

A possible formulation is:

$$\mathbf{SEBI = w_1 C + w_2 ET + w_3 \Delta LST + w_4 V + w_5 SM}$$

where the weights should be determined before final analysis.

23. RESULTS

Based on the verified public information and transparent reconstruction described above, the six-mill system has an estimated reference area of approximately:

24,412 hectares

with cane-equivalent production of approximately:

1.195 million tonnes

The associated gross atmospheric CO_2 fixation is approximately:

958,000 tonnes CO_2 per crop cycle

Using the benchmark sugarcane evapotranspiration of 1,438.23 mm per crop cycle, the six-mill area would transfer approximately:

351 million m^3 of water

through evapotranspiration.

The corresponding latent-energy flux is approximately:

860,000 TJ per crop cycle

These results indicate that the sugarcane landscape has a substantial potential environmental-regulation capacity.

24. DISCUSSION

The most important finding is not that sugarcane can directly cancel the thermal output of RNPP. Rather, the analysis demonstrates the magnitude of the biological and physical processes associated with a large sugarcane landscape.

The reconstructed six-mill system represents approximately 24,412 ha of agricultural land. Even at moderate national sugarcane productivity, such an area supports a very large annual biomass flux.

The estimated gross CO_2 fixation of approximately 0.96 million tonnes per crop cycle is environmentally significant. However, much of this carbon eventually enters harvested products, decomposes or returns to the atmosphere. Consequently, future research must separate gross fixation from net ecosystem carbon retention.

The evaporative-cooling estimate is equally important. Sugarcane is a high-water-use, high-biomass crop whose canopy can transfer substantial quantities of water into the atmosphere. This process consumes latent energy and reduces the fraction of available energy converted into sensible surface heating.

Therefore, sugarcane can legitimately be regarded as a component of **regional surface-energy regulation**.

The appropriate interpretation is consequently:

RNPP provides a large thermal-energy flux at the infrastructure scale, while surrounding vegetation provides a biological surface-energy and carbon-regulation service at the landscape scale.

These two systems should be evaluated together within a regional environmental assessment framework.

25. IMPLICATIONS FOR ROOPPUR

RNPP's two-unit thermal output is approximately 6.4 GWth.

The surrounding agricultural landscape cannot be assumed to neutralize this heat.

Nevertheless, if the sugarcane fields demonstrably reduce daytime land-surface temperature, increase latent heat flux and remove substantial atmospheric CO_2, then preservation of those agricultural landscapes becomes environmentally relevant to the broader regional system.

This suggests a potentially important policy principle:

Agricultural green belts surrounding large energy facilities should be considered as ecosystem-service assets rather than treated exclusively as production land.

26. POLICY RECOMMENDATIONS

26.1 Establish an agricultural environmental monitoring network

Permanent stations should monitor sugarcane microclimate around RNPP.

26.2 Protect high-density sugarcane areas

Conversion of large agricultural green areas to impervious surfaces should be carefully evaluated.

26.3 Integrate agricultural data into environmental assessment

Future environmental monitoring of RNPP should include:

- vegetation cover
- land-surface temperature
- evapotranspiration
- agricultural carbon
- soil carbon

26.4 Develop a regional carbon account

The six sugar-mill systems could be incorporated into a regional agricultural carbon inventory.

26.5 Establish a long-term satellite monitoring programme

Annual LST and vegetation-index maps should be produced.

CONCLUSION

This study quantitatively evaluates the environmental-regulation potential of sugarcane agroecosystems associated with six sugar mills in Bangladesh in the context of the Rooppur Nuclear Power Plant.

Using publicly documented agricultural and industrial information and transparent quantitative assumptions, the reconstructed six-mill system represents approximately **24,412 ha** of sugarcane-associated land.

At the reference yield used in this study, this corresponds to approximately **1.195 million tonnes of cane-equivalent production**.

Using a published sugarcane CO_2-fixation factor, the associated gross biological fixation is approximately:

958,000 tonnes CO_2 per crop cycle.

Using a published benchmark sugarcane evapotranspiration of 1,438.23 mm per crop cycle, the same landscape could theoretically transfer approximately:

351 million m^3 of water

to the atmosphere, corresponding to approximately:

860,000 TJ of latent-energy transfer.

These results demonstrate that extensive sugarcane agroecosystems can provide substantial environmental services through atmospheric carbon fixation and evapotranspiration.

However, these processes should not be described as directly cancelling or neutralizing RNPP's total waste heat. The energy driving evapotranspiration is predominantly solar and meteorological, whereas RNPP's heat originates from nuclear fission. The scientifically appropriate interpretation is therefore one of **environmental buffering rather than direct heat compensation**.

The principal contribution of this study is the development of a quantitative framework linking:

nuclear-energy infrastructure

with

agricultural carbon sequestration

and

vegetation-mediated surface-energy regulation.

The next stage should replace reconstructed/historical mill-area values with current GIS-derived cultivated areas and replace benchmark evapotranspiration values with direct field measurements or calibrated remote-sensing estimates.

If subsequent field measurements confirm that sugarcane fields near the RNPP region exhibit significant CO_2 fixation, evapotranspirative cooling and lower land-surface temperatures than appropriate controls, the sugarcane landscape could reasonably be recognized as an important component of regional environmental resilience.

DATA QUALITY STATEMENT

This manuscript deliberately distinguishes between:

Verified reported data

and

derived estimates.

The following are directly supported by published sources:

- RNPP unit thermal output: 3,212 MW per unit.
- Bangladesh 2023–24 sugarcane yield: 48.95 t ha^{-1}.
- Natore 2025–26 cultivation target: approximately 10,000 acres.
- North Bengal 2025–26 cane-crushing target: 200,000 tonnes.
- Pabna historical mill-associated sugarcane area: approximately 6,000 ha before closure.
- Rajshahi mill-associated sugarcane area: approximately 4,036 ha in the cited season.
- Kushtia historical cane-crushing target: 100,000 tonnes.
- Faridpur historical mill-associated sugarcane area: approximately 4,200 ha.
- Sugarcane CO_2 fixation benchmark: approximately 802 kg CO_2 per tonne fresh cane.
- Sugarcane ET benchmark: 1,438.23 mm per crop cycle.

The derived estimates are calculated from these reported values and should be identified as such in any journal submission.

RECOMMENDED TITLE FOR JOURNAL SUBMISSION

Preferred title

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

Shorter alternative

Sugarcane Agroecosystems as Environmental Buffers in the Rooppur Nuclear Power Region of Bangladesh

REFERENCES

1. Bangladesh Sugarcane Research Institute. Information on sugarcane-growing areas in Bangladesh. Government of Bangladesh.
2. Bangladesh Bureau of Statistics. Recent crop statistics and agricultural publications. Government of Bangladesh.
3. Bangladesh Sugar and Food Industries Corporation. Official information and records concerning state-owned sugar mills. Government of Bangladesh.
4. Rooppur Nuclear Power Plant Project. Main Technical Features of Rooppur NPP. Government of Bangladesh.
5. International Atomic Energy Agency. PRIS reactor data for Rooppur-1 and Rooppur-2.
6. Bangladesh Sugarcane Research Institute. Annual Research Programme. Government of Bangladesh.
7. Wu, Y., et al. (2026). Carbon sequestration efficiency of sugarcane across developmental stages. Frontiers in Sustainable Food Systems.
8. Published sugarcane water-balance research reporting crop evapotranspiration of approximately 1,438.23 mm per crop cycle.
9. United Nations Framework Convention on Climate Change. Biomass carbon accounting methodology reporting a carbon fraction of approximately 0.45 and approximately 802 kg CO_2 fixed per tonne fresh cane under the cited sugarcane inventory framework.
10. BSS. North Bengal Sugar Mills begins sugarcane crushing. 2025.
11. BSS. Sugarcane crushing begins at Rajshahi Sugar Mills. 2025.
12. BSS. Natore sees rise in sugarcane and maize cultivation. 2026.
13. The Daily Star. State-owned sugar mills: Closed to cut costs but continue to incur loss.
14. Financial Express. No visible efforts yet to resume operation of Pabna Sugar Mills. 2025.
15. New Age. Rajshahi Sugar Mills crushes sugar cane only 21 days.
16. The Daily Star. Mills fear sugarcane shortage. 2021.

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