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Research and Development Cell of Tezpur College
Tezpur, Assam, Pin- 784001
Email id: insight@tezpurcollege.com
Website: https://tezpurcollege.com/insight

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Email-*nabanita@biswanathcollege.in*
Contact No.-8720911720

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A Comparative SRIM/TRIM Study of Swift Heavy Ni and Ag Ions Irradiation Effects In Cadmium Telluride

Riya Baidya[1], Ratan Das[1*]
[1]*Nano-Physics & Nanotechnology Research Laboratory, Department of Physics, Tripura University, Suryamaninagar, India-799 022*
*Corresponding author
Email- dasratanphy@gmail.com

Abstract

In this work, a comparative Monte Carlo simulation study of swift heavy ion irradiation effects in Cadmium Telluride (CdTe) has been carried out using the SRIM/TRIM package. High-energetic Ni (80 MeV) and Ag (225 MeV) ions are irradiated in CdTe to understand the ion–matter interaction mechanisms, including stopping power, ion trajectories, ionization energy loss, projected range, range straggling, and collision events. The SRIM results show that electronic stopping dominates over nuclear stopping for both ions, with Ag ions exhibiting higher electronic energy loss than Ni ions. The main motive of this study is to understand the influence of higher electronic energy loss of Ag on ionization profile, penetration depth, lateral spread, and displacement damage profile of CdTe.

Keywords: Ion irradiation; CdTe; Electronic energy loss; SRIM; Damage Profile.

1. Introduction:

Cadmium telluride (CdTe) is an II–VI semiconductor that has attracted significant attention due to its exceptional electronic, optical, and structural properties owing to its direct band gap, high absorption coefficient, and excellent radiation hardness (Tiwary et al., 2025; Pandey et al., 2006; Singh et al., 2017). CdTe has found widespread applications in photovoltaic devices, infrared detectors, and optoelectronic systems (Scarpulla et al., 2023; Abu-Farsakh et al., 2023). The performance of CdTe-based devices is strongly influenced by its structural (Norris et al., 1996), which can be deliberately modified using external techniques such as doping and ion irradiation.

Swift heavy ion (SHI) irradiation has emerged as an effective ion irradiation method for tailoring the physical properties of semiconductor materials (Abhirami et al., 2013). When an energetic ion falls in a solid, they interact with both the electronic and nuclear subsystems of the target, leading to energy loss through ionization, excitation, atomic displacement, and defect generation (Nath et al., 2022). These interactions result in localized structural modifications, defect formation, and changes in electrical and optical properties. Unlike conventional doping or thermal treatments, ion irradiation allows controlled modification of materials without altering their overall chemical composition (Nath et al., 2022).

The interaction of energetic ions with matter is primarily governed by two energy loss mechanisms such as nuclear stopping and electronic stopping (Ziegler et al., 2010). Nuclear stopping arises from elastic collisions between incident ions and target nuclei, leading to atomic displacements and defect creation. Electronic stopping, on the other hand, originates from inelastic interactions with target electrons and is dominant for high-energy ions. In materials like CdTe, where electronic stopping plays a crucial role, ionization-driven processes significantly influence the extent of lattice modification and defect evolution.

Understanding ion–matter interactions require detailed knowledge of parameters such as stopping power, ion range, lateral and radial spread, energy deposition profiles, and collision events (Nath et al., 2022; Ziegler et al., 2010). Experimental investigations, although valuable, are often limited by cost, time, and complexity. In this context, Monte Carlo simulation tools such as the Stopping and Range of Ions in Matter (SRIM) and Transport of Ions in Matter (TRIM) (Ziegler, 1999) codes provide a powerful alternative for predicting ion behaviour in materials. These simulation frameworks employ well-established physical models to compute

energy loss, ion trajectories, range distributions, and radiation-induced damage, offering valuable insight into irradiation processes prior to experimental implementation.

In the present work, a detailed comparative simulation study of high-energy nickel (80 MeV) and silver (225 MeV) ion irradiation on CdTe has been carried out using SRIM and TRIM codes. These ions were selected due to their distinct mass and energy characteristics, enabling a meaningful comparison of ion–matter interaction mechanisms. The study focuses on analyzing stopping power, ion trajectories, ionization-induced energy loss, projected range, range straggling, and collision events in the target CdTe. Finally, the effect of higher electronic energy loss of Ag on ionization profile, penetration depth, lateral spread, and displacement damage has been studied in CdTe material.

2. Simulation methodology:

In this work, the numerical simulation has been performed using SRIM (Ziegler, 1999) software. In SRIM simulations, heavy ions with higher speed are typically directed normally onto the target material, which in this case is CdTe. A key advantage of this tool is that it allows the user to define essential parameters such as ion type, energy, and target material, making it convenient to conduct and analyze simulations. The software uses theoretical models to replicate ion–matter interactions also SRIM determines the energy loss and stopping power, showing how rapidly ions lose energy as they pass through the material (Ziegler, 1999). In the present study, we have analysed the various parameters such as, including stopping power, ion trajectories, ionization energy loss, projected range, range straggling, and collision events for 80 MeV Ni ions and 225 MeV Ag ions on CdTe target material. The main purpose of the study is to compare the results between 80 MeV Ni ions and 225 MeV Ag ions on target materials.

3. Results and Discussion:

3.1 SRIM Analysis: Ion Behaviour in CdTe:

When heavy ion falls on a target material, it undergoes different phenomena such as ionizing and exciting the target's electrons, scattering off nuclei, and losing energy through multiple processes. This leads to the ion's gradual slowdown and eventual halt within the material. In addition to this, secondary particles may also emerge from collisions, contributing to energy loss. These combined effects known as stopping power of the ion (Scarpulla et al., 2023; Ziegler, 2010). Fig. 1(a) and (b) shows ion energy (dE/dx) versus stopping power in CdTe. The red dotted line represents nuclear energy losses, remains consistently low and parallels the x-

axis, signifying minimal interaction-induced energy loss as ions penetrate the material. In contrast, the black dotted line, depicting electronic energy losses, displays a gradual and consistent increase with increasing ion energy.

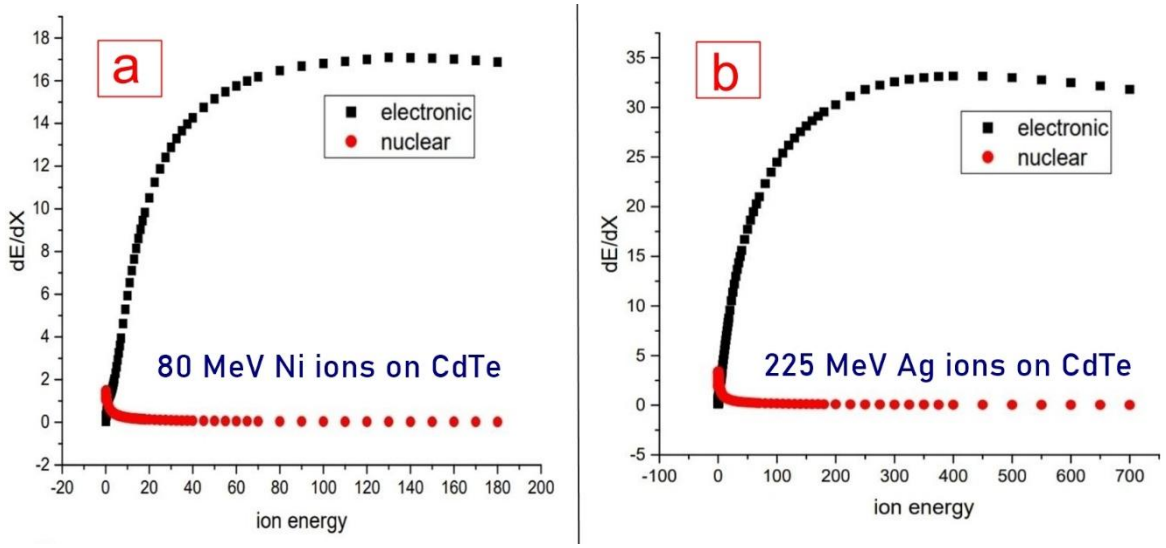

Figure: 1 Energy loss (dE/dx) profile for (a) 80 MeV Ni and (b) 225 MeV ions on CdTe

Additionally, it has been observed that after a specific point, electronic energy loss reaches saturation. Beyond this point, regardless of the ion's energy, the energy loss remains constant, which is called the stopping power of the ion (Stoller et al., 2013). These saturation points highlight energy thresholds at which ion-material interactions stabilize, leading to a plateau in energy losses. It is clearly visible that at very low incident energy, nuclear energy losses predominate over electronic energy losses. However, as ions go deeper into the CdTe material, the trend shifts, with electronic energy losses gaining prominence. The noticeable difference in slopes between the red and black lines highlights the increasing significance of electronic energy losses in ion-CdTe interactions. Now, we have plotted the electronic energy loss curve for different ions. It has been observed that silver ions actually produce more electronics as well as nuclear energy loss in comparison with Ni ions, as shown in Fig. 2, which is expected to influence the ion trajectories, ionization, projected range, range straggling, and collision events of CdTe.

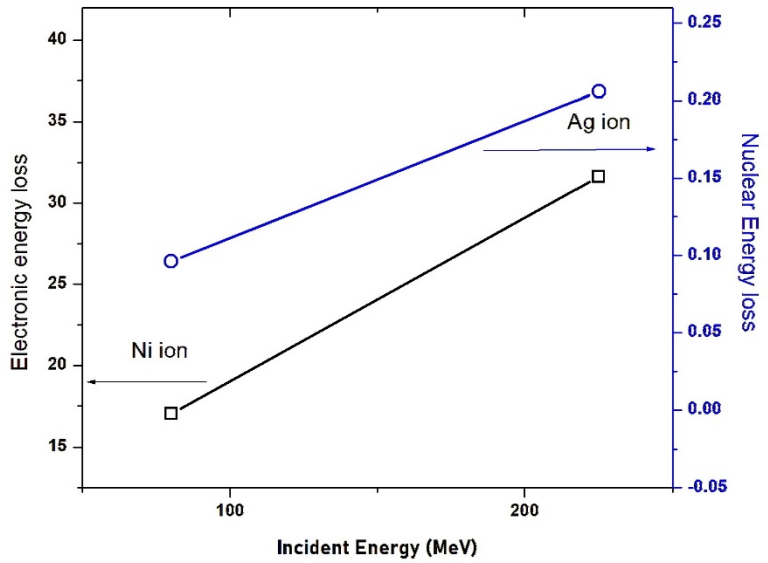

Figure: 2 Variation of Electronic and Nuclear Energy loss with incident energy for 80 MeV Ni and 225 MeV ions on CdTe

3.2 TRIM Data Analysis:

3.2.1 Ion trajectory in CdTe:

Here, TRIM code has been used to obtain the ion trajectories of 80 MeV Ni ions and 225 MeV Ag ions on CdTe material, as shown in Fig. 3. The lateral projection of heavy ions in CdTe target material has been obtained for Ni ions as 9521 Å and ~1 µm for Ag ions. These values indicate that the ions undergo lateral scattering within the material. The higher lateral projection observed for Ag ions compared to Ni ions suggests a wider lateral dispersion, leading to a broader energy deposition profile in the transverse direction.

Similarly, the radial distribution has been obtained as 1.81 µm for Ni ions and 1.56 µm for Ag ions, which correspond to the radial spread of ions around their primary trajectories. The relatively larger radial extent for Ni ions indicates a slightly broader radial distribution compared to Ag ions, reflecting differences in scattering behaviour and ion–target interaction dynamics.

From Fig. 3, the percentage contribution of energy loss due to ionization has been obtained, which shows notably high for both ion species, accounting for 97.07% in the case of Ni ions and 97.31% for Ag ions. This dominance of ionization energy loss confirms that ionization is the primary mechanism through which energetic ions transfer energy to the CdTe lattice under

the present irradiation conditions. The negligible contributions from vacancy formation and phonon generation further indicate that these energy loss channels play a minor role.

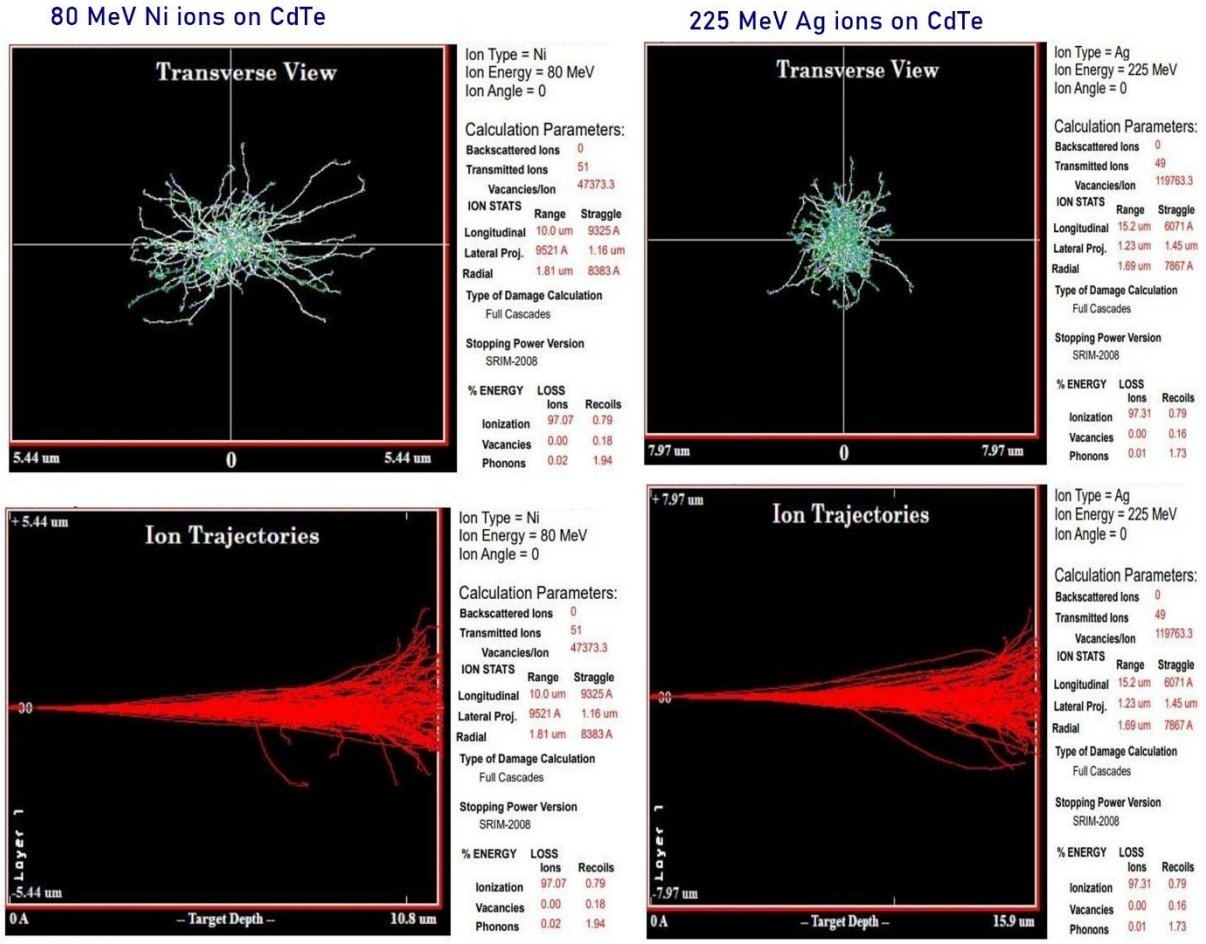

Figure: 3 Ion Trajectories of 80 MeV Ni ions and 225 MeV Ag ions on CdTe material.

3.2.2 Ionization:

As ion trajectory study from the TRIM (Fig. 3) confirms more than 97% energy dissipates via Ionization so it is important to study the ionization profile for both Ni and Ag ions in CdTe. Fig. 4 illustrates the variation of ion energy loss as a function of penetration depth within the target material. The x-axis originates at zero, representing the surface of the target, and increases with depth as the ions propagate into the material, while the y-axis denotes the energy lost by the ions primarily through ionization interactions with the target atoms.

It is evident from the figure that the maximum energy loss occurs at point of ion entry at the target surface. At this stage, the ions experience rapid energy dissipation due to intense ionization interactions with surface atoms. As the ions penetrate deeper into the material (with increasing x-values), the energy loss gradually decreases. This reduction arises from the

continuous loss of kinetic energy through ionization processes and the consequent decrease in interaction probability as the ions move further into the target.

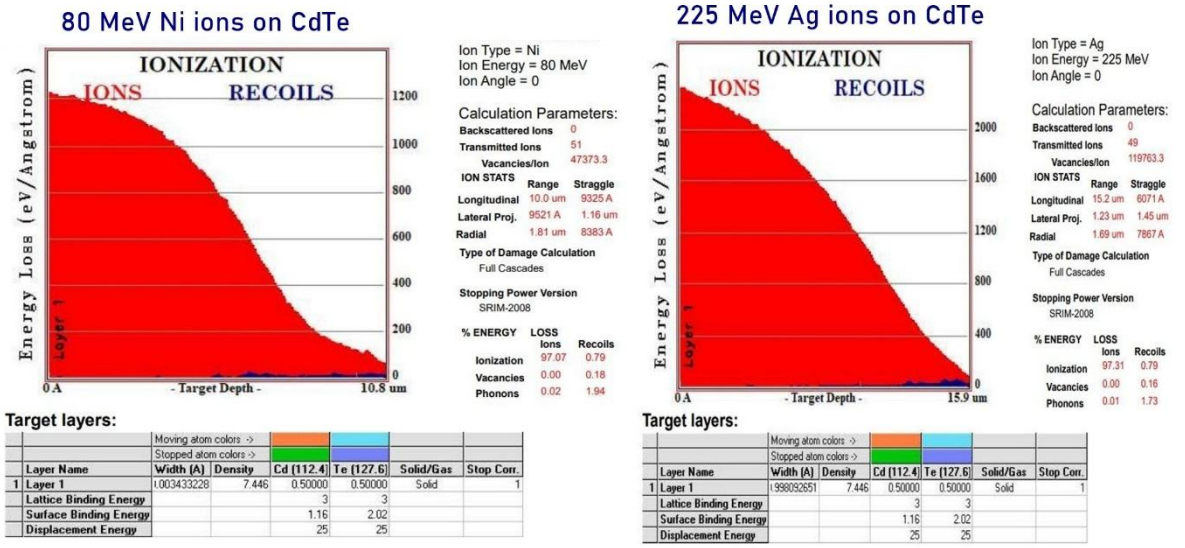

Figure: 4 Energy loss profile for 80 MeV Ni ions and 225 MeV Ag ions on CdTe material.

The steep initial decline in energy loss near the surface signifies strong ionization effects in the near-surface region. The subsequent gradual decrease in energy loss with depth indicates reduced interaction frequency as the ion's traverse regions of comparatively lower atomic density (Yuan & Wu, 1961).

In addition to the energy loss behaviour, the longitudinal and lateral range parameters further support the comparative ion–matter interaction characteristics. The longitudinal projected range is observed to be ~10 µm for Ni ions and ~15.2 µm for Ag ions, indicating deeper penetration of Ag ions into the target material. Furthermore, the lateral projected range for Ni ions is 9521 Å, whereas Ag ions exhibit a significantly larger lateral spread of ~1.23 µm, suggesting enhanced transverse scattering for Ag ions.

Overall, the higher energy loss, greater longitudinal penetration depth, and increased lateral spread observed for Ag ions compared to Ni ions confirm their stronger ionization capability and more pronounced interaction with the target material throughout the penetration depth.

3.2.3 Ion range:

Based on the TRIM analysis (Figs. 5), a clear comparative distinction is observed between Ni and Ag ions in terms of their penetration behavior within the target material. The projected ion range for Ag ions (15.2 μm) is significantly higher than that for Ni ions (10.7 μm), indicating deeper penetration of Ag ions under identical irradiation conditions. This enhanced penetration depth of Ag ions can be attributed to their higher mass and energy transfer characteristics.

Additionally, the negative skewness values for both ions (−1.2554 for Ni and −1.5033 for Ag) indicate left-skewed ion range distributions. However, the more negative skewness for Ag ions suggests a stronger asymmetry in their distribution. The kurtosis values (5.7788 for Ni and 5.6365 for Ag) reveal that both ion species exhibit sharply peaked distributions compared to a normal distribution.

Overall, the comparative TRIM analysis demonstrates that Ag ions penetrate deeper, whereas Ni ions exhibit shallower penetration. These differences in ion range characteristics reflect distinct ion–matter interaction mechanisms and confirm the stronger penetration efficiency and ionization behavior of Ag ions within the target material.

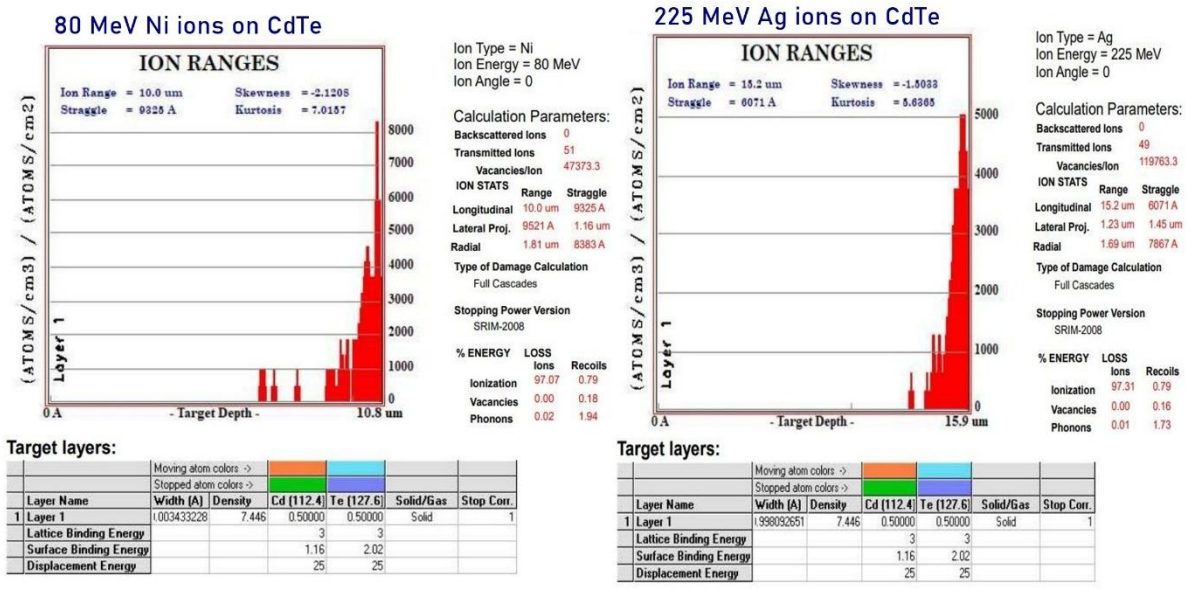

Figure: 5 Ion range profile for CdTe

3.2.4 Collision event:

Fig. 6 depicts the collision events occurring within cadmium telluride (CdTe) when subjected to irradiation by Ni and Ag ions. In each graph, the x-axis represents the target depth within the material, measured in angstroms, indicating the penetration depth of the ions, while the y-

axis denotes the number of collision events per angstrom per ion, reflecting the frequency of ion–target interactions.

The red-colored region corresponds to target displacement events, representing atoms displaced from their original lattice positions due to ion impact. For Ni-ion irradiation, a displacement of 48,613 CdTe atoms per angstrom is observed, whereas Ag ions produce a significantly higher displacement of 122,886 atoms per angstrom. This higher displacement rate in the case of Ag ions indicates more severe structural damage within the CdTe lattice.

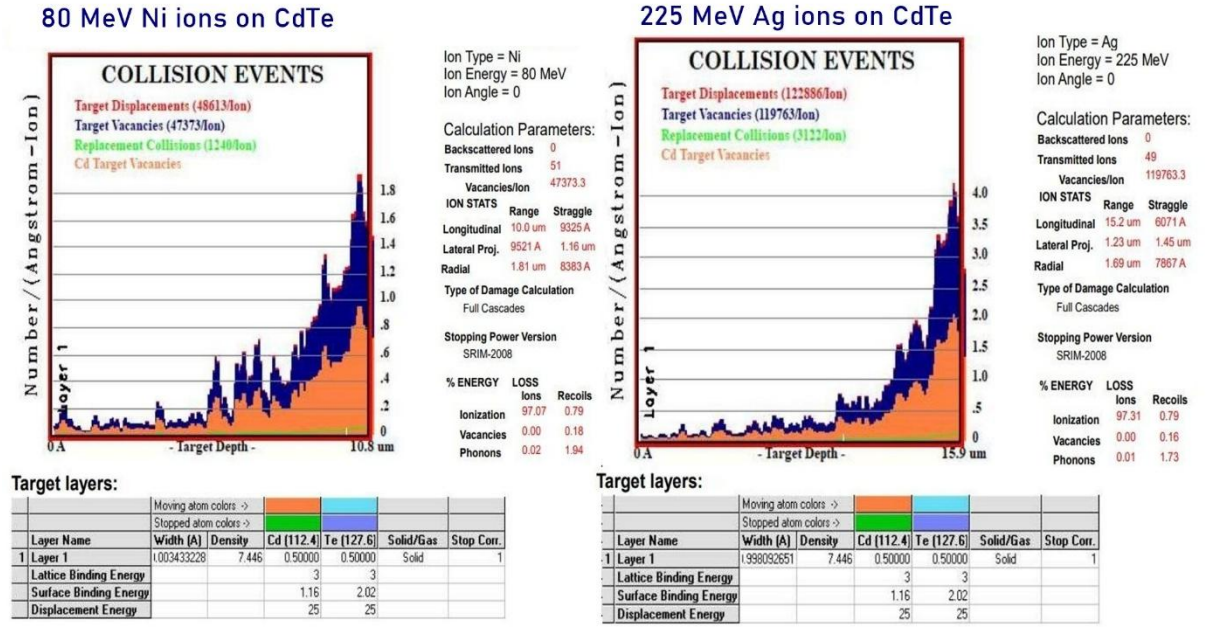

Figure: 6 Collision event of 80 MeV Ni and 225 MeV Ag ions on CdTe

Additionally, the blue-colored region in Fig. 6 represents the formation of target vacancies within the CdTe lattice, with 47,373 vacancies per angstrom generated by Ni ions, compared to 119,763 vacancies per angstrom for Ag ions. The creation of these vacancies indicates the lattice disruption and can significantly influence material properties such as electrical conductivity and carrier transport. The green-colored region (Fig. 6) denotes replacement collisions, where incident ions substitute CdTe lattice atoms. In the case of Ni ions, approximately 1,240 replacement collisions per angstrom are observed, while Ag ions exhibit a higher number of replacement events (3,122 per angstrom), suggesting a greater tendency for compositional modification.

Overall, the comparative analysis reveals that Ag-ion irradiation induces more pronounced displacement damage, vacancy formation, and replacement collisions than Ni ions, which may be attributed to the higher electronic energy loss of Ag ion in comparison with Ni ions.

4. Conclusion

A systematic SRIM/TRIM-based comparative analysis of high-energy Ni (80 MeV) and Ag (225 MeV) ion irradiation on CdTe has been carried out to elucidate ion–matter interaction mechanisms and irradiation-induced modifications. The results confirm that electronic stopping dominates over nuclear stopping for both ions, with Ag ions exhibiting higher energy loss and deeper penetration into the CdTe lattice. TRIM simulations show that Ag ions possess a larger projected range and enhanced lateral spreading compared to Ni ions, indicating stronger transverse scattering and broader energy deposition. Ionization accounts for more than 96% of the total energy loss, establishing it as the primary mechanism of energy transfer under the present conditions. Furthermore, collision event analysis reveals significantly higher atomic displacement, vacancy generation, and replacement collisions for Ag-ion irradiation, reflecting more pronounced lattice damage. Overall, the study demonstrates that Ag ions are more effective than Ni ions in inducing structural and ionization-driven modifications in CdTe, providing valuable insight for controlled material engineering and device-related applications.

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Tectonics of Housing and House-Type Transformation in Tezpur Town, Assam: Processes and Driving Factors

Prakash Jyoti Saikia[1*]
[1*]*Department of Geography, Tezpur College, Tezpur-784001, Assam*
*Corresponding author

E-mail address: saikia.prakashjyoti01@gmail.com (Dr. Prakash Jyoti Saikia)
Contact no.: +91 9706160688

Abstract

Urban housing in small but rapidly developing towns is undergoing continuous transformation due to a complex interplay of socio-economic, cultural, and spatial forces. Increasing demands for housing to be compatible with evolving lifestyles have led residents to modify original dwelling configurations for personal use, rental purposes, and home-based enterprises. Rising housing dissatisfaction, shaped by socio-economic conditions, education levels, shifting perceptions, and changing needs, has further accelerated these transformations. However, the processes and factors of such dynamics in a historically significant and demographically expanding town, such as Tezpur in Assam, remain poorly understood. Therefore, this study intends to explore the tectonics behind the nature and extent of changes in housing and house types by examining variations in building materials, architectural design, spatial organization, and structural forms. In addition to analysing the causal dimensions of housing transformation, the study also puts forward a set of recommendations for future housing development in the town so that appropriate and applicable design frameworks can be constructed for economic prosperity and socially justified urban growth.

Keywords: Housing; house types; transformation; urban area; Tezpur.

1. Introduction:

Personal observation as well as published findings suggest that physical transformations in any urban area go hand-in-hand alongside the process of urbanization (Khamaisi, 2013; Bolaane & Kalabamu, 2014; Nuissl & Siedentop, 2021). Similarly, it is now widely acknowledged that there is a direct relationship between urban transformation and changes in urban housing patterns. In order to satisfy their needs, urban dwellers often make minor to significant physical adjustments and improvements to their homes (Jones, 2021). Houses are, thus, not static objects. They generally go through a process of transformation.

Studies have shown that housing transformations are fueled by numerous interrelated factors. The socio-cultural aspects of the inhabitants and the spatial trends could be targeted for these transformations. According to Morris and Winter (1975), people often assess the quality of their dwelling based on certain cultural and family norms. To them, a housing deficit is likely to develop when a household's current living arrangements do not conform to expected norms and lifestyles. Modifications to housing can also be attributed to changes in family and community values from a traditional to a Western way of life. Aduwo and Ibem in 2017, noted the spatial patterns as one of the factors fostering housing transition.

Many families also make changes to their houses for financial reasons, since they may need to conduct business from home or rent out extra rooms to generate income (Tipple 2000). Connected to these are the Behavioral variables, such as enhancing the quality of surfaces and interior spaces to meet the new image the family wants to project. These upgrades are typically made to enhance the structural integrity and aesthetic appeal of the houses.

A substantial amount of research investigates how housing is changing in the urban areas of developing nations (Mai and Shamsuddin, 2007; Olatubara and Fatoye 2007; Fatoye and Odusami 2009; Jiboye 2009; Ilesanmi 2010; Clement and Kayode 2012; Ibem and Amole 2012; Maina 2014). To explain housing transformation, theories like housing adjustment have also been proposed.

In reality, even if the population remains static, the ever-changing technology, changes in culture and lifestyle of the communities, etc., may cause the existing housing stock to turn obsolete in satisfying the needs of the individuals. The dimensions and pace of change, particularly within the urban places, however, demand an appropriate and applicable design framework for economic prosperity and socially justified urban growth. In this regard, it becomes imperative to review the process and factors governing the transformation.

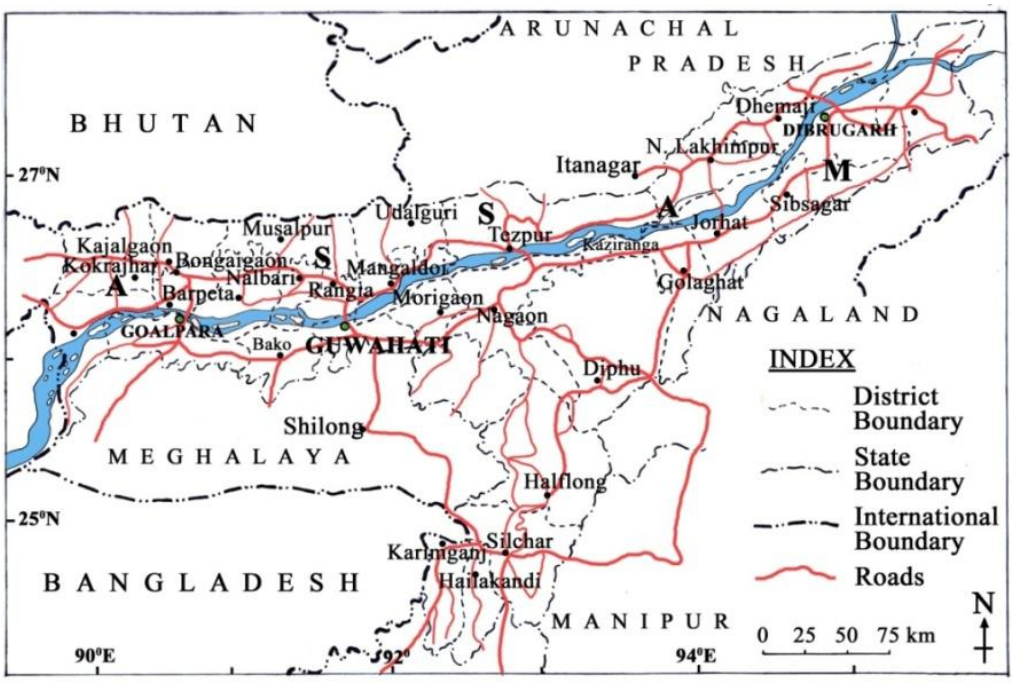
Tezpur is a small town of Assam, India, and like the other urban places, it has also experienced tremendous changes in the spatial and structural fabrics of its housing in recent decades. The commercial structures and rented housing gradually engulfed the central part of the town, and people started experiencing various negative implications. The escalating demand for housing has compelled the dwellers to explore and adopt the modern and contemporary housing forms and techniques, and consequently, there has been a gradual rejection of traditional housing stock. However, there is a paucity of understanding of the processes involved in housing transformation in general. The present work focuses on some of the qualitative and quantitative aspects of the housing transformations in Tezpur town of Assam and intends to explore the tectonics behind the physical changes in the houses that are occurring over time.

2. Background and the Present Scenario of the Study Town:

Tezpur is a small administrative town. It is the headquarters of Sonitpur district of Assam, India. It is located on the north bank of the Brahmaputra River and the absolute location is 26°37′N latitude and 92°47′E longitude (Figure 1). The area of its Municipal jurisdiction is 7.1 square kilometres, and the Master Plan area of the town covers an area of 126.6 square kilometres.

Till 1960, Tezpur was a very small peaceful town (with a population of only about 24,000) and acted as the district headquarters. But, after the Chinese aggression in 1962, it also came up as a defence town. The Chinese aggression, in fact, had a great impact on this town, bringing many Government and Semi-Government offices to the town. The employment opportunities created by these establishments had attracted a considerable number of people from its fringing areas as well as from outside. So, major changes took place in its structure and along with this, the town had also begun to experience some pace of industrialisation and business establishments. During the 1980s, the town became one of the important educational hubs of Central Assam. This is another main cause for the migration to the town. Because of population growth, the demand for housing, infrastructure, and transportation facilities also increased tremendously and resulted in congestion and high rates in housing, especially in its central part. Recently, decentralisation of the core area is also taking place, resulting in the formation of suburbs around the town. In the last 10 years, due to some regulations laid by the Town Development Authority, an industrial belt has been built up near the Dolabari region of the town. These industries also attract a large number of people for employment and settlement near them. Recently, the town has also emerged as a medical hub in the region. Recreational

facilities are also seen to be growing at a rapid pace, which can be attributed to the increased affordability of the dwellers of the town. To be noted that, the town at present comes under the category of 'Class One' town of India.



Source: Natun Asomiya Bhuchitravali & modified by Author

Figure: 1 Location of Tezpur town in the perspective of its surroundings

Some of the key aspects of the Urban Housing Sector of Tezpur that demand a proper planning framework are:

1. Employment opportunities are on the rise because of the continuing growth in the secondary and tertiary sectors. This has been keeping the housing demand in the town in upward momentum.

2. With various architectural styles, Tezpur has a mixed pattern of housing typologies.

3. About 45% of the town's population lives in its fringing areas, and this area is growing day by day. The housing in this area is also condensing at a rapid pace.

3. Objective of the Study:

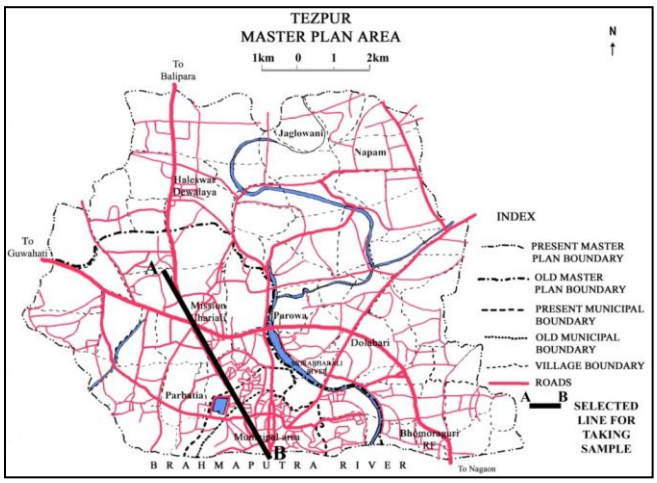
With an aim at understanding the urban housing change in the rapidly developing Tezpur town of Assam, the main objective of the present work is to identify the process of transformation

and factors responsible for the same. It also attempts to outline some recommendations for future housing development in the town.

The present study becomes significant as it not only focuses on the identification of urban housing change but also the factors responsible for the same. However, the study has only considered the private housing units and excluded the public ones. It also does not incorporate the issue of authorised or unauthorised housing in the town.

4. Methodology:

The study is exploratory in nature. It is based on primary and secondary data sources. A questionnaire survey with both qualitative and quantitative questions was used to collect primary data. The questionnaire was based on general methods like revealed preference and preference methods to assess and derive the necessary information. The revealed preference method is used to study the existing housing attributes, where each scenario is evaluated by individuals concerning their existing conditions. Similarly, a set of questions was designed to collect information on the change in their old housing, the reasons for it, housing preferences of an individual, area preferred for stay, reasons for the area preferred, future housing preferences, etc. As such, the questionnaire for the study had not only closed and open-ended questions, but also questions based on the Likert system, having a 5-point scale.



Source: Tezpur Development Authority & modified by Author

Figure: 2 Tezpur Master Plan area, showing the selected line for taking samples

4.1 Primary Data Collection:

Primary data is achieved through a questionnaire survey carried out on a selected line. As shown in Figure 2, this line was selected in such a way that it coincides with the trunk road,

connecting the town with Mission Chariali. Samples were collected transacting along this particular line. Households from both sides of this line were taken for the sample and a random sample selection of 197 samples was done for the study. The study is focused on understanding various housing attributes of the residents of the town in terms of the past and present housing conditions and future housing developments.

4.2 Secondary Data Collection:

Necessary information was collected from books, reports, and related documents to understand the profile of the town in terms of development scenario, growth in various directions, changing housing trends, the real estate scenario, etc. Village and ward level Census data were also collected for necessary computations like density, decadal growth, etc. This was done to understand the spatio-temporal pattern of the population and households in the master plan area of the town. The information is then mapped to present the total picture of the town. Surveys on transformations of architectural character from an early period to the present were also carried out and recorded to draw the connection of changes in housing types over time. It also assists in assessing the influence of housing change on the morphological character of the town and the reasons thereof.

Findings from the secondary data are then linked with the findings from primary data to understand the correlation between housing attributes and decadal growth trends of the various areas of the town.

5. Secondary Survey & Findings:

Tezpur has grown tremendously in recent decades as a result of expanded work prospects, as well as educational, medical, cultural, and leisure activities. In recent years, it has evolved into an educational and medical hub for the entire north-eastern region. Furthermore, the changing economy and recent industrial developments (especially on the outskirts) have not only increased demand for more and more residences at a rapid rate but have also aided in the recent expansion of real estate in the town. As a result, along with the changing character of the town, there has been a shift from single-family homes to cooperative housing. People began to prefer locations on the outskirts of town, and as a result, these areas are currently rapidly developing in terms of services and infrastructure.

5.1 Growth of the Town:

At present, Tezpur is the seventh-largest town in Assam. It has a defence base of the Indian Army in its western fringe and, accordingly, it bears strategic importance. The location and close proximity of many tourist destinations, including Kaziranga National Park has rapidly changed its character from a small, beautiful administrative town to an educational centre and the medical nucleus of the entire region at present.

The foundation of the present form of Tezpur was laid when the British colonial rule came to the region and, considering the strategic location, made it a garrison town.

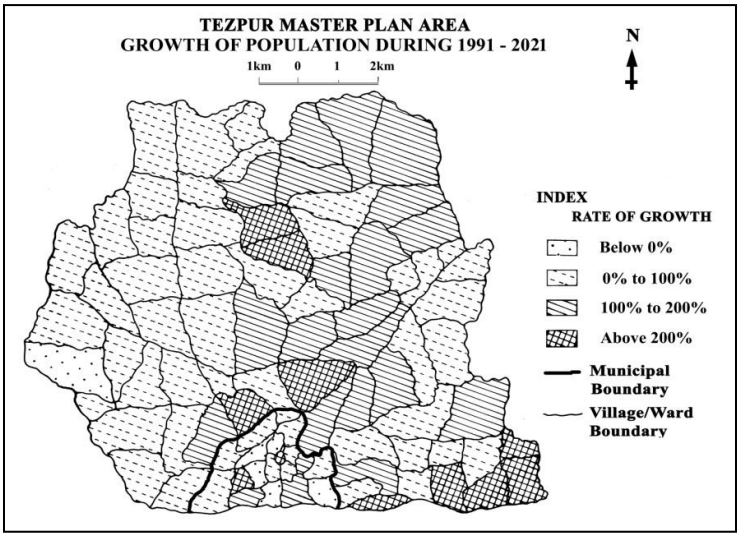
In 1935, Tezpur became the headquarters of the Darrang district of that time, and it grew into a prominent trade and business centre over time. The town benefited from its location on the bank of the Brahmaputra River. Again, having many tea gardens in its surrounding region, the town began to act as a river port for the colonial commercial ventures in its hinterland. At that period, the town stretched for a mile only. In 1893-94, the town Municipality was formed when the population of the town was just over 5,000.

Table 1 shows the trend of growth of population both in the master plan area as well as in the municipal area of the town for the past few decades. It can be seen that the growth of the population was vigorous after 1971.

Table: 1 Trend of Growth of Population in Tezpur Town, 1961- 2021

Year	Population (Master plan area)	% of change	Population (Municipal area)	% of change
1961	76,100	-	24,159	-
1971	1,03,393	35.86	39,870	65.07
1991	1,57,783	52.60	55,084	38.16
2001	2,02,384	28.27	80,575	46.28
2011	2,56,536	26.76	75,540	- 6.25
2021	3,01,645	17.58	102,505	35.70

Source: Census of India & computations by Author



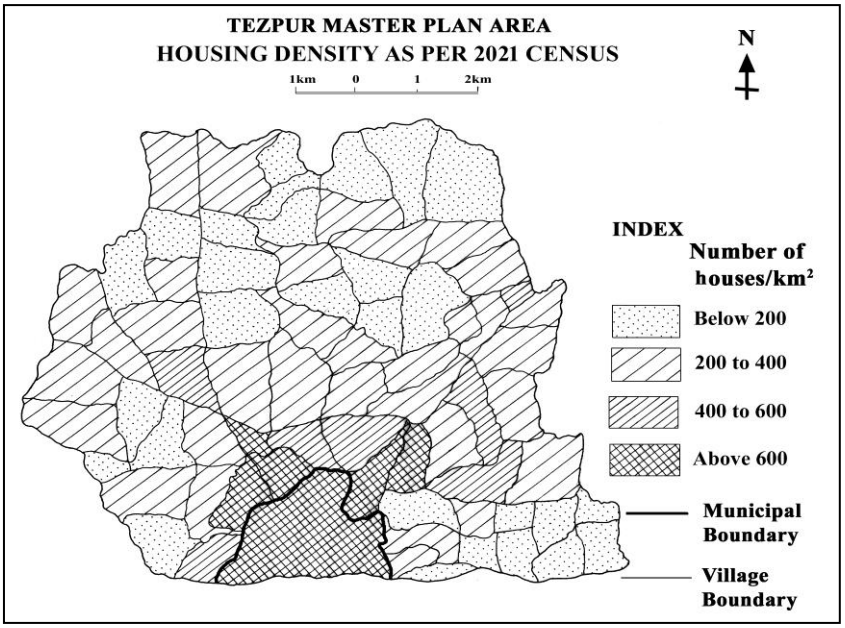
Source: Created by Author

Figure: 3 Spatial Pattern of Population Growth, 1991-2021

Figure 3 illustrates that the peripheral region, bordering the municipality, mostly to the north and north-east, recorded high growth of population during the period from 1991 to 2021. Another fact regarding this spatial pattern is that there has been a rapid growth of population in most of the newly settled areas in the north-eastern and eastern sections of the master plan area. These areas are mostly inhabited by the Muslim community. In contrast, the western half shows moderate growth.

5.2 Distribution and Growth of Houses:

According to the 2021 Census, the master plan area of Tezpur had a total of 56,694 households, out of which 17,808 (31.41%) were in its municipal area. Upon calculating the density, it has been found that the density of housing ranges from a mere 76 houses per square kilometre in Haleswar Dewalaya to 2,508 houses per square kilometre in the municipality area. Figure 4 illustrates the spatial distribution of households (as per the 2021 census) in terms of their density. It is seen that most of the villages forming the master plan area have a housing density ranging between 200 and 400 houses per square kilometre.

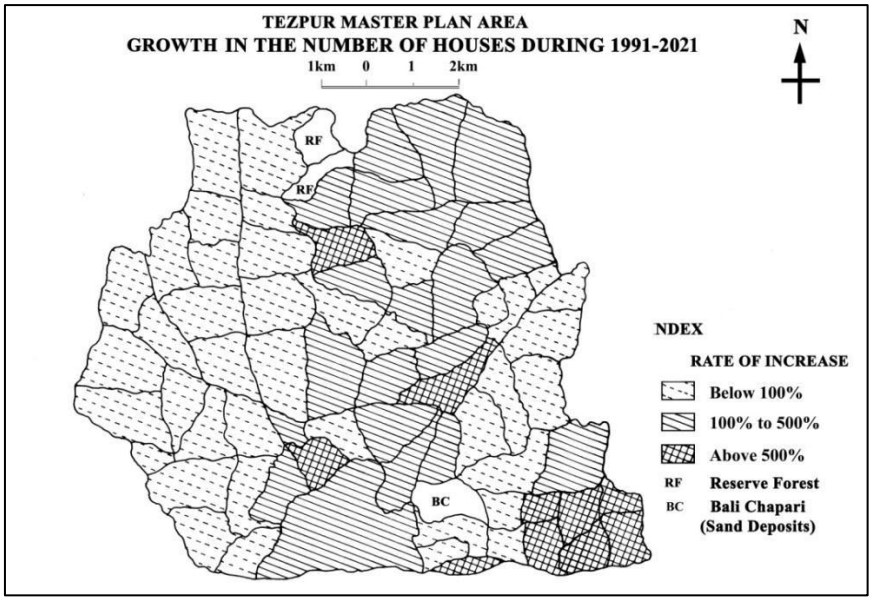


Source: Created by Author

Figure: 4 Spatial Pattern of Housing Density (2021 Census)

The municipality and its outgrowths like Dolabari, Deorigaon, Parbatia, Dekargaon etc. have a high density of houses, which is above 600 households per square kilometre. But the central, northern, and south-eastern portion of the master plan area has a low housing density, below 100 houses per square kilometre. Thus, there is a lot of scope for proper development in these areas with a suitable plan.

Regarding the growth of houses, the number of houses in the master plan area as a whole increased from 29,788 houses in 1991 to 56,694 houses in 2021 (i.e., a rise of 90.32 per cent during the period). In the municipality, the rise was 70.64 per cent (from 10,436 houses in 1991 to 17,808 houses in 2021). Figure 5 illustrates the spatial variations of growth in the number of houses during 1991-2021. It reveals that the western part of the master plan area records a low growth (less than 100 percent). In contrast to this, high growth can be seen in a belt stretching from the municipality area to the north-eastern corner of the master plan area. Again, a comparison of Figures 4 and 5 reveals that the south-eastern corner of the master plan area, although it has a low housing density, exhibits a high growth in the number of households during the period.



Source: Created by Author

Figure: 5 Spatial pattern of growth in Housing, 1991-2021

5.3 Housing Types Prior to 1980:

During colonization, the British used local materials to construct unique and beautiful structures and named them the Assam-type house. These houses ensured comfort and sustained the climate of the region. Therefore, most of the offices, educational buildings, and residential accommodations for the officials during and after the British rule were of the Assam-type house. Though most of these buildings were single-storeyed, some of them were constructed as double-storeyed. These buildings used whole wooden structures and wooden frameworks for their walls and roofs. For rooftops, they used materials like G.I. Sheets or, in rare cases, country tiles. Thus, there came the first change in the nature of the house, both in terms of architecture, use of materials, and technology.

On the other hand, the common dwellers then had constructed their houses with roofs made of thatch. Their walls were made of bamboo, plastered with a mixture of cow dung and mud. These houses were also well-suited for the tropical, humid climate of the region. These houses were single-storeyed and mainly served the purpose of multi-family housing. From the point of view of the main entrance, all these houses were inward-oriented. Hence, a sense of privacy was ensured. The spaces were all aligned around a central opening known as *'Sotal'*. In all these houses, more emphasis was put on maintaining spacious open areas than closed rooms. The rooms are smaller in comparison to the plot sizes. Ventilators were installed at very high

levels to let out the warm air and maintain favourable indoor temperatures. Individual units were favoured rather than an entire continuous building. Toilets were located towards the back (away from the main plot).

5.4 Architecture and Technology:

"When built on flatlands, the common plan shape is rectangular for single/two-family houses, and L- and C-shaped for a multi-family houses. Generally, the building plan is regular for houses with smaller built-up areas.… When built on slopes, the common plan shape is rectangular with the long side running along the slope, and the access is from the hill slide with a verandah facing the valley side; as a variation, the verandah runs along the full length of the building instead of being located just at the end of the building" (Kaushik and Babu, 2009).

Due to the region being prone to high amounts of rainfall, high gable roofs are constructed to sustain the climate. Houses are geometrically simple, being both regular and rectangular in the plan; about 6 metres in length and 3 metres in width. Their average height is around 4 metres, and the sloped roof includes a pitch of about 2 metres. Depending upon the permeability of the material used for roofing, the roof slope of the houses may vary from a third to a fifth of the total span (Kaushik and Babu, 2009). Also, in comparison to tin-sheet roofs, thatched roofs consist of a steeper slope.

The kitchens in these houses are the most susceptible to fire outbreaks. Therefore, to avoid such accidents, a 3-metre-long open space called "verandah" is generally constructed between the house and the kitchen. The houses mostly have small doors and windows, approximately 900x2100 mm and 900x1200 mm, respectively. The locally sourced *Hallock* or *Sal* wood is usually used to construct the framework and panels of the doors and windows, and they are generally placed at the centre of the room length. Though *Sal* and *Hallock* woods are used, in some cases, however, other locally available woods like *Gamari*, *Nahar*, Mango, etc. are also used for the purpose. These woods have similar engineering properties to Teak wood, but their texture is of inferior quality in comparison to teak.

In the construction of typical Assam-type houses, no specific formal foundations are implemented. The main wooden posts of the houses are inserted up to about 60-90 centimetres into the ground. In the case of the construction of formal houses, masonry is adopted to support the posts, and concrete pillars are built over the ground or sill level. These wooden posts and pillars are connected with the help of U-clamps and steel bolts (Mitra, 2020).

The homeowners mostly build these houses for their own use, making it an individual ownership type of occupancy. The families occupying these houses may be single or joint families. The number of family members may range from 4 to 10 people. Generally, the blueprint is designed in such a way that the house can be made into its final construction size at its initial effort itself. Since these houses do not require high-level engineering in their construction, locally skilled artisans are hired.

The main reason for constructing a mixed typological building is to use them for either commercial or residential purposes. In some cases, they are also used for corporate and institutional purposes. Consequently, the way they are configured also differs according to their specific functional requirements. For instance, if it is meant for a significantly big office, a two-storeyed building may be constructed with large windows.

Similarly, if the requirements are for a Prayer House, the shape of the roof, its slope, the windows and doors, etc., will be constructed differently than an institutional building. Although lacking any elevators or fire-protected stairwells, the architectural blueprint generally includes at least one rear door in the house for emergency exit in case of an accident.

5.5 Building Materials:

The raw materials used for the construction of common houses are generally locally sourced and economical, which lessens or completely nullifies any costs incurred due to transportation. One such material widely used for building pillars, roofs, beams, doors, etc. is bamboo.

Wood and other such materials are extensively used to build Assam-type houses. Wooden planks and logs are used to build elevated flooring, posts, a basic framework for the walls, and a roofing framework, etc. '*Ikara'*, a type of reed that grows abundantly in river banks, is used to make not only the walls but also the roofs of the house. These *Ikara* reeds are placed in a vertical direction against the wooden framework and filled into bamboo frames to make the panels for the walls. These panels are then plastered with mud and cow dung paste on either side to get a hard and durable wall. Thick piles of *Ikara* are also used to cover the roofing framework made up of wooden planks. Although metal-sheet roofs are built by those who can afford them, in that case, the wooden framework is common.

Thus, the use of Gothic architecture, a basic wooden framework for walls as well as for roofs, unique brick size, complex carving, sloping of the roof, and unique beautification elements are some of the notable features of housing types constructed before 1980. The houses generally

have a living room, a verandah, and a kitchen. There is generally only one bathroom nearer to the main block, without any attached toilet. The toilets are situated even further away towards the back of the plot.

5.6 Housing Types after 1980:

The 20th century, especially in its latter half, witnessed many changes in the social setup. The joint families broke up, and the average family became smaller. This resulted in multifamily buildings replacing the older ones. These buildings generally have two or three-storeyed structures, and most of them are rectangular in shape. Here, another major change that occurred regarding the central Open-Square, called *Sotal*. The central *Sotal* is replaced by an open courtyard in the front or back of these houses. The character of its facades also changed considerably. Even the interiors and exteriors were changed with new designs, and most of the old building materials were replaced with new ones. These structures are either made of wood frames with brick infill or entirely of brick (including pillars). The windows are large, and the roofs are made of tin sheets. In terms of ventilation, these structures outperform Assam-type houses. The brick dimensions used in British times have changed.

Thus, gradually, *Ikora* was replaced by constructions in bamboo and then in bricks (Kaushik and Nagaraju, 2016). All these buildings came up with a high, thick boundary wall enclosing the front or the rear courtyard, and they all have a gate in front of the house. Such buildings are very common in the northern and western sides, where the town has its older residents.

In this period, the houses began to grow, both in size and in number. People began to show interest in a more compact type of houses and two-storey buildings started becoming popular. Whether single-storey or double-storeyed, these houses are significantly larger, and they are mostly made of bricks and concrete. The wooden frameworks of the previous generation of buildings were replaced by a concretised iron frame. The use of cement and iron bars is common in these houses. On average, each of these houses has three to four bedrooms and one living room near the entryway. The concept of a living room in the front is a new addition because earlier it was the central *Sotal*, which was used for the purpose or it was situated at the back of the house. The concept of an attached toilet and bathroom was another change that has taken place. The kitchens became small, and there came a new space in the house called the dining hall/room. Application of mosaic floor, ceramic tiles (up to one square foot), and marbles for flooring has given these houses another dimension. Many changes also came to the exterior.

By the 1990s, as car ownership increased manyfold, houses began to have a garage alongside them. The number of bathrooms has also increased from one to at least two in each of the typical houses. The idea of a master bathroom, master bedroom, etc., has come to the construction of houses. In recent years, the concept of false ceilings has been on the rise. Similarly, the use of glass is also seen rising. For roofing the top, the most popular material nowadays is the colour-coated roofing sheets locally known as *Dynaroof*. All of these changes had a significant impact on the character of Tezpur and its surroundings.

6. Primary Survey and Analysis:

Various housing aspects related to housing units, ownership patterns, location preferences, and economic aspects, future housing preferences are touched in the study. The focus of the survey is to understand various factors responsible for housing selection for an individual today and factors responsible for the selection of future housing locations. Findings are based on the survey done for 197 samples on the selected line.

6.1 Socio-Economic Status of the Residents:

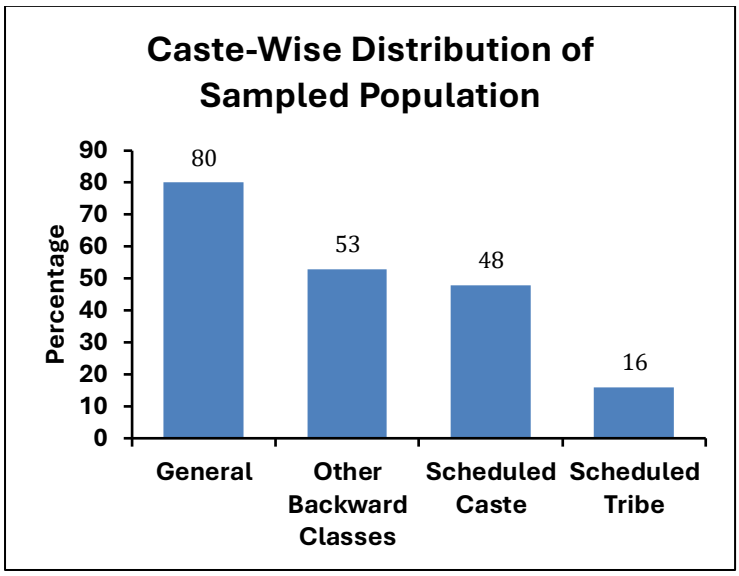
The total population of the 197 sampled households was found to be 583. Out of this, 305 are male, and 278 are female (the sex ratio is 911/1000). Table 2 shows the age-wise distribution of this population. It is seen that the majority of the population falls in the age group of 30 to 40 years, and the population below 10 years is the least. There is an increased male population in the age group of 20 to 40 years.

Table: 2 Age Groups of the Population

Age group (in years)	Male	Female	Total
Below 10	21	13	34
10 to 20	33	56	89
20 to 30	65	51	107
30 to 40	77	49	126
40 to 50	41	50	91
50 to 60	25	30	55
Above 60	44	37	81
Total	**305**	**278**	**583**

Source: Author's Field survey

Most of the population belongs to the Hindu community (107 houses out of 197 sampled houses), whereas the other 90 houses belong to the Muslim Community.

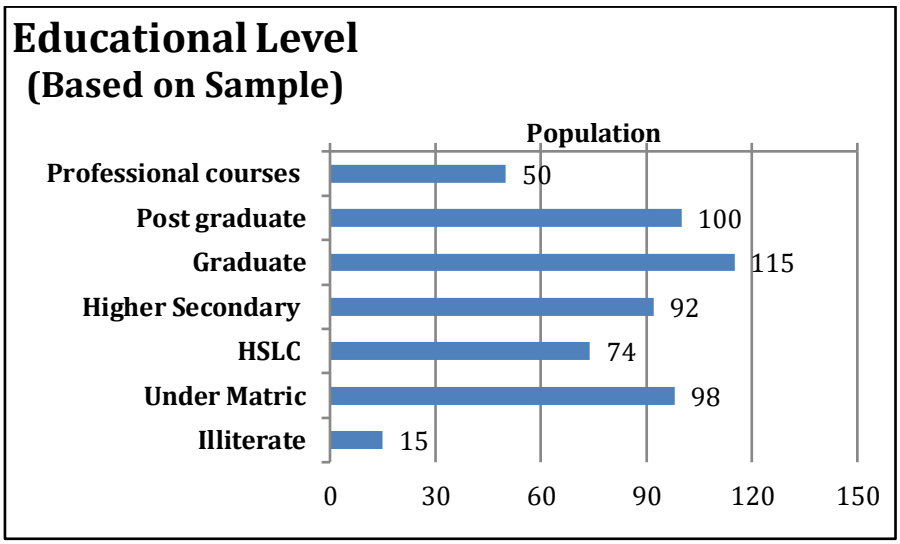


Source: Author's Field survey

Figure: 6 Caste-wise distribution (based on sample)

The caste-wise distribution of the sampled households is presented in Figure 6. It is seen that the General caste predominates the sampled data. It is followed by the OBC and the SC caste.

Turning to the education and family size, a large quantum has education up to graduation, followed by post-graduation (Figure 7).



Source: Author's Field Survey

Figure: 7 Educational level (based on sample)

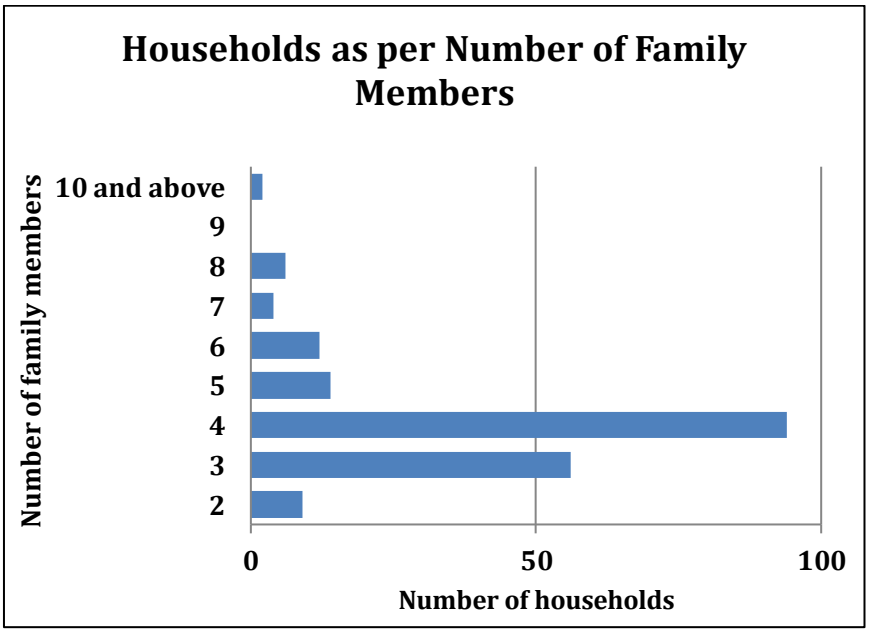
Table 3 shows the monthly income of the sampled households. According to Table 3, the majority of the surveyed households have an average monthly income that varies between Rs. 10,000/- and Rs. 50,000/-. This brings an annual income in a range of Rs. 1,20,000/- to 6,00,000/-.

Table: 3 Monthly Income (based on sample)

Monthly Income	Population (based on sample)
Below Rs. 10,000	10
Rs. 10,000 to 20,000	88
Rs. 20,000 to 50,000	80
Rs. 50,000 to 1,00,000	19

Source: Author's Field survey

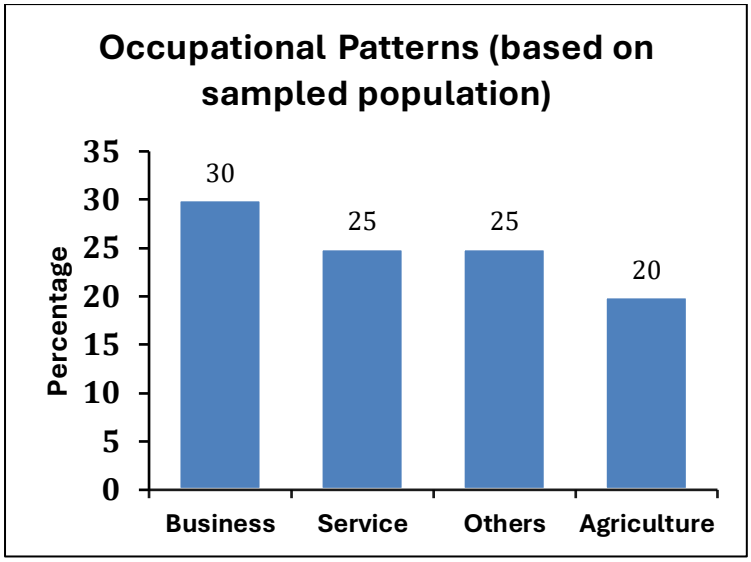
Regarding the number of members in each family, about 47 per cent of households have a family size of 4 members, followed by 28 per cent with a family size of 3 members. Only 13 per cent of households have a family size of 6-10 members and above. 71 per cent of the families are nuclear families, while the rest are joint families. The distribution of households by the number of family members is depicted in Figure 8.



Source: Author's Field survey

Figure: 8 Distribution of households as per the number of family members

As far as the occupation of the families is concerned, the occupational distribution is presented in Figure 9. The sample data showed us that the majority of the population of the surveyed households are engaged in business, followed by service.



Source: Author's Field survey

Figure: 9 Occupational patterns (based on sample)

6.2 Years of Stay at Current Location:

The study area is limited to the selected line from Tribeni Chariali to Mission Chariali of the town. The maximum percentage showing years of stay at the current location is 50 to 60 years, followed by 40 to 50 years, and then 10 to 20 years (Refer to Table 4). The percentage of households before 1960 is found to be only 7 per cent. This suggests that the percentage of the migrated population to the town for employment purposes or any other reason began to settle in the town after 1960. The rate of growth of households from 1960 to 1980 was more than the period from 1980 to 2000. There is also an increasing trend of new houses from 2000 to 2021. People staying in the study area for more than 40 years are around 53 per cent.

Table: 4 Years of Stay in Tezpur (based on sample)

Years	No. of Houses
Less than 10 years	15
10 to 20 years	33
20 to 30 years	29
30 to 40 years	17

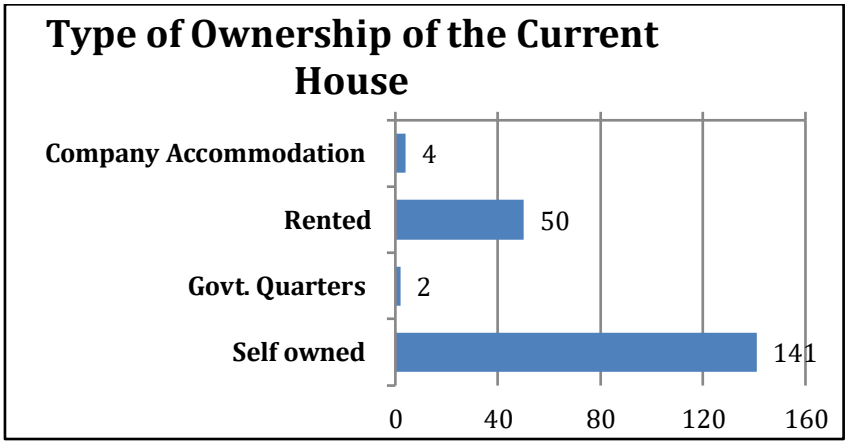
40 to 50 years	41
50 to 60 years	50
Above 60 years	14

Source: Author's Field survey

6.3 Current Location of the House:

Out of the total 197 samples surveyed, the prominent current stay location is Murhateteli, followed by Kachari gaon. Maximum samples are taken from the areas which are fast developing sub-urban areas of the selected line to understand why people have preferred this location for stay, what the situation of amenities and infrastructure is, etc. And if current residents of these areas are satisfied with the location, or they are looking for some other area as their future housing location. If it is so, then what are the reasons behind it?

Analysis shows around 25 per cent stay in rented accommodation against 71 per cent stay in self-owned accommodation (Please see Figure 10). This suggests that rental housing is still a prominent option chosen by people as an affordable housing option in the town.



Source: Author's Field survey

Figure: 10 Type of ownership of the current house

6.4 Year of Construction and Cost of House at the Time of Purchase/Build:

A maximum number of houses were constructed in the span of the last 40 years, from 1991 to 2020. The price of the houses at the time of acquisition or construction varies from ten to fifty *lakhs* and higher, as indicated in Table 5. A smaller percentage has a longer stay, i.e. more than 50 years at the current location. Regarding the finance for the purchase of the property, as

previous analysis shows, service is the main occupation, most of the owned houses are found to be purchased through a combination of personal savings and bank loans.

Table: 5 Cost of the House at the Time of Purchase/Build

Cost (in Rupees)	Number of Houses
1-10 lakhs	19
11-20 lakhs	34
21-30 lakhs	18
31-40 lakhs	11
41-50 lakhs	43
Above 50 lakhs	16

Source: Author's Field survey

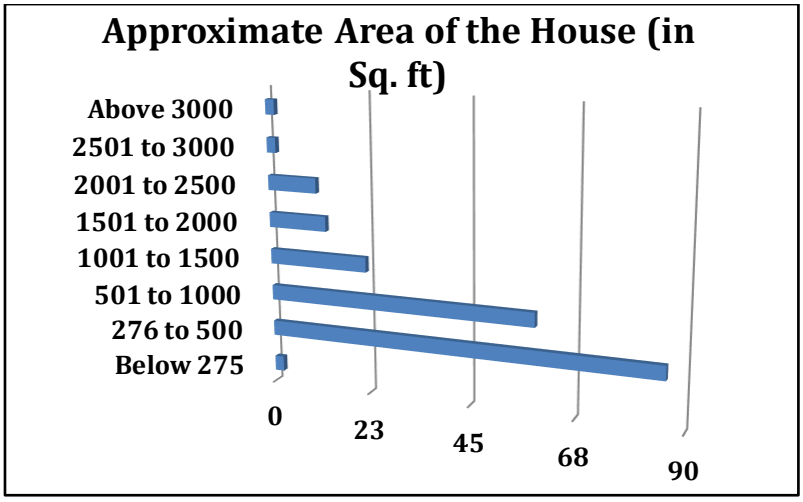
NOTE: Only considered those samples, who have their own house

6.5 House Types and their Conditions:

The sample survey shows that about 46 per cent of the houses in the locality are of Assam-type, followed by 28 per cent RCC houses. The percentage of inferior *maati ghar* is less, only 5 per cent. In general, we can say that the conditions of the houses are good. All the houses are bounded by boundary walls, and it is seen that 46 per cent of the boundary walls are of *pucca* type. We have also seen bamboo being used as boundary walls, but the percentage is less - only 20 per cent. Another observation regarding the boundary wall is that about 60 per cent of them are constructed recently, so it can be said that there is a transformation of boundary wall preferences from bamboo to *pucca*. About 72 per cent of the roofs are covered with tin sheets, while the others are of the RCC type.

6.6 Approximate Area of the House and Number of Rooms:

The majority of the surveyed households have their area of the house in the range of 276 – 500 square feet. It is followed by a range from 501 to 1000 square feet. The survey, thus, clearly reveals that the percentage of one BHK units is more than two BHK units, which comes second. Apart from toilets, most of the houses have 6 rooms. Approximately 78 per cent of people have reported that they are satisfied with the area of their current house. They feel that the current house is adequate for their family.

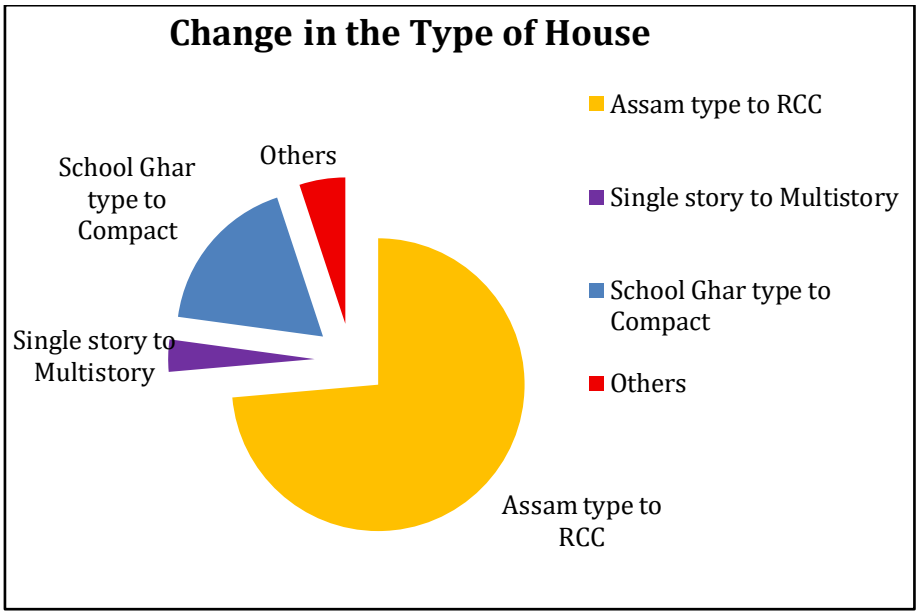


Source: Author's Field survey

Figure: 11 Approximate area of the house (in square feet)

6.7 Change in Type of the House:

Figure 12 presents the results of the sample survey regarding the change in the type of house. The sample study shows that about 74 per cent of the houses are transformed from earlier Assam-type to RCC houses in recent years. Further changes are also seen from the school-*Ghar* type to Compact houses. Some of the houses have also transformed from single-storey to multistorey, but the percentage of such houses is less (only 3%).



Source: Author's Field survey

Figure: 12 Change in the type of house

6.8 Change in the Use of Houses:

Though a majority of the families use their houses for their own purpose, about 14 per cent of the families converted their houses or part of them for rental purposes. Almost 6 per cent of the families are seen to convert their rooftops into rental houses. These houses may accommodate families or be used as spaces for small businesses such as tuck shops.

7. Major Findings/ Factors Responsible for Change:

After having analysed the primary surveys, with the appropriate support of secondary data and literature, relevant conclusions are established. This has provided important points, which are not only regarding housing scenarios in different eras but also the factors that can be assigned to such a scenario. These observations will be very helpful for decision-making in the housing sector in the near future. The main points are -

- A major change in housing patterns had started largely after the Chinese invasion in 1962 and its aftermath.
- The increased rate of urbanisation within the town and the resultant growth of the town during the 1980s and 1990s were the main drivers for the change. Thus, one of the prime factors for change in housing is the population factor. It had not only created a demand for accommodation but also led to an increase in the size of households.
- Development of the service sector at Tezpur, inviting people to the new jobs, is mainly responsible for more and more town-bound migration from different parts. A considerable percentage of people are of migrated population staying in the city for more than the last 30 years.
- 25 per cent of people are seen preferring rental accommodation and wish to move into new houses soon.
- People have reported that the affordability and connectivity to other parts of the town are the main reasons for the selection of their house location. Access to amenities, utilities, and services are other main aspect responsible for selecting their housing location. Along with these, while selecting house locations, people are also seen to consider future growth patterns.

- The study reveals that most of the available options in the town area are unaffordable to a major section of society, resulting in the spread of the town outside the municipal limits.
- People at present are seen to prefer staying in community housing due to the much-needed security and other amenities in place. The study spotted a rapidly growing real estate sector development in recent years.
- In relation to growing housing demand, the pace of infrastructure development is very slow. There is a town development plan to deal with different aspects of development in the town. But the inability of this town development plan is evident when it comes to the matter of making land available for affordable housing developments.
- The study revealed that the urban housing administration in the town is ineffective in controlling the indiscriminate addition of new structures alongside the old ones. In some cases, such an addition leads to the encroachment of the Government property space. For instance, the whole stretch of Railway land from Chandmari up to Mission Chariali can be seen under such constructions. Most of the respondents have reported that they did not even inform or take prior permission from the planning authorities for their housing changes.
- There is a lack in initiating and providing incentives to promote Rental Housing from the side of the Govt. Private developers are also seen to be silent in this regard.
- With the improvement in the educational and economic status of the urban residents, coupled with the level of awareness of changes in the neighbourhoods, these dwellers have transformed their houses and created provision of space for home-based enterprises or to generate additional income by renting it. It was found that the prevalent transformations are either related to the economic or social needs of the residents.
- The inconvenience or dissatisfaction that arises due to the disturbing noise and congestion in the neighbourhoods or due to alteration of the neighbourhood into shops, etc., is also leading people to convert their space, most often with no specific standard.
- There is a lack of a policy framework for redeveloping the housing sector as a whole, instead of some guidelines for promoting single building redevelopment.

- Another important factor is time. The scientific and technological discoveries over time have changed the attitudes and behaviours of the residents to transform their houses. This change in attitude can also be attributed to the response of the residents to their socio-economic needs, which kept unfolding with time. Residents began to convert their rooms, corridors, or even the open spaces into shops and rental purposes to generate additional income.
- Along the same lines as pointed out by Abdulrahman Mukaila El-Hussain in 2018, "the findings from the present study also revealed that there is a need to strengthen the housing administration to manage and maintain the inconveniences of spontaneous physical housing changes in the town" (El-Hussain, 2018). In this regard, to quote Abdulrahman Mukaila El-Hussain -

"There is a need for more collaborative planning of urban lands where all the stakeholders will be involved for effective implementation. This would ensure effective urban housing management and administration for routine checking of the physical developments in the neighbourhoods to ensure that all additional physical developments meet the planning requirements and are also implemented in the manner so approved. The attitude of seat-at-office by the urban administrators for clients to come forward for physical development approval is not allowing many alterations work to be properly captured at the inception of the construction works. In addition, there is the need to have supplementary physical housing documents for carrying out any form of housing alterations in the region. The document would define in clear terms the kind of alterations that requires planning permission from those that can be embarked upon without notifying the statutory body. The document will protect and preserve other housing infrastructures like road, drainage and Trees." (El-Hussain, 2018).

8. Recommendations:

Taking into consideration the broad objectives like improvement in quality of life, better environment, and comprehensive development, the following is an attempt to formulate some recommendations for the town to adopt.

8.1 Housing in the near future for Tezpur needs to have a comprehensive policy focusing on long-term housing needs, supported with adequate services and infrastructure

Making land available for development and housing has always been a critical factor in all urban centres. Identification of adequate land for the future plays a key role in catering to future housing demands (WEF Insight Report, 2019).

Simply put, the land availability would be in directions where people have given their choice of future housing. In the case of Tezpur town, sub-urban areas are still less dense than the core part. A proper planning framework for optimum use of these areas, such as Dekargaon, Parbatia, and Deurigaon, is needed for comprehensive development.

Densification of already developed areas can be thought of as one measure for the supply of land. Provided a supply of adequate social and physical infrastructure, areas with low-rise developments that are already there can be redeveloped. For fulfilling the same purpose, a detailed study of existing land use is needed for the suburban areas of Tezpur, as these are the main target areas of the people for future housing developments.

The study shows that there is a shortage of land availability within the municipality's limits for new developments. So, the effective way to increase housing stock will be the redevelopment of old and dilapidated buildings. In today’s context, however, a futuristic approach in policymaking is necessary. It is because the current trend of new housing with the redevelopment of old single buildings is a prominent pattern of development in the town. In the areas having older buildings, this has already created a higher density of units and, in turn, is creating a burden on existing social and physical infrastructure, roads, utilities, etc. This results in reducing the standard of living of the community. So, what is needed is that the policy should be there to develop other infrastructure facilities as well, so that the pace of these developments matches the pace of development of housing units.

Another point which has to be considered is that instead of applying a redevelopment of old single building strategy to the whole town, at times, based upon appropriate surveys and study, it should be flexible enough to suit local needs to go for a large building agglomeration. Housing policy surely needs to be user-oriented to make housing easily accessible and affordable to a large proportion of the population at present and in the future too. Priority should be to develop housing stock to satisfy housing needs first, and then housing demand in growing urban areas like Tezpur.

8.2 Promotion of rental housing initiated by the government with the participation of private developers will be a good model:

The primary survey concludes that a remarkable segment, i.e., 25 per cent of people, is seen preferring and staying in rental housing. Most of these are migrant families in search of employment and education in the town. Tezpur being an educational hub, a large no of students also stay in the town. As many of these people do not need a permanent house for their period of stay in the town, or they can't afford to buy a new house immediately, they prefer a rented house as an affordable option for their stay. It also allows them to choose accommodation near their workplace. So, the promotion of rental housing initiated by the government with the participation of private developers will be a good model of development for the town. If the location of such houses can be made possible based on connectivity, affordability, and available infrastructures, they will become a good source of housing for the floating population coming to the town. The identification of such a location should be based on a proper study on the location preference of the target group and should be on the basis of the availability of transport facilities, social and physical infrastructure, nearness to the existing major employment nodes, and educational institutions.

8.3 Introducing Floor Space Index Regulations:

The practice of Floor Space Index regulation for the entire town can be introduced and reviewed at regular time intervals in accordance with the increase in population and increasing housing demand in various income groups.

8.4 Establishment of Microfinance Institutions:

Primary survey reveals that a major percentage of occupation patterns in the town is from the business and formal service sector. But a large section of the dwellers is also engaged in the informal employment sector. They have an income range lower than that of the formal employment sectors. As they lack the fulfillment of requirements needed for getting loans to build their house, they majorly face the problem of formal housing finance supply. So, there is a need for the establishment of microfinance institutions so as to make available finance to this sector with fewer critical legal requirements.

9. Conclusion:

The study concludes that, in existing housing accommodation, most of the houses are one BHK units with an area up to 500 square feet, and this is an adequate area for the families staying in

an average family size of 5 members. The majority of residents have business and service as their main occupation and financial source for buying a new house or for taking housing or other bank loans. A major quantum of surveyed households, i.e., 25 per cent, stays in rental housing, which supports the need for rental housing promotion and policy framework for the town. This will also help in catering to the problem of housing shortage and affordability. As per the study, affordability plays a major role in the selection of house location along with other aspects like connectivity, available social and physical infrastructure, etc.

The findings reveal that the physical housing changes in Tezpur town are rapid and largely spontaneous in nature, and they are all in favour of socio-economic pursuits of the urban dwellers. The growing demand to attain compatibility between housing form and lifestyle has made it necessary for people of the town to change the initial configurations of their homes and surroundings for personal occupation, rental functions, and home-based enterprises. It is seen that housing dissatisfaction in accordance with socio-economic wellbeing of the occupants, level of education and knowledge, ever-changing perspectives on housing matters, and also the want to transform houses within the line due to their changing desires is on the rise

In a rapidly growing town like Tezpur, the process of urbanisation is inevitable. There is also no doubt that the escalating demand for housing and the simultaneous modern housing stock and the obviously built environment is an unavoidable reality in the town. The study made it apparent that the urban dwellers neither resort to building regulations requirements nor have any projected plan for most of their housing transformations. The consequent inconveniences can be made evident in congestion, noise, heat, and sound pollution, etc. So, rather than being left at the discretion of the house owners, the transformations should be better organised. Simply put, the issue demands proper planning so that, with a good policy guide, the problems that arise out of housing transformations could be controlled to an acceptable level.

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A COMPARATIVE NON-PARAMETRIC ANALYSIS OF HSLC EXAMINATION PERFORMANCE: EVIDENCE FROM SELECTED SCHOOLS OF DIBRUGARH DISTRICT

Ajit Goswami[1*]

[1*]*Department of Statistics, DHSK Commerce College, Dibrugarh, Assam, India*

*Corresponding author

E-mail address: agoswami09@gmail.com

Abstract

Public exams are a key measure of quality and student performance. Disparities in performance are as a result of variance in socio-economic status, school facility, teacher effectiveness and learning environment. In this study non-parametric statistical approaches are used in analyzing the result of HSLC examination conducted through three selected schools of Dibrugarh district, Assam. Due to the lack of normality and the ordinal character of ranked data, overall school performance and pairwise comparisons are investigated using Kruskal–Wallis test and Mann–Whitney U test. The findings in this paper shows that there are significant differences between the schools which indicate the heterogeneity in academic outcomes and also it provides empirical evidence to support data-driven evaluation of school-level performance and can assist policymakers and educators in improving educational quality.

Keywords: HSLC; School Evaluation; Non-parametric Tests; Mann–Whitney U Test; Kruskal–Wallis Test.

1. Introduction:

Education is widely recognized as a key driver of social and economic development. School education, in particular, plays a vital role in shaping students' cognitive abilities, values, and future opportunities. Academic achievement, commonly measured through examination results, varies considerably across students and institutions due to multiple contextual factors such as socio-economic conditions, teacher quality, infrastructure, and administrative support.

In recent years, statistical analysis of examination results has gained importance as a scientific tool for evaluating institutional effectiveness and identifying performance disparities. However, examination data often violate the assumptions of parametric methods, such as normality and homogeneity of variance. In such situations, non-parametric methods provide robust alternatives for meaningful comparison.

Against this background, the present study undertakes a comparative analysis of HSLC examination results of three selected schools in Dibrugarh district using non-parametric statistical techniques.

2. Objectives of the Study:

The main objectives of the study are:

1. To examine whether there exists a significant difference in overall HSLC examination performance among the selected schools of Dibrugarh district.

2. To compare the pairwise performance of schools using appropriate non-parametric tests.

3. To assess the suitability of non-parametric statistical methods in the analysis of school examination results.

3. Data Source:

Dibrugarh district has a total of 198 high schools. For the present study, three schools were selected randomly from Dibrugarh town, namely: - Salt Brook School, South Amolapatty - Amolapatty Girls' High School, Amolapatty - Government Girls' Higher Secondary and M.P. School, Dibrugarh.

For each selected school, 50% of the students who appeared in the HSLC examination were randomly chosen. The overall marks obtained (out of 400) by these students formed the basis of the analysis.

4. Materials and Methods:

4.1 Mann–Whitney U Test:

The Mann–Whitney U test is a widely used non-parametric method for comparing two independent samples. It tests the null hypothesis that the two samples are drawn from identical populations. The test is particularly useful when the assumptions of the two-sample t-test are not satisfied.

The hypotheses are formulated as: -

Null hypothesis **H_0:** The distributions of examination scores of the two schools are identical. Alternative hypothesis **H_1:** The distributions of examination scores of the two schools are not identical.

The test statistic is computed based on the ranks of the combined samples, and for large sample sizes, a normal approximation is used to determine significance.

Computing the values of U:

For the values of n_1 and n_2, the method of counting for determining the value of U may be rather exhaustive. A different approach is applied here which gives equivalent result is to designate the rank 1 to the lowest score in combined (n_1+n_2) group of scores and to designate the rank $N= n_1+n_2$ to the highest score. Then Mann Whitney U statistics is defined as,

$$U= \min (U_1,U_2)$$

Where, U_1 = Total no. of times X proceeds Y

U_2 = Total no. of times Y proceeds X

Reject H_0 if $U> C_1$ or $U\leq \sum T$

Where C_1 and C_2 are given in table for small sample is given by Auble (1953) Mann Whitney (1947) which are obtained from the distribution of U under H0.

There is a simple way to calculate U_1 and U_2. If $n1 < n_2$ and R_1 = sum of the ranks of the sample whose size is n_1 and R_2 = sum of ranks of the samples whose size is n_2 then

$$U_1 = n_1 n_2 + n_1(n_1+1)/2 - R_1$$

$$U_2 = n_1 n_2 + n_2(n_2+1)/2 - R_2$$

Large sample (n2 larger than 20)

If n_1, n_2 increase in size, the sampling distribution of U rapidely approaches the normal distribution with.

$$\text{Mean} = E(U) = \frac{n_1 n_2}{2}$$

And standard deviation (S.D) $= \partial_U = \sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}$

If n_2>20 one can compute the significance of an observed value of U by

$$Z = \frac{U - E(U)}{\partial_U} = \frac{U - \frac{n_1 n_2}{2}}{\sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}}$$

which is approximately normally distributed with zero mean and unit variance. The normal approximation U may also be used when n_1 and n_2 are greater than 8.

4.2 Kruskal–Wallis Test:

The Kruskal–Wallis test is an alternative non-parametric method in case of one-way analysis of variance (ANOVA) for comparing more than two independent samples. It tests the null hypothesis that all samples originate from the same population.

The hypotheses are stated as: - Null hypothesis **H_0:** The median performance of all selected schools is the same. Alternative hypothesis **H_1:** At least one school differs in median performance from the others.

In K-W test, the test statistic follows a chi-square distribution with ((k-1)) degrees of freedom, where (k) is the number of groups.

If the K-samples belongs to identical populations, that is, if the null hypothesis is true then the test statistics is distributed as chi-square with (k-1) d.f. which provided that the different K-sample sizes are not too small, that is

$$\therefore KW(H) = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1)$$

Where k = Number of samples

n_i = number of ith samples

R_i = sum of ranks in ith samples

$\sum_{i=1}^{k}$ = directs one to sum over the K-samples (column) is distributed approximately as chi-square with (K-1) d.f. when sample size is sufficiently large.

5. Results and Interpretation:

5.1 Overall Comparison of Three Schools:

The Kruskal–Wallis test was applied to compare the overall HSLC examination performance of the three schools.

Table: 1 Overall Comparision of three Schools
(Level of Significance $\alpha = 0.05$ and d.f. = 2)

Name of School	**Rank total (received by the students)**	**Tabulated χ^2 value**	**Calculated KW value**
Saltbrook School	4672	5.991	75.123
Amolpatty Girls' HS	220		
Govt. Girls' HS & MP School	1894		

The calculated value of the Kruskal–Wallis statistic exceeded the tabulated (critical) value of chi-square at 5% level of significance. Hence, the null hypothesis was rejected, indicating a statistically significant difference in overall performance among the three schools.

5.2 Pairwise Comparison Using Mann–Whitney U Test:

Pairwise comparisons were carried out between: - Salt Brook School & Amolapatty Girls' High School and Salt Brook School & Government Girls' HS and M.P. School.

Table: 2 Pairwise Comparison of two Schools
(Level of Significance $\alpha = 0.05$)

Name of School	**Rank total (received by the students)**	**Tabulated Z-value**	**Calculated Z- value**
Saltbrook School	R_1=2106	1.96	5.71
Amolpatty Girls' HS	R_2=105		

Table: 3 Pairwise Comparison of two Schools
(Level of Significance $\alpha = 0.05$)

Name of School	Rank total (received by the students)	Tabulated Z-value	Calculated Z- value
Saltbrook School	R_1=3944	1.96	8.47
Govt. Girls' HS & MP School	R_2=1309		

In both cases, the calculated Z-values exceeded the tabulated (critical) value at the 5% significance level. This confirms that the differences in overall examination performance between the respective pairs of schools are statistically significant.

6. Discussion:

The results clearly indicate heterogeneity in HSLC examination performance among the selected schools of Dibrugarh district. Such differences may be attributed to variations in teaching methodologies, institutional resources, student backgrounds, and academic support systems. The study demonstrates that non-parametric methods are effective tools for analyzing educational data that do not conform to classical parametric assumptions.

7. Conclusion:

The present study concludes that significant differences exist in the HSLC examination performance of the selected schools in Dibrugarh district. Both overall and pairwise analyses confirm that student achievement varies across institutions. The use of non-parametric statistical techniques such as the Kruskal–Wallis test and Mann–Whitney U test proves to be appropriate and robust for educational data analysis. The findings may assist educators, administrators, and policymakers in identifying performance gaps and formulating strategies for academic improvement.

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Ants as Alternative Food Sources: A Review of Their Nutritional and Ethnocultural Importance in Assam, India

Hridisha Nandana Hazarika[1*]

[1]*Department of Zoology, Tezpur College, Tezpur-784001, Assam, India*

*Corresponding author

E-mail address: hnhazarika4@gmail.com (Dr. Hridisha Nandana Hazarika)

Contact no.: +91 9706867388

Abstract

The increasing global demand for sustainable and nutrient-rich food sources has drawn attention to entomophagy, particularly the consumption of edible ants (Hymenoptera: Formicidae). Ants are widely consumed in many tropical and subtropical regions due to their high nutritional value, ecological sustainability, and ethnobiological significance. This review provides a comprehensive overview of existing literature from 2010 to 2026 on edible ants, focusing on their diversity, nutritional composition, traditional consumption practices, and potential health benefits. Special attention is given to Northeast India, particularly Assam, where edible ants are closely associated with indigenous food culture and traditional knowledge. In Assam, only five edible ant species have been documented so far, among which *Oecophylla smaragdina* is the most widely consumed and culturally important species. Edible ants are rich sources of protein, essential fatty acids, vitamins, minerals, and bioactive compounds possessing antioxidant, antimicrobial, and other functional properties. The review highlights the importance of edible ants as a promising alternative food resource and emphasizes the need for further scientific research on their nutritional, medicinal, and socioeconomic potential.

Keywords: Ants; Entomophagy; Assam; North East India.

1. Introduction:

One of the major challenges of the 21st century is ensuring a stable and nutritious food supply for the rapidly growing global population. According to Food and Agriculture Organization (FAO, 2013), the world population is expected to reach nearly 10 billion by 2050, leading to a substantial increase in the demand for food, especially protein-rich sources. Protein plays a vital role in human health, supporting growth, tissue repair, and immune function (WHO, 2007). However, meeting this rising protein demand through conventional sources such as livestock is becoming increasingly difficult due to environmental, economic, and social constraints.

Livestock production is a major contributor to environmental degradation, accounting for a significant share of greenhouse gas emissions and requiring extensive land, water, and feed resources (Gerber et al., 2013). It is also associated with deforestation, biodiversity loss, and soil degradation (Steinfeld et al., 2006). At the same time, access to high-quality animal protein remains limited in many developing regions due to affordability and supply issues, contributing to persistent malnutrition and micronutrient deficiencies (FAO, 2013). These challenges highlight the urgent need for sustainable and nutritionally adequate alternative protein sources.

In this context, edible insects have emerged as a promising solution. Entomophagy, the practice of consuming insects, has been traditionally followed in many parts of Asia, Africa, and Latin America and is now gaining global attention as a sustainable food strategy (van Huis et al., 2013). Insects offer several advantages, including high nutritional value, efficient feed conversion, and low environmental impact (Oonincx et al., 2010). They are rich in protein, essential amino acids, healthy fats, and important micronutrients, making them suitable for addressing nutritional deficiencies (Rumpold and Schlüter, 2013).

Among edible insects, ants represent an important yet underexplored resource. They are nutritionally rich, environmentally sustainable, and culturally significant in many indigenous communities. In regions such as Northeast India, particularly Assam, edible ants are an integral part of traditional diets and ethnomedicinal practices. In Assam, *Oecophylla smaragdina,* or the red weaver ant, which is locally known as amroli porua, is widely consumed and valued for their unique taste and perceived health benefits. Indigenous communities possess extensive traditional knowledge regarding the collection, preparation, and use of ants, which supports both food security and biodiversity conservation (Chakravorty et al., 2016).

Despite their potential, edible ants remain relatively understudied compared to other edible insects, especially in the context of their nutritional composition, cultural relevance, and role in sustainable food systems. A comprehensive understanding of these aspects is essential for promoting their wider acceptance and integration into future food strategies. Therefore, the objective of this review is to critically examine the nutritional value, ecological significance, and ethnocultural importance of edible ants in Assam. The review also aims to highlight their potential as an alternative protein source and to identify existing research gaps for future studies.

2. Materials and methods:

For the preparation of the manuscript, a thorough literature search was carried out using Google Scholar and various databases such as ScienceDirect, PubMed, Springer, and Web of Science. Relevant research and review articles published from 2000 to 2026 were identified using various keywords such as edible ants, Formicidae, entomophagy, nutritional composition, ethnoentomology, traditional food practices, Assam, Northeast India, Mising, Bodo, and Rabha. Duplicate studies and research articles lacking relevant information were excluded from the study. Research and review articles at the regional, national, and international levels were selected based on their relevance to the research topic. The selected articles were studied carefully over several weeks to obtain a detailed understanding and to collect important data and findings. Finally, the articles were screened and included based on the criteria described in Table 1.

Table: 1 Inclusion and Exclusion Criteria for Article Selection

Inclusion Criteria	**Exclusion Criteria**
Articles published in English	Articles published in other languages without an accessible translation
Peer-reviewed research articles and review papers	Conference abstracts, editorials, opinion pieces without substantial data
Studies focusing on edible ants (Family: Formicidae) as food or protein sources	Studies focusing on insects other than ants without specific reference to ants
Studies related to nutritional composition (protein, fat, micronutrients) and/or ethnocultural practices	Studies with no relevance to Assam, Northeast India

3. Results and Discussion:

3.1 Diversity and Utilization of Edible Ants:

Entomophagy, or the practice of eating insects, is common in tropical and subtropical regions where biodiversity is rich and traditional food knowledge is strong (Devi et al., 2024; Conway et al., 2024). Assam, located in Northeast India, is home to many tribal communities that have practised entomophagy since ancient times. Among edible insects, ants represent an important yet comparatively underexplored food resource. Although more than 14,000 ant species have been reported worldwide (Kass et al., 2022), only 59 species are commonly consumed as food (Fernando et al., 2025). In Assam, only five edible ant species have been documented so far, including *Oecophylla smaragdina*, *Camponotus compressus*, *Atta* sp., *Lasius niger*, and *Tetraponera rufonigra* (Table 2). Among these, *Oecophylla smaragdina*, commonly known as the red weaver ant, is the most widely consumed species.

Communities such as the Bodo, Mising, Karbi, Rabha, Ahom, Lalong, Koch-Rajbongshi, and Tiwa commonly consume ants as part of their daily diet as well as during seasonal festivals (Neog et al., 2025). The consumption of *Oecophylla smaragdina* is particularly common in different parts of Assam. In Upper Assam, its larvae are regarded as one of the most popular edible insects (Borah et al., 2020). Similarly, tribal communities in the Kamrup district consume different developmental stages of this species, especially during festive occasions as part of their traditional food culture (Sharma, 2018; Choudhury and Hazarika, 2021). In general, ants in Assam are consumed at various life stages, including eggs, larvae, pupae, and adults (Table 1). Eggs and larvae are especially preferred because they are soft in texture, easy to cook, and have a desirable taste. In contrast, adult ants are mainly valued for their sour or tangy flavour, which is associated with the presence of formic acid (Chakravorty et al. 2016; Deka et al., 2021).

Edible ants are incorporated into the diet through a variety of traditional preparations such as chutney, soups, roasted dishes, and fried foods (Table 2). The practice of consuming ants and other edible insects is influenced by several factors, including traditional beliefs, cultural preferences, environmental awareness, and the seasonal and regional availability of insect species (Gahukar, 2020; Deka et al., 2021; Kalita et al., 2022; Nsevolo et al., 2023).

Table: 2 Edible ant species reported from Assam.

Scientific name	Common Name	Local name	Stage of intake	Mode of intake	References
Oecophylla smaragdina	Weaver ant	Amroli porua	Eggs, Larva, Adult	Roasted, fried, raw or smoked	Chowdhury et al., 2015; Narzari and Sarmah, 2015; Dutta et al., 2016; Hazarika and Goyari, 2017; Rahman et al., 2018; Das et al., 2019; Borah et al., 2020; Sailo et al., 2020; Kalita et al., 2022; Dhar et al., 2024; Gogoi and Bhuyan, 2025
Camponotus compressus	Carpenter ant	Porua	Adult	Roasted	Doley and Kalita, 2012
Atta sp.	Leaf-cutter ant	Porua	Grubs, adults	Fried, cooked, or raw	Gogoi and Bhuyan, 2025
Lasius niger	Black garden ant	Porua	Adult	Roasted or fried	Das et al., 2024
Tetraponera rufonigra	Bi-coloured arboreal ant	Porua	Adult	Inserted inside eri cocoon and worn around the neck hanging in the chest	Gogoi and Bhuyan, 2025

3.2 Ants as food in different tribes of Assam:

Different communities of Assam, including the Bodo, Mishing, Karbi, Koch-Rajbongshi, Ahom, Tiwa, and Rabha, are known to consume *Oecophylla smaragdina* (weaver ants) as part of their traditional diet (Narzari and Sarmah, 2015; Das et al., 2019; Kalita et al., 2022; Dutta et al., 2025). Among the Bodo community, eating the larvae of weaver ants during the Bwisagu festival is a traditional practice to welcome the spring season (Sharma, 2018). Studies have also shown that high consumption of weaver ants among the Karbi people. The Ahom community has a long-standing tradition of eating weaver ants on the auspicious occasion of Bohag Bihu in the month of April (Chowdhury et al., 2015; Sharma and Banu, 2019; Pradhan et al., 2022).

3.3 Nutritional Value:

Edible ants are considered a highly nutritious food source. Their nutritional value may vary among species and different life stages within the same species (Raheem et al., 2019). Eggs and larvae contain more fat and provide higher energy compared to adults. Similar observations have been made in global studies, where insect larvae are considered energy-rich food sources (Zhou et al., 2022). It was reported that hymenopteran insects, including ants, contain a high protein level, approximately 45% of dry weight (Rumpold and Schlüter, 2013). It was also reported that 100 g of *Oecophylla smaragdina* contains 12.5- 13.9% Protein, 2.7- 2.9% Carbohydrate, 3.5- 3.6% Fat, and 16.6- 16.7% Moisture (Das et al., 2019; Dutta et al., 2025; Rahman et al., 2018). They also contain essential amino acids, fatty acids (especially unsaturated fatty acids), and important minerals such as calcium (Ca), potassium (K), magnesium (Mg), phosphorus (P), sodium (Na), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn) and selenium (Sn) (Rumpold and Schlüter 2013).

3.4 Bioactive Compounds:

Ants contain several important bioactive compounds, including phenolics, peptides, antioxidants, antimicrobials, anticancer, and antidepressant compounds (Fernando et al., 2025). Among the edible ants of Assam, *Oecophylla smaragdina* is one of the most dominant, widely consumed, and extensively studied species. Research conducted in different parts of the world has confirmed that this species possesses antibacterial and antioxidant properties. Studies have shown that *Oecophylla smaragdina* contains high amounts of phenolics and flavonoids, which makes it a potential source of bioactive ingredients for nutraceuticals and entomoceuticals (Raza et al., 2022). Borah et al. (2019) identified 74 possible probiotic isolates from extracts of *Oecophylla smaragdina*. Among them, *Bacillus* sp. PD6 was considered the most promising strain. Its cell-free extract showed antimicrobial activity against harmful bacteria such as *Listeria monocytogenes*, *Escherichia coli*, and *Bacillus cereus* (Borah et al., 2019). In addition, peptides obtained from *Oecophylla smaragdina* hydrolysates demonstrated strong antioxidant activity. Pattarayingsakul et al. (2017) reported that the peptide CTKKHKPNC was effective against ABTS and DPPH radicals. Further studies on the abdominal glands and extracts of *Oecophylla smaragdina* also confirmed their antioxidant potential (Vidhu and Evans, 2015; Alagappan et al., 2021).

3.5 Ethnobiological Importance of Ants in Assam

The use of ants in Assam is closely associated with traditional culture and indigenous knowledge. Communities such as the Bodo, Mishing, Karbi, and Ahom regularly consume ants as part of their traditional diet. Ants are commonly prepared as chutney from ant eggs, roasted products, and fermented foods depending on local customs (Chakravorty et al., 2016). Besides their use as food, ants are also used in traditional medicine. Local communities believe that ants help in improving digestion, increasing immunity, and reducing fatigue. The mishing community people use *Oecophylla smaragdina* for treatment of various diseases including malaria, scabies, tooth aches, stomach disorders, blood pressure (Chakraborty et al., 2011). However, scientific evidence supporting these medicinal uses is still limited (Deka et al., 2021; Kalita et al., 2022). Indigenous knowledge also supports sustainable harvesting practices. Local people have knowledge about ant behaviour, seasonal occurrence, and nesting habits, which helps in collecting ants without causing environmental damage. This reflects traditional ecological knowledge and sustainable use of natural resources (Chakravorty et al., 2016; Gahukar, 2020).

4. Conclusion

Edible ants are an important but underutilized food resource with significant nutritional and cultural value. Although thousands of ant species exist worldwide, only a few are commonly consumed, mainly in tropical regions where traditional knowledge is well preserved. In Assam, *Oecophylla smaragdina* is the most widely consumed species, highlighting its dietary and cultural importance among local communities. Ants are consumed at different life stages, particularly eggs and larvae, which are preferred because of their better taste and higher energy content. Edible ants are rich in protein, healthy fats, minerals, and bioactive compounds, making them a potential alternative to conventional animal-based foods. Despite their nutritional and ethnobiological importance, studies on edible ants in Assam remain limited. Further research is needed to document indigenous knowledge, evaluate their nutritional and medicinal properties, and encourage sustainable utilization of this traditional food resource.

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AI-Powered Dynamic Pricing and Its Influence on Impulse Buying Behaviour: A Behavioral Economics Perspective

Kasturi Saikia[1*], Lipi Bhuyan[2]

[1*]*Department of Business Management, D.H.S.K Commerce College, Dibrugarh, Assam.*

[2]*Department of Business Administration, University of Science and Technology, Meghalaya.*

*Corresponding author

E-mail address: kas2risaikia07@gmail.com

Abstract

Artificial Intelligence (AI) has enabled e-commerce firms to adopt dynamic pricing strategies that react in real time to demand, competitive prices, and individual consumer signals. This paper examines how AI-powered dynamic pricing influences impulse buying behaviour from a behavioural economics perspective. Drawing on theoretical constructs such as prospect theory, loss aversion, anchoring, and scarcity heuristics, the study combines a literature review with a survey of 150 Indian online shoppers and quantitative analysis to explore relationships between exposure to dynamic pricing tactics and frequency of impulse purchases. Results indicate a statistically significant positive relationship between exposure to dynamic pricing cues (time-limited discounts, scarcity messages, personalized offers) and self-reported impulse buying frequency. The paper also discusses ethical and regulatory concerns including algorithmic price discrimination and transparency requirements under India's recent data governance environment. Recommendations for responsible AI deployment and directions for future empirical research conclude the paper.

Keywords: AI; dynamic pricing; impulse buying; behavioural economics; e-commerce; ethics; India.

1. Introduction:

The integration of Artificial Intelligence (AI) into digital commerce has significantly transformed modern pricing strategies, particularly through the implementation of dynamic pricing systems that adjust prices in real time, considering demand conditions, competitive signals, and individual consumer data. Unlike traditional static pricing models, AI-powered systems are designed to learn continuously and adapt to market conditions, enabling firms to optimize revenue and personalize offers at scale. While the operational advantages of such systems are well-documented, the behavioral implications for consumers have not received adequate attention. In digital marketplaces, pricing functions not merely as an economic mechanism but also as a contextual cue that can influence consumer attention, evaluation, and timing of purchases. Real-time discounts, tailored offers, and time-sensitive promotions may significantly affect consumer responses to purchasing opportunities, potentially leading to an increase in spontaneous or unplanned purchases. Impulse buying, which constitutes a critical driver of e-commerce revenues, is especially relevant in online environments characterized by immediacy, personalization, and reduced deliberation time. However, empirical research that specifically isolates AI-powered dynamic pricing as a behavioral stimulus influencing impulse buying behavior remains limited. This research gap is particularly pronounced in emerging digital economies, such as India, where rapid expansion in online retail, growing smartphone penetration, and the adoption of AI-driven marketing practices have intensified the application of adaptive pricing systems. Concurrently, there is an increasing focus on data governance, transparency, and algorithmic fairness, which raises important questions regarding the broader implications of personalized pricing strategies. Understanding how AI-powered dynamic pricing influences consumer behavior and under which conditions its effects may be amplified or diminished. In this context, the present study aims to investigate the relationship between exposure to AI-driven dynamic pricing cues and the frequency of impulse buying among Indian online shoppers. Employing a behavioral economics framework, the study posits that the impact of dynamic pricing on impulse buying operates through psychological mechanisms such as perceived urgency and emotional arousal. Additionally, it explores whether perceived fairness serves as a moderating factor in this relationship. By integrating behavioral theory with empirical evidence, this research seeks to contribute to the ongoing discourse surrounding AI-enabled marketing practices and their implications for consumer decision-making and responsible digital commerce.

2. Literature Review:

The expansion of Artificial Intelligence (AI) in digital commerce has fundamentally transformed contemporary pricing strategies, particularly through the widespread adoption of dynamic pricing mechanisms that adjust prices in real time based on demand fluctuations, competitor behaviour, browsing history, inventory levels, and consumer-specific signals. Unlike traditional static pricing models, AI-powered systems continuously learn from large volumes of data to optimize revenue, conversion rates, and customer engagement. This evolution reflects a shift from conventional revenue optimization toward behaviourally informed price engineering. Dynamic pricing systems therefore function not merely as economic tools but as psychologically embedded mechanisms that influence how consumers perceive value, urgency, and opportunity within digital marketplaces.

From a behavioural economics perspective, pricing operates not only as a monetary signal but also as a psychological stimulus. While classical economic theory assumes rational evaluation of price–value trade-offs, behavioural research demonstrates systematic deviations from rational decision-making (Tversky & Kahneman, 1974). Digital commerce environments, particularly those supported by AI-driven systems, are structured in ways that activate cognitive biases and affective responses. Consequently, pricing cues can shape consumer behaviour beyond objective economic evaluation.

Prospect theory provides a foundational explanation for such behaviour. According to Kahneman and Tversky (1979), individuals evaluate outcomes relative to reference points rather than in absolute terms and exhibit greater sensitivity to losses than equivalent gains. This principle of loss aversion is particularly salient in online retail environments where AI-powered dynamic pricing frequently frames discounts as limited-time opportunities. Consumers may perceive the potential loss of missing a deal as more significant than the potential gain of saving money. Empirical evidence supports this theoretical linkage. Ali, Maqsood, and Janjua (2025) find that scarcity and urgency cues significantly heighten perceived loss, thereby increasing impulsive purchase intentions. Similarly, Farro (2025), examining the Indian market, reports that flash-sale environments amplify fear of missing out (FOMO), reinforcing loss-sensitive decision-making. These findings suggest that AI-enabled dynamic pricing systems strategically trigger loss aversion through disappearing offers, countdown timers, and fluctuating price displays.

Anchoring bias further explains how dynamic pricing influences consumer evaluation. Individuals tend to rely heavily on initial reference values when making judgments (Tversky & Kahneman, 1974). In e-commerce settings, dynamic pricing algorithms commonly display the original price alongside a discounted price, thereby establishing a high reference anchor that enhances perceived savings. Ariely, Loewenstein, and Prelec (2003) demonstrate that even arbitrary anchors can produce stable demand patterns in the absence of stable preferences, highlighting the powerful role of price framing in shaping consumer valuation. Digital platforms capitalize on this tendency by dynamically adjusting reference prices to maximize perceived deal attractiveness. Singh et al. (2024) report that anchoring combined with urgency cues significantly increases click-through rates and purchase likelihood. Consequently, anchoring mechanisms embedded within AI pricing architectures may distort reference-based evaluations and facilitate impulsive purchasing decisions.

Scarcity heuristics provide an additional behavioural mechanism linking AI-driven pricing to impulse buying. The perception of limited availability increases desirability, whether framed as time scarcity or quantity scarcity. Suri and Monroe (2003) show that time pressure reduces systematic cognitive processing, encouraging reliance on heuristics rather than deliberate evaluation. Systematic reviews confirm that scarcity and urgency are among the most consistent predictors of online impulse buying (Kaur & Sharma, 2024; Chaurasia et al, 2024). Experimental research by Schilling and Sergeeva (2025) further demonstrates that exposure to time-limited offers significantly increases impulsivity scores. In AI-driven environments, such scarcity cues are dynamically personalized based on consumer data, potentially intensifying psychological pressure and amplifying impulsive tendencies.

Impulse buying has long been conceptualized as spontaneous, emotionally driven purchasing without prior planning (Beatty & Ferrell, 1998). Early theoretical models and subsequent digital adaptations explain this behaviour using the Stimulus–Organism–Response (SOR) framework, wherein environmental stimuli influence internal emotional states that subsequently drive behavioural responses. Lee and Chen (2021) apply the SOR framework to live-streaming commerce and demonstrate that digital stimuli such as promotional cues and interactivity significantly increase impulse buying through emotional arousal. Similarly, Huo et al. (2023) show that interactive features and time-limited promotional tactics in live-streaming environments stimulate impulsive purchases by intensifying excitement and urgency. These findings reinforce the view that algorithmically generated pricing cues function

as external stimuli that activate affective and cognitive mechanisms leading to impulsive behaviour.

With the rise of e-commerce, online atmospherics and interface design have become central drivers of impulse buying. Verhagen and van Dolen (2011) demonstrate that website interactivity and perceived enjoyment significantly increase impulse buying intentions, suggesting that digital environments intensify exposure to real-time stimuli while reducing deliberation time. Meta-analytical evidence further highlights the centrality of affective mechanisms. Anoop and Rahman (2024), synthesizing 25 years of impulse buying research, identify emotional arousal as the strongest predictor of impulsive purchasing across contexts. Li and Deng (2026) propose an integrated marketplace framework incorporating behavioural economics and technological immersion, arguing that AI-driven cues amplify emotional responses and shorten cognitive evaluation cycles. Consistent with this perspective, Ali et al. (2025) confirm that perceived urgency mediates the relationship between scarcity cues and purchasing behaviour. These findings collectively indicate that perceived urgency and emotional arousal operate as key psychological mechanisms connecting exposure to dynamic pricing cues with impulse buying behaviour.

AI-powered systems further intensify traditional behavioural triggers through personalization. Personalized pricing and promotional offers increase perceived relevance, reduce cognitive resistance, and heighten emotional engagement. Priyanka (2025) finds that AI recommendation systems significantly increase impulse buying intentions by activating affective responses. Gao and Liang (2025) similarly report that AI-driven virtual try-on technologies enhance immersive experiences and increase impulsivity, particularly when brand trust is high. These findings suggest that personalization does not neutralize behavioural biases; rather, it amplifies them by tailoring stimuli to individual preferences and behavioural histories. In dynamic pricing contexts, personalization may result in individualized scarcity framing, differential discounts, or customized urgency cues, thereby creating heterogeneous exposure levels that influence impulse purchase frequency.

The Indian e-commerce landscape provides a particularly relevant context for examining these dynamics. Rapid smartphone adoption, increased digital payment penetration, and the expansion of online retail platforms have created fertile ground for algorithmic personalization and AI-driven pricing strategies. Farro (2025) demonstrates that Indian consumers exhibit strong responsiveness to FOMO-based marketing tactics, while case-based analyses reveal that

large-scale sale events strategically leverage scarcity and anchoring principles to stimulate impulse buying. Despite the growing prevalence of AI-enabled dynamic pricing in India, empirical research directly examining its behavioural consequences remains limited.

The behavioural potency of AI-driven pricing also raises important ethical and regulatory concerns. Algorithmic price discrimination, opaque pricing logic, and personalized urgency cues may compromise consumer autonomy and informed decision-making. These issues highlight the necessity of balancing technological innovation with responsible AI deployment and consumer protection safeguards.

Overall, the literature demonstrates that AI-powered pricing systems embed behavioural economic principles, that scarcity, anchoring, and loss aversion significantly influence purchasing decisions, and that emotional arousal and perceived urgency mediate impulse buying behaviour. However, limited empirical research directly examines how AI-powered dynamic pricing specifically influences impulse buying through behavioural economic mechanisms in emerging digital markets. Accordingly, the present study integrates prospect theory, anchoring bias, and scarcity heuristics to investigate the relationship between exposure to AI-driven dynamic pricing cues and impulse buying frequency among Indian online shoppers, conceptualizing perceived urgency and emotional arousal as mediating variables.

3. Objectives and Hypotheses:

3.1 Objectives- The objectives of the paper are as follows:

1. Quantify the relationship between exposure to AI-driven dynamic pricing cues and impulse buying frequency.
2. Identify mediating psychological constructs (urgency, emotional arousal, perceived fairness).
3. Discuss ethical implications and propose best-practice recommendations.

3.2 Hypotheses:

H1: Higher exposure to AI-driven dynamic pricing cues is associated with higher self-reported impulse buying frequency.

H2: Perceived urgency and emotional arousal mediate the relationship between exposure to dynamic pricing and impulse buying.

H3: Higher perceived unfairness of dynamic pricing moderates (reduces) the effect of pricing cues on impulse buying.

4. Research Methodology:

4.1 Research Design: This study utilized a cross-sectional survey design with structured questionnaires to gather data on respondents' exposure to dynamic pricing, the frequency of impulse buying, and various psychological factors that mediate these behaviors.

4.2 Sample and Data Collection: The research involved a sample of 150 frequent online shoppers residing in India. Participants were selected through a convenience sampling method, where the survey was distributed online via social media platforms, WhatsApp groups, and email lists. This approach allowed for efficient access to individuals who regularly engage in online shopping, making them ideal for examining impulse buying behavior in digital commerce environments. The final sample included 150 usable responses. In terms of gender distribution, 62 percent of respondents were female (n = 93), while 38 percent were male (n = 57). This indicates a slightly higher representation of female online shoppers in the study, which aligns with existing evidence that suggests strong female participation in e-commerce purchasing activities.

In the analysis of age distribution, the majority of participants fell within the 25–34 age bracket, constituting 44 percent of the sample (n = 66). This group was followed by respondents aged 18–24, who accounted for 28 percent (n = 42). Those in the 35–44 age range made up 18 percent of the sample (n = 27), while individuals aged 45 years and older represented 10 percent (n = 15). Collectively, the sample predominantly comprised young and middle-aged adults, reflecting the demographic segments most actively engaged in online shopping in India. The chosen sample size of 150 respondents is considered adequate for conducting statistical analyses aimed at examining the relationships between exposure to AI-powered dynamic pricing and impulse buying behavior.

4.3 Measures (Likert Scales 1–5): The present study employed structured measurement scales to evaluate key constructs. The majority of the variables were assessed using five-point Likert scales, which ranged from 1 (“strongly disagree”) to 5 (“strongly agree”), unless otherwise indicated. The utilization of Likert-type scales facilitated the systematic quantification of respondents’ perceptions, attitudes, and behavioral tendencies in relation to AI-driven dynamic

pricing and impulse buying behavior. Exposure to Dynamic Pricing (EDP) was quantified through a composite index derived from five items that measured the frequency with which respondents encountered AI-generated pricing cues in online shopping environments. These items encompassed experiences such as viewing time-sensitive discounts, receiving personalized price suggestions, observing fluctuating prices, and encountering "limited stock" notifications. Higher scores signified greater exposure to dynamic pricing mechanisms. The scale exhibited strong internal consistency, with a Cronbach's alpha of 0.84, thereby confirming its reliability in measurement.

Impulse Buying Frequency (IBF) was operationalized through two complementary methodologies. Initially, participants reported the number of impulse purchases they had made over the past three months. These responses were subsequently normalized to facilitate comparability among participants. Additionally, a five-item Impulse Buying Tendency Scale was employed to assess the predisposition toward spontaneous purchasing behavior, exemplified by instances of buying without prior planning. This scale demonstrated high reliability ($\alpha = 0.88$). The integration of behavioral frequency and dispositional tendency enhanced construct validity by capturing both actual purchasing behavior and underlying impulsive characteristics. Perceived Urgency (PU) was evaluated using a three-item scale that measured respondents' feelings of time pressure or a compulsion to act swiftly in response to dynamic pricing cues (e.g., "I felt rushed to buy"). The scale exhibited satisfactory reliability ($\alpha = 0.81$), indicating consistent measurement of urgency perceptions among participants. Emotional Arousal (EA) was assessed via a four-item scale designed to capture affective reactions such as excitement, nervousness, or anxiety that respondents experienced in reaction to dynamic pricing stimuli. This measure reflects the emotional activation aspect that is core to impulse buying theories. The reliability coefficient for this scale was 0.79, signifying acceptable internal consistency. Perceived Fairness (PF) was measured through a four-item scale that evaluated respondents' perceptions of fairness, transparency, and trustworthiness in AI-driven pricing practices. The items focused on whether the pricing adjustments were deemed reasonable and ethically acceptable. The scale indicated acceptable reliability ($\alpha = 0.76$), suggesting consistent evaluations among respondents. Lastly, demographic variables—including age, gender, income level, and digital literacy—were collected to provide contextual background and serve as control variables in the statistical analysis. Digital literacy was included to assess participants' familiarity with and comfort level regarding online platforms, which may influence susceptibility to dynamic pricing cues. In conclusion, the reliability

coefficients for all multi-item constructs exceeded the widely accepted threshold of 0.70, affirming satisfactory internal consistency and reinforcing the robustness of the measurement model.

4.4 Analytical Techniques: The data analysis was conducted using a combination of descriptive and inferential statistical techniques to examine relationships among the study variables and test the proposed mediation and moderation effects.

Descriptive statistics were first computed to summarize the characteristics of the sample and key study variables. Means and standard deviations were calculated for all continuous variables, including exposure to dynamic pricing, perceived urgency, emotional arousal, impulse buying frequency, and perceived fairness. Frequency distributions were generated for demographic variables such as age, gender, income, and digital literacy. These statistics provided an overview of central tendencies, variability, and distribution patterns within the dataset.

Pearson correlation analysis was then performed to examine the strength and direction of linear relationships among the primary constructs. Correlation coefficients were calculated to assess associations between exposure to dynamic pricing, perceived urgency, emotional arousal, impulse buying frequency, and perceived fairness. This step helped identify preliminary relationships and assess potential multicollinearity issues before conducting regression-based analyses.

To test the mediating roles of perceived urgency and emotional arousal in the relationship between exposure to dynamic pricing and impulse buying frequency, mediation analysis was conducted using the Baron and Kenny (1986) approach. This involved estimating a series of regression models: first, testing the direct effect of exposure to dynamic pricing on impulse buying frequency; second, examining the effect of exposure to dynamic pricing on the proposed mediators; and third, assessing whether the mediators significantly predicted impulse buying while controlling for exposure. A reduction in the direct effect after inclusion of the mediators indicated mediation. To strengthen the robustness of the findings, bootstrapped indirect effects were computed using bias-corrected confidence intervals. Bootstrapping provides a non-parametric resampling method that does not rely on normality assumptions and offers more reliable estimates of indirect effects.

Multiple regression analysis was further employed to examine moderation effects, particularly the role of perceived fairness in influencing the strength of the relationship between dynamic pricing exposure and impulse buying. Interaction terms were created by multiplying standardized predictor and moderator variables. A significant interaction term indicated the presence of moderation. Control variables such as age, gender, income, and digital literacy were included in regression models to account for potential confounding influences.

Together, these analytical procedures enabled comprehensive testing of direct, mediating, and moderating relationships within the proposed behavioural framework.

5. Results:

5.1 Descriptive Statistics: The descriptive statistics provide valuable insights into respondents' perceptions of AI-powered dynamic pricing and the phenomenon of impulse buying. The metric for Exposure to Dynamic Pricing (EDP) yielded a mean score of 3.41 (SD = 0.82), indicating that respondents experienced a moderately high level of exposure to time-limited offers and personalized pricing suggestions. Conversely, the Impulse Buying Frequency (IBF) averaged 3.12 (SD = 0.95), reflecting a moderate inclination toward impulsive purchasing behavior, with notable variability among participants. The Perceived Urgency (PU) scored 3.26 (SD = 0.88), suggesting that respondents frequently encountered feelings of time pressure in response to dynamic pricing cues. Emotional Arousal (EA) displayed a mean of 3.05 (SD = 0.90), indicating moderate levels of excitement or anxiety associated with exposure to pricing stimuli. Perceived Fairness (PF) recorded the lowest mean at 2.87 (SD = 0.91), suggesting that respondents exhibited a tendency toward neutrality or mild skepticism concerning the fairness and transparency of AI-driven pricing practices.

Table 1: Descriptive Statistics

Variable	**Mean**	**SD**
EDP (1–5)	3.41	0.82
IBF (1–5)	3.12	0.95
PU (1–5)	3.26	0.88
EA (1–5)	3.05	0.90
PF (1–5)	2.87	0.91

Source: Computed from Primary Data Collected through Survey, 2026.

Collectively, these findings indicate moderate exposure to dynamic pricing and impulse buying tendencies, accompanied by significant psychological responses, as well as ethical considerations regarding perceptions of fairness in AI-driven pricing systems.

5.2 Correlations: The Pearson correlation analysis presents several statistically significant relationships among the study variables. Firstly, exposure to dynamic pricing (EDP) is positively and moderately correlated with impulse buying frequency (IBF) ($r = 0.52$, $p < 0.001$). This finding indicates that individuals who report a higher level of exposure to AI-driven pricing cues, such as time-limited offers and personalized price suggestions, also tend to report increased frequencies of impulse buying. The strength of this correlation suggests a meaningful behavioral association that supports the central premise of the research.

Table 2: Correlation Table

Variable	**1**	**2**	**3**	**4**
1. EDP (Exposure to Dynamic Pricing)	1			
2. IBF (Impulse Buying Frequency)	0.52***	1		
3. PU (Perceived Urgency)	0.63***	0.58***	1	
4. PF (Perceived Fairness)	—	−0.24**	—	1
Note. Values represent Pearson correlation coefficients (r). ***p < .001, **p < .01. Dash (—) indicates correlations not reported or not statistically significant.				

Source: Computed from Primary Data Collected through Survey, 2026.

Secondly, the analysis reveals a strong positive correlation between exposure to dynamic pricing and perceived urgency (PU) ($r = 0.63$, $p < 0.001$). This represents the strongest correlation observed among the analyzed variables, indicating that dynamic pricing cues are closely associated with feelings of time pressure or the compulsion to make swift purchasing decisions. This finding reinforces the theoretical argument that AI-driven pricing activates psychological mechanisms related to urgency. Thirdly, perceived urgency is positively correlated with impulse buying frequency ($r = 0.58$, $p < 0.001$). This moderate-to-strong association suggests that individuals experiencing heightened urgency are more likely to engage in impulsive purchasing behavior. Together with the previously established correlations, this pattern provides preliminary evidence for the mediating role of perceived urgency in the relationship between dynamic pricing exposure and impulse buying behavior.

Lastly, perceived fairness (PF) exhibits a negative correlation with impulse buying frequency ($r = -0.24$, $p = 0.004$). Although the strength of this correlation is small, it remains statistically significant. This indicates that consumers who perceive AI-driven pricing as less fair or transparent are more likely to report higher levels of impulse buying. One plausible interpretation is that urgency-driven or opaque pricing strategies may diminish fairness perceptions while simultaneously encouraging spontaneous purchasing behavior. In summary, the correlation results offer initial empirical support for the proposed behavioral framework. Exposure to dynamic pricing is significantly associated with psychological activation (perceived urgency) and behavioral outcomes (impulse buying), whereas perceptions of fairness reveal a small yet significant inverse relationship with impulsive purchasing tendencies.

5.3 Regression: The multiple regression analysis provides strong empirical support for the proposed relationship between AI-powered dynamic pricing and impulse buying behaviour. Results indicate that EDP has a statistically significant positive effect on impulse buying frequency (IBF), even after controlling for demographic variables. The standardized regression coefficient ($\beta = 0.48$, $t = 6.20$, $p < 0.001$) suggests that higher exposure to AI-driven pricing cues, such as time-limited discounts and personalized pricing, substantially increases impulsive purchasing behaviour. The overall model explains a meaningful proportion of variance in impulse buying frequency (Adjusted $R^2 = 0.29$), indicating moderate explanatory power within the context of consumer behaviour research. This finding confirms that dynamic pricing mechanisms play a significant role in shaping impulsive buying tendencies.

Table 3: Multiple Regression Analysis Predicting Impulse Buying Frequency

Predictor	**β**	**SE**	**T**	**p**	**Model Statistics**
Exposure to Dynamic Pricing (EDP)	.48	.08	6.20	< .001	R^2: 0.31
Perceived Urgency (PU)	.36	.07	5.14	< .001	AdjustedR^2: 0.29
Emotional Arousal (EA)	.22	.06	3.67	< .001	F: 38.44***
Perceived Fairness (PF)	−.18	.07	−2.54	.012	
Note. Standardized coefficients (β) reported. ***p < .001.					

Source: Computed from Primary Data Collected through Survey, 2026.

Further analysis shows that perceived urgency (PU) is positively and significantly associated with impulse buying behaviour, indicating that consumers experiencing heightened time pressure are more likely to engage in spontaneous purchases. Similarly, emotional arousal (EA) demonstrates a significant positive relationship with impulse buying, suggesting that dynamic pricing cues may heighten emotional activation, thereby increasing impulsive responses.

In contrast, perceived fairness (PF) exhibits a negative and statistically significant association with impulse buying behaviour ($\beta = -0.18$, $p < 0.05$). This finding suggests that when consumers perceive AI-driven pricing strategies as less fair or transparent, impulsive purchasing tendencies decline. The negative coefficient highlights the importance of maintaining fairness perceptions in dynamic pricing environments.

Overall, the regression results demonstrate that AI-powered dynamic pricing significantly influences impulse buying behaviour. Exposure to pricing cues, psychological activation (urgency and emotional arousal), and fairness perceptions collectively contribute to explaining variations in impulsive purchasing tendencies. These findings align with behavioural economics principles and reinforce the strategic importance of intelligent pricing mechanisms in digital commerce.

6. Discussion:

6.1 Findings: The findings provide empirical support for hypotheses H1 and H2, indicating that exposure to AI-driven dynamic pricing cues is positively correlated with impulse buying frequency. This relationship is mediated by perceived urgency and emotional arousal. Consumers who encounter personalized discounts, fluctuating prices, and time-limited offers with regularity are more inclined to engage in spontaneous purchasing behavior. From the perspective of behavioral economics, these findings are consistent with principles derived from prospect theory and heuristic-based decision-making. AI-powered dynamic pricing systems establish reference points and anchors (for instance, "was ₹X, now ₹Y"), which significantly affect consumers' value perception through anchoring bias. Simultaneously, cues such as scarcity and time pressure trigger loss aversion and the urgency heuristic, leading consumers to prioritize the avoidance of potential losses over a thorough assessment of their actual needs. The synergistic effects of anchoring, scarcity framing, and emotional arousal diminish deliberation time, thereby increasing the likelihood of impulsive purchasing decisions. Consequently, dynamic pricing operates not solely as an economic adjustment mechanism but

as a psychologically structured stimulus that enhances spontaneous buying behavior. Furthermore, the moderating effect of perceived fairness (H3) introduces a critical practical consideration. The negative interaction between exposure to dynamic pricing and perceived fairness suggests that when consumers perceive pricing practices as unfair, opaque, or discriminatory, their responsiveness to AI-driven cues diminishes. Accordingly, while dynamic pricing may enhance short-term conversion rates, its effectiveness is contingent upon consumers' trust in the pricing system. This situation highlights a significant trade-off in the realm of AI-enabled commerce. While personalization and real-time price adjustments can improve engagement and drive impulse purchases, concerns regarding algorithmic discrimination or a lack of transparency may erode trust and impair long-term customer relationships. Therefore, organizations that extensively utilize behavioral price engineering must carefully balance the optimization of conversion rates with the principles of fairness, transparency, and ethical pricing practices to sustain consumer trust over time.

6.2 Managerial Implications: The findings yield several significant implications for managers and digital commerce strategists engaged in the deployment of AI-powered dynamic pricing systems. First, organizations should implement pricing strategies that are ethically informed, ensuring a balance between conversion optimization and transparency. While time-limited discounts and personalized offers can effectively drive impulse purchases, it is imperative to communicate clearly regarding the structure of discounts and the rationale behind personalization. For example, explicitly indicating the reasons for presenting a particular offer or clarifying whether a discount is broadly applicable or customized for an individual can enhance transparency and mitigate perceptions of manipulation. Second, caution is advised in the segmented application of urgency cues. Although messages that convey scarcity and time pressure can increase short-term sales, the excessive or artificial utilization of these tactics may harm credibility and long-term trust. Aligning urgency cues with genuine inventory constraints or authentic promotional periods is essential to maintaining brand integrity while ensuring effectiveness. A strategic moderation of behavioral triggers guarantees that the use of urgency enhances engagement without undermining consumer confidence. Third, consumer education plays a vital role in fostering perceived fairness. Providing concise explanations regarding the benefits of personalization, such as tailored recommendations or relevant discounts, can reduce suspicion toward algorithmic pricing. Additionally, offering clear opt-out options along with transparent disclosures about data usage empowers consumers and enhances trust. Such

initiatives can mitigate the negative effects of perceived unfairness while maintaining the persuasive efficacy of dynamic pricing strategies.

6.3 Regulatory and Ethical Considerations: The increasing utilization of algorithmic price personalization raises considerable regulatory and ethical concerns. AI-driven pricing systems may lead to differential pricing across consumer segments based on behavioral data, geographic location, purchasing history, or inferred willingness to pay. While these practices may be economically advantageous, they also prompt concerns regarding fairness, discrimination, and consumer autonomy. Globally, regulators are intensifying scrutiny of algorithmic pricing mechanisms, particularly in relation to anticompetitive risks and opaque price discrimination practices. In the Indian context, the Digital Personal Data Protection (DPDP) Act underscores the importance of lawful data processing, transparency, and principles of fairness. Ongoing discussions regarding AI governance further emphasize the necessity of responsible algorithmic deployment. Failure to ensure fairness and transparency may expose organizations to regulatory intervention, reputational damage, and a decline in consumer trust. Consequently, adherence to data protection laws and proactive ethical governance are fundamental components of sustainable, AI-driven pricing strategies.

6.4 Limitation: The study has made significant contributions; however, it also has several limitations that should be considered. First, the research is based on a small sample size collected through convenience sampling, which restricts the ability to draw strong causal conclusions about the relationship between exposure to dynamic pricing and impulse buying behavior. Second, the reliance on self-reported measures of impulse buying may lead to recall bias and social desirability bias, potentially influencing the accuracy of responses. Third, the analysis does not include real transaction-level pricing data from e-commerce platforms. Incorporating behavioral logs and pricing histories generated by these platforms would greatly enhance the causal interpretation and external validity of the findings. Future research could address these limitations by conducting experimental field studies where platforms randomly vary dynamic pricing cues, allowing for the estimation of causal effects on purchasing behavior. Longitudinal studies that track consumer trust, satisfaction, and repeat purchasing behavior following exposure to dynamic pricing would shed light on long-term relational impacts. Additionally, cross-cultural comparative research could investigate variations in sensitivity to urgency cues and perceptions of fairness across different markets. Furthermore, utilizing neurophysiological methods, such as eye-tracking or EEG, could provide a deeper

understanding of real-time emotional arousal and attention processes in response to dynamic pricing stimuli.

6.5 Recommendations: To ensure the ethical and sustainable implementation of AI-powered dynamic pricing, organizations must adopt responsible deployment practices. Primarily, transparency mechanisms must elucidate the rationale behind the display of specific prices or offers. For example, it should be communicated if an offer is based on prior browsing behavior. Secondly, entities should conduct periodic fairness audits of their pricing algorithms to identify and address potential biases or discriminatory effects. Thirdly, empowering consumers with control over personalization settings—including clear options to opt out—enhances their autonomy and fosters trust. Fourthly, adherence to data protection regulations, such as the Digital Personal Data Protection (DPDP) Act and forthcoming AI governance frameworks, is critical. Finally, organizations are encouraged to employ an ethics-by-design approach, integrating fairness constraints and consumer welfare considerations into pricing algorithms rather than prioritizing revenue maximization alone. Implementing these measures can contribute to a balance between innovation and profitability while upholding fairness, transparency, and long-term consumer trust in AI-driven digital commerce ecosystems.

7. Conclusion:

AI-powered dynamic pricing constitutes a transformative mechanism in contemporary e-commerce, enabling organizations to augment conversion rates and enhance revenue performance by strategically capitalizing on behavioral triggers that encourage impulse purchases. Analyzing this phenomenon through the lens of behavioral economics reveals that the efficacy of dynamic pricing extends beyond mere price modifications; it effectively engages cognitive and emotional processes. Anchoring effects influence consumers' perceptions of reference prices, loss aversion heightens sensitivity to missed opportunities, and urgency cues related to scarcity amplify emotional arousal. Collectively, these factors increase the probability of spontaneous purchasing decisions. Nonetheless, the very mechanisms that drive short-term sales performance simultaneously give rise to significant ethical and relational concerns. Issues such as perceived unfairness, lack of transparency in algorithmic decision-making, and potential price discrimination threaten to undermine consumer trust and weaken long-term customer relationships. If consumers perceive that personalized pricing is characterized by a lack of transparency or disproportionately disadvantages specific segments, the persuasive impact of AI-driven strategies may diminish over time. Consequently,

organizations must navigate the delicate balance between innovation and profitability while adhering to principles of responsible AI governance. Transparent communication, fairness-oriented algorithm design, and meaningful consumer control mechanisms are imperative to sustain trust within digital marketplaces. Furthermore, a collective effort involving policymakers, industry stakeholders, and technology developers is essential to establish regulatory and ethical frameworks that safeguard consumer rights while fostering the innovative potential of AI-enabled pricing systems**.**

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Women in the Traditional knowledge System in Conserving Deepor Beel Wetland: An Ecofeminist Study

Jyotisikha Dutta[1*]
[1*]*Department of Women's Studies, Gauhati University, Guwahati-781014, Assam*
*Corresponding author
E-mail address: jyotisikhadatta@gauhati.ac.in

Abstract

The Deepor Beel, the only Ramsar site of Assam, India, is the hub of both rich biodiversity and the cultural heritage of local indigenous communities. Women of these communities play a significant role in conservation of the Beel. Though their contributions are noteworthy, their knowledge is ignored in most of the conservation policy decisions. This paper tries to find out the knowledge and contributions of the women in conservation measures of the Beel through the questions: How do women's traditional practices contribute to Deepor Beel's conservation? In what ways does ecofeminism help interpret women's ecological roles and environmental agency? What are the social, economic, or institutional constraints on women's participation in wetland governance? The paper uses Ecofeminism as a theoretical base for understanding women's roles as environmental stewards, linking their marginalization to environmental degradation. The interviews, participant observation and focus group discussion are used to gathered data. The study found that social, economic and institutional constraints hinder women's participation in decision making process.

Keywords: Deepor Beel; Ecofeminism; traditional knowledge; women.

1. Introduction:

Deepor Beel[1], only Ramsar site of Assam, India, supports both rich biodiversity and the cultural heritage of local indigenous communities (Choudhury, 2005; Sarma et al., 2020). Women in these communities are central to the transmission and practice of traditional ecological knowledge, spanning sustainable fishing, aquatic plant collection, ritual observances, which are crucial for the wetland's ecological health. To address the relationship between gender and environment, Bina Agarwal presents the concept of feminist environmentalism, which examines the relationship between the environment and women through the lenses of gender, caste, class and race, as well as the organization/society of production, reproduction, and distribution. As a theory for action, this perspective advocates for fights concerning both resources and their meanings (Agarwal, 2007; Agarwal, 2018). This framework incorporates notions such as the seizure of resources by dominant societal groups via control over property and power. In similar way, Shiva emphasizes that women maintain a unique connection with nature. This is evident in several ways. Firstly, the reciprocal nature of women's interactions with nature is highlighted, as they find themselves intimately linked to nature through their roles in both producing and nurturing the soil and society. Secondly, women engage in a collaboration with nature, not merely by utilizing its resources but also by giving something back. They do not consider nature as property to be owned, but rather advocate for active participation in the processes of nurturing and fostering growth. Finally, women act as producers in harmony with nature, contributing to the sustenance of society and relationships. They are advocates of a sustenance economy and pioneers of the first productive economy (Shiva, 1988). The methods by which this control is exerted, both ideologically and institutionally, signify privilege and thus warrant further investigation.

Ecofeminism provides a valuable theoretical framework for understanding women's roles as environmental stewards, linking their marginalization to environmental degradation (Mies & Shiva, 2014).

1.1 Statement of the Problem:

Deepor Beel is facing increased threats from urbanization, pollution, and resource overexploitation (Sarma et al., 2020). As ecofeminist such as Vandana Shiva, Bina Agarwal stated that forms of environmental/ecological degradation, including water, land and wind

[1] Beel is an Assamese word which means wetland.

erosion, declining surface or groundwater levels, and the undiscerning sinking of tubewells, among other factors, are connected to exploitation at various levels of power and governance. The phenomenon of statization, or the increasing control of the state over natural resources, has been observed since the era of colonial rule. This has resulted in widespread natural resource degradation as well as deforestation. After independence, the government has actively implemented policies that alienate the populace from their rights to common forest land as well as other natural resources. As a result, local communities are deprived of access of them including wetlands that once provided them with sustenance and livelihood. The privatization of common natural resources has led to the growing commercial exploitation of them. The loss of community resource management systems, the prohibition of local populations-particularly women from control over these natural resources, excessive population growth have consequent pressures on natural resources.

The conservation policies often overlook the knowledge and leadership of indigenous women, despite their sustained roles in wetland management (Agarwal, 2018). The marginalization of women's roles in conservation perpetuates both ecological and social injustice, issues made visible through the ecofeminist perspective (Mies & Shiva, 2014).

2. Review of Literature:

Traditional knowledge systems (TKS) possessed by indigenous and local women are crucial for the conservation of wetlands, which are essential for biodiversity and human livelihoods. Ecofeminism, which connects ecological issues with gender justice, emphasizes how women's close relationships with nature and their communities uniquely position them as guardians of wetland ecosystems. Women's traditional ecological knowledge encompasses sustainable harvesting, resource management, and cultural practices that aid in the preservation of wetlands (Mishra & Behera, 2019; Mohanty et al. 2021). Research from various geographical areas demonstrates women's leadership in wetland governance based on indigenous knowledge. women spearhead local Wetland Management Committees in Northern Uganda, where their knowledge of utilizing wetland plants for medicinal, craft, and subsistence purposes supports conservation initiatives. Their methods include the selective harvesting of mature resources such as papyrus for brooms, which facilitates the regeneration of younger plants, exemplifying sustainable practices grounded in profound ecological insight. This kind of community-driven strategy has effectively restored thousands of hectares of wetlands, reinforcing the socio-

ecological resilience nurtured by women's knowledge and efforts (UN Women, 2020; PEDRR, 2022).

Various researches also underscore how women's traditional agricultural methods-such as water-saving techniques, crop diversification, and organic farming-promote wetland health by maintaining water balance, enhancing soil fertility, and supporting biodiversity. These knowledge systems interlace ecological stewardship with cultural values, exemplifying holistic conservation paradigms. For instance, studies from India highlight traditional fishing and plant use by indigenous women in wetland regions, where such practices mitigate overexploitation and sustain ecosystem services (Barman et al, 2025).

Ecofeminist scholars highlight how patriarchal systems marginalize women's roles, leading to loss of biodiversity and degradation of wetlands. The link of gender inequality and environmental harm is evident as women face disproportionate impacts from wetland degradation and climate change, such as increased labor in water collection and reduced access to natural resources. Recognizing and empowering women's traditional knowledge is essential for inclusive conservation and climate resilience frameworks (Shiva, 1992).

Furthermore, women's engagement in wetland conservation nurtures socio-economic benefits through eco-enterprises, improving household welfare while enhancing ecosystem protection. These multifaceted roles challenge stereotypical views of women as passive victims, instead positioning them as proactive agents of sustainability in local environmental governance (UN Women, 2023; PEDRR, 2022).

Through participatory approaches, literature advocates for integrating traditional knowledge with modern conservation science that respect cultural diversity and enhance community empowerment. Such integration can lead to adaptive management strategies that sustain wetlands and reinforce gender equity instantaneously. However, challenges remain as constant including institutional barriers, unclear land tenure, and climate-induced stressors that threaten these systems, requiring policy measures that address socio-ecological dynamics and power imbalances (Barman et. al, 2025).

Deepor Beel is not only an ecological harbor but also a livelihood source for indigenous communities, especially women who hold rich knowledge of the wetland's biodiversity and sustainable use practices (Saikia, 2019). Women in the Deepor Beel region traditionally shoulder responsibilities related to food collection, water management, agriculture, and use of wetland resources, making them key custodians of wetland ecosystems. Their close connection to the environment places them as important actors in conservation efforts. Studies emphasize that acknowledging women's roles and traditional ecological knowledge empowers them in

governance and decision-making related to wetland conservation (Saikia and Adhyapok, 2023). Ethnographic evidence from the communities around Deepor Beel, demonstrates that women's knowledge is embedded in cultural practices, folklore, and rituals that emphasize environmental stewardship. The external pressures such as fishing bans, urbanization, pollution, and habitat degradation increasingly threaten Deepor Beel. These challenges complicate the traditional knowledge systems, limiting women's access to natural resources and, thereby, their ability to practice conservation (Talukdar, 2016).

From the reviewed existing literature, it can be seen that there is no systematic study on the role of women in the traditional Knowledge System in Conserving Deepor Beel Wetland through an ecofeminist lens. Therefore, this study has undertaken to bridge the gap in the existing literature.

3. Objectives of the Study:

The paper is based on the following objectives:

1. To document and analyse the traditional ecological knowledge practiced by women around Deepor Beel.
2. To interpret women's roles in wetland conservation through an ecofeminist lens.
3. To investigate barriers faced by women participating in conservation of the Beel.
4. To suggest how women's local knowledge can be integrated into inclusive conservation policy.

3.1 Research Questions:

1. How do women's traditional practices contribute to Deepor Beel's conservation?
2. In what ways does ecofeminism help interpret women's ecological roles and environmental agency?
3. What are the social, economic, or institutional constraints on women's participation in wetland governance?

4. Methodology:

4.1 Type of study and data source:

The study is qualitative and descriptive in nature. The study is based on both primary and secondary data. For the base of the study, secondary is used. The secondary data is collected

from various government reports, documents, from research papers published in reputed journals etc.

For primary data, study used semi-structured interviews and participant observation with indigenous and fisher women; focus group discussions; and review of policy and research documents from governmental and non-governmental sources (Creswell & Poth, 2018). Tables, charts and picture are used wherever necessary.

4.2 Data collection:

To collect fishing and water management related data, total of 30 women were selected randomly in Azara and Mikirpara Chakardew area. For paddy cultivation, necessary information were collected from the respective village headmen. For traditional knowledge used by women in conserving animals and forests and medicinal purposes, randomly 30 women were consulted in above mentioned revenue villages. The necessary data were collected during August-September, 2025.

4.3 Analysis:

Thematic analysis is used to identify patterns in traditional knowledge, gender roles, and ecofeminist insights (Braun & Clarke, 2006). The radical ecofeminism and cultural ecofeminism are used to assess the role and challenges women face in conservation process of the Deepor Beel wetland.

4.4 Focus Group Discussion:

The focus group discussion was designed to investigate women's viewpoints and their roles in the conservation of the Deepor Beel wetland. A purposive sampling method was employed to select participants who were either knowledgeable about or actively engaged in conservation efforts. The discussion was steered by open-ended questions formulated around essential themes concerning women's involvement, the challenges they face, and their contributions to wetland governance.

The data underwent thematic analysis, which included familiarizing oneself with the transcripts, coding significant statements, and categorizing codes into themes that reflect women's roles in conservation. For instance, themes such as "Community leadership," "Environmental education," and "Challenges in governance participation" were identified. Quotations from participants were utilized to exemplify these themes.

4.5 Use of Radical ecofeminism and cultural ecofeminism theory:

Radical ecofeminism and cultural ecofeminism are two main branches of ecofeminism, which links patriarchal oppression of women with environmental exploitation.

4.5.1 Radical Ecofeminism:

Radical Feminism argues that patriarchal society dominates both women and the environment through similar mechanisms of control and devaluation. It seeks to pull apart these links by challenging male-centered norms that consider natural resources like objects (Miles, 2025).

4.5.2 Cultural Ecofeminism:

Cultural ecofeminists highlight women's connection to nature through body/biology (e.g., reproduction) and roles (e.g., nurturing), fostering greater environmental sensitivity. They promote alternative women's cultures rooted in feminine traits undervalued by patriarchy to address ecological crises. This branch comes from goddess worship and nature spirituality to value women's intuitive care for the earth (Carlassare, 2000).

4.6 About the Deepor Beel:

The Wetlands are among the productive ecosystems on Earth, which provide a wide array of economic, ecological, and cultural benefits. In India, Deepor Beel is happened to be one of the important riverine wetlands. The Deepor Beel is located within the coordination of 91°35F to 91°43F E. and 26°05' to 26°11F N. It lies on 165 -186 feet above MSL (Saikia and Bhattacharjee 1987). The Beel is one of the largest freshwater wetlands and is the key storm water storage basin for the Guwahati city (Deka and Goswami 1993). The Beel is situated on the Southern bank of the river Brahmaputra. The revenue village Azara and National Highway No.37 lie on the North; revenue village Lakhara, Lakhara NC, under it Tetelia and Pachim Baragoan to the East; Revenue village Pamehi, Mikirpara Chakardeo, Gorbhanga Reserve Forest, Chakardeo Hill to the South West (from Revenue Circle Office). The fishing community (keot) resides under Azara revenue village. On the basis of its biological and environmental importance and for undertaking conservation measures, the Beel has been listed as the only Ramsar site of the state Assam in November 2002, (Ramsar, 2002). The Beel is gifted with rich floral and faunal diversity. In addition to huge flock of residential water birds, the wetland ecosystem anchorages large number of nomadic waterfowl every year. It supports

various species of fish belonging to more than 20 families. The Beel provides its natural resources directly or indirectly to the villages adjacent in its precincts for their livelihood.

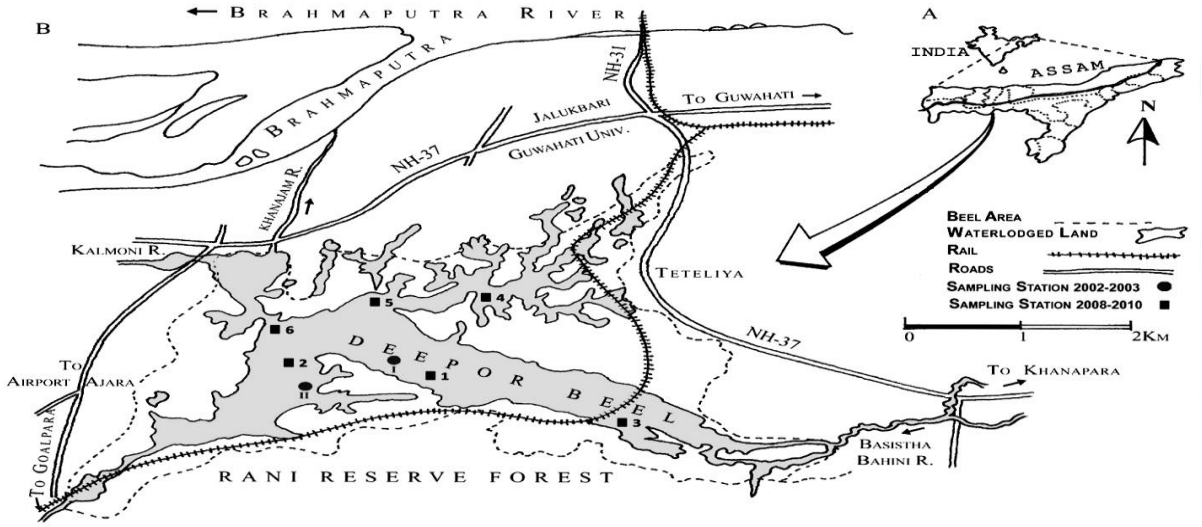

Figure 1: Map of Deepor Beel (Source: Ramsar official website)

5. Findings and Discussion:

5.1 Brief overview of the socio-economic conditions of the respondents:

As previously stated, a total of 30 women were interviewed to gather the necessary data for the study. These women belong to the Karbi and Keot communities. Out of the total, 27 are married while 3 are widowed. Nearly 70 percent (20 women) have completed their education up to high school. The remaining 7 have passed higher secondary, and 3 have obtained a Bachelor of Arts degree. The widowed women serve as heads of their households; however, most household decisions are made collectively by all members of the household. Only the widowed women possess land ownership, while the other women do not hold any rights to land or other assets. Despite their extensive involvement in fishing activities, fodder collection, and gathering medicinal plants from the wetland, they do not receive any income from these efforts.

5.2 Documentation of the traditional ecological knowledge practiced by women around Deepor Beel:

5.2.1 Sustainable Fishing and Water Management:

Fishing in Deepor Beel is a gendered activity, with women actively participating in fish sorting, drying, and marketing. Traditional practices, such as using handwoven nets, other fishing

equipment and small-scale fishing, ensure that fish populations are not overexploited. There are approximately 850 household are depended on Deepor Beel for their livelihood (i.e. fishing) (from the report submitted by the Village Headman, Keotpara to Azara Revenue Circle). They belong to Keot community. Women in the community around Deepor Beel employ traditional fishing practices that are both sustainable and efficient. They use indigenous methods, such as bamboo traps and hand nets, to minimize by catch and avoid overexploitation of fish populations. They always fish at the peripheral area of the Beel during breeding season (May-November) so that the pregnant fish(livebearers/gravid) can be saved. Additionally, women contribute to water management by maintaining natural channels and ensuring that water remains clean and navigable. Their knowledge of fish breeding seasons and habitats enables them to regulate fishing activities, preventing ecological disruption.

The water of the Deepor Beel considered sacred by the people living near the wetland. By this believe they actually conserving the water quality, flora and fauna of the Beel. Every year Ganga Puja and Maa Manasha Puja are celebrated with joy and devotion. The women particularly play an important role in these celebrations. They pass the knowledge of the importance of the Beel for their survival as well as the entire ecological health of Guwahati city to the next generation. This legacy continues to generation after generation. They also believe that the Beel is the food provider of the community, therefore it is their responsibility to protect and conserve the wetland. For that both men and women participate in various conservations practices. Every year, The Deepor Beel Pachpara Samabay Samiti[2], releases juvenile fishs/fingerlinks to the Beel so that the fish intake will not go down. It cleans the water hyacinth and other harmful substances from the beel time to time (Dutta and Sharma 2020).

For sustainable fishing, the women use jakoi, sepa, polo and juluki just to catch fishes which they need for daily consumption. The pictures of the equipment are given in the Table 1.

[2] A cooperative society set up by the people near the Beel for the development and conservation of the Wetland. The society was established in the year 05/08/1976 and registered in the year 1977 with the registration number 5/76/77. The samiti collects annual fees for smooth running of various activities undertaken by it.

Table 1: Fishing equipment used during fishing by the women

Sl no	Name of the equipment	Picture
1	Jakoi and khaloi	
2	Sepa	
3	Polo	
4	Juluki	

Source: Field data, pictures are extracted from the internet and Dutta (2012)

5.2.2 Agriculture and Paddy Cultivation:

Women's experience of traditional agriculture proves helpful in paddy cultivation in the area around Deepor Beel. There were approximately 60 families of paddy growers, according to Keotpara's village headman. People worked to a very small extent in vegetable growing. Women take part in various paddy farm activities in this area. It can be seen that the women employ organic manures such as compost and cow dung instead of chemical manures to aid in the fertility of the soil. Mixed cropping and crop rotation, which aid in biodiversity and minimize the chances of pests and diseases, are also practiced by the women. The women's knowledge of seasonality in water availability and flood patterns is crucial in preventing crop failure.

5.2.3 Conservation of Animals and Forests:

The women residing in the peripheral villages of Deepor Beel have knowledge about the vegetation and fauna of the wetland. They are able to characterize plant species in terms of their utility as food, medicine, or handicraft material. Locally, women are actively engaged in

the conservation of vegetation and wildlife around Deepor Beel. Women are tracking wildlife and are also involved in the conservation of endangered species such as greater adjutant stork and Asian elephant. Women are also engaged in the conservation of forest products by regulating firewood and non-timber forest produce collection to ensure sustainable harvesting.

5.2.4 Medicinal Resource Utilization:

The knowledge of ethno medicine is another area where women are brilliant. In Deepor Beel, the women discover and collect medicinal plants from the wetland and nearby forests to cure common diseases. This locally originated knowledge reflects the beautiful harmony of the local inhabitants with nature. Such practices of women not only preserve biodiversity but also offer natural remedies to the present and future generations. Uses of various herbs, shrubs and trees found in the Beel are described in the Table 2.

Table 2: Women's Traditional Knowledge on medicinal plants and trees

Vernacular name	**Scientific name of the species**	**Family**	**Parts used**	**Use (s)**
Herbs and flower				
Mitha borial	Scoparia dulcis	Plantaginaceae	Root	Used to treat white discharge in females
Moira tikira	Elephantopus scaber	Asteraceae	Root	Use to treat excessive period bleeding
Mankochu	Alocasia indica	Araceae	Stem, leaf	Paste of the leaf is used to wound to control bleeding and stem is used as vegetable to purify blood
Kehraj	Eclipta alba	Asteraceae	Leaf, flower	Used in jaundice and ulcer. It is also applied on wounds and skin diseases of cattle
Sarumanimuni	Hydrocotyle sibthorpioides	Apiaceae	Leaf, stem	Leaf and stem juice are consumed for curing liver problem and skin diseases
Bor Manimuni	Centella asiatica	Apiaceae	Stem, leaf	Juice of Stem and leaves are used consumed to improve memory. It is also used to cure skin disease
Kolmou	Ipomoea aquatica	Convolvulaceae	Young leaf and stem	Consider good source of vitamins, minerals, plant proteins
Panikhutura	Alternanthera philoxeroides	Amaranthaceae	Twig	Juice is used with lukewarm water to

				cure stomach pain
Matikanduri	Alternanthera sessilis	Amaranthaceae	Twig	Used in fever
Podum	Nelumbo nucifera	Nymphaeaceae	leaf petiole, stem, fruiting torus	Used for consumption due to its high protein and mineral values
Panitengesi	Marsilea quadrifolia	Marsileaceae	Tender shoot	Tender shoots are used as vegetable
Bihlongoni	Polygonum hydropiper	Polygonaceae	Leaf	Leaf juice is used in uterine disorder and skin disease
Ronga-bhet	Nannodiplax rubra	Nymphaeaceae	Flower, stem, seeds and fruit	Used for vegetable and raw consumption
Boga vet	Nymphaea alba	Nymphaeaceae	Stem	Stem is used to treat dysentery.
Bon paleng	Rumex nepalensis	Polygonaceae	Leaf	Juice of the leaf is applied in burning.
Singori	Trapa natans var. bispinosa	Trapaceae	Fruit	Raw fruits are eaten and used for curing problem of liver, kidney, urinary trouble
Bach/Vacha/Dol ghah	Acorus calamus	Araceae	Rhizome	Used to cure whooping cough found among children, asthma, diabetes
Basak pat	Justicia adhatoda	Acanthaceae	Leaf	Used in respiratory disorder, chest congestion, bleeding, uremia
Narasingha paat	Bergera koenigii	Rutaceae	Leaf	Used for blood suger, digestion, skin,eye, hair health, anti inflammatory
Halodhi	Curcuma longa	Zingiberaceae	Fruit	Skin care, Cough, Pain relief
Brahmi saak	Bacopa monnieri	Plantaginaceae	Leaf	Increase brain functions
Climber				
Paan	Piper betle	Piperaceae	Bud	Period cramps
Pani lao	Lageneria siceraria	Cucurbitaceae	Fruit, leaf	Used as vegetable as well as stomach problem
Xoguni lota (Giloy)	Tinospora cordifolia	Menispermaceae	Stem	Fever, immune system, diabetes
Bhedailota	Paederia foetida	Rubiaecea	Leaf	diarrhea, dysentery, stomach pain, asthma, anti inflammatory
Shrubs				

Tulosi	Ocimum tenuiflorum	Lamiaceae	Leaf	Cough and cold
Joba ful	Hibiscus rosa-sinensis	Malvaceae	Leaf, Flower	fever, treatment of hair
Narzi/ Gendhai phul	Tagetes erecta	Asteraceae	Leaf	Wound healing
Nemu	Citrus limon	Rutaceae	Leaf, Fruit	Vomiting, gastric as well as source of vitamin C
Bengena	Solanum melongena	Solanaceae	Fruit	Used as vegetable, bronchitis, dysentery
Godhuli gopal	Mirabilis jalapa	Nyctaginaceae	Root	White discharge in females
Trees				
Xewali phool	Nyctanthes arbor-tristis	Oleaceae	Leaf, flower	Fever, liver problem, diabetes, flower is prepare curry
Bel	Aegle marmelos	Rutaceae	Leaf, fruit, root	Used to treat diarrhea, dysentery, peptic ulcers, and respiratory problems
Omita	Carica papaya	Caricaceae	Leaf, fruit	Can be used to treat gastrointestinal disorders, intestinal parasites, nerve pain, and elephantoid growths
Kol Goch	Musa paradisiaca	Musaceae	Leaf, fruit, stem, flower, roots	Can be used to treat hysteria, epilepsy, leprosy, fevers, hemorrhages, diarrhea, kidney stones, urinary tract infections, and high blood pressure
Dalim	Punica granatum	Lythraceae	Fruit, Leaf	Used for treatment of dysentery, anemia
Amlokhi	Phyllanthus emblica	Phyllanthaceae	Fruit	anti-inflammatory, antibacterial properties, antioxidant properties, antidiabetic properties, gastroprotective properties
Arjun Goch	Terminalia arjuna	Combretaceae	Bark	Used for heart related diseases, Jaundice
Sojona	Moringa oliefera	Moringaceae	Fruit, leaves	Pox
Madhuriam	Psidium guajava	Myrtaceae	Tender Leaf	Sugar control,
Xilikha	Terminalia chebula	Combretaceae	Fruit	Constipation
Bokul	Mimusops elengi	Sapotaceae	Bark	Tooth ache

Neem	Azadirachta indica A. Juss	Meliaceae	leaf	Used in skin diseases, anti-inflammatory, dental disorder etc
Ou tenga	Dillenia indica	Dilleniaceae	Fruit	Pox, Dysentery

Source: Survey

A study done by Deka et al. (2019) and Kalita and Saikia (2024) got the similar results.

5. How do women's traditional practices contribute to Deepor Beel's conservation?

Women's traditional practices play a pivotal role in conserving Deepor Beel by combination of indigenous knowledge, cultural rituals, sustainable resource use, and innovative community action.

6.1 Indigenous Knowledge and Folklore:

Form the study it can be found that the local women pass down ecological knowledge through storytelling, folklore, and community song, which helps maintain awareness of the wetland's significance and natural cycles. Rituals such as Johong Puja, Ganga Puja, Manasha Puja celebrate the wetland's beauty and invoke protection for natural resources. . Ganga Puja is celebrated for the protection of the fishermen during fishing. The people of Keot community believe that by celebrating Ganga puja, Ma Ganga protect the fishermen from all kinds of dangers and evil during fishing. This actually strengthening the community's spiritual bond with the environment.

6.2 Sustainable Livelihood Practices:

It is found that women are primarily responsible for gathering edible herbs, medicinal plants, and fodder from Deepor Beel. Their knowledge on selective harvesting techniques and seasonal cycles help preserve habitat and biodiversity. Traditional fishing methods—from knitting the nets to preserve the caught fishes, shared across generations—emphasize communal resource management and ecological balance, discouraging overexploitation.

6.3 Handicrafts and Innovations:

With the initiative of the few young people, local women further contribute by transforming invasive species, such as water hyacinth, into eco-friendly products like handmade paper and handicraft items. These initiatives not only restore ecological health by removing invasive

plants but also create alternative livelihoods, empowering women economically while improving wetland conditions.

6. Results of Focus Group Discussion and interview:

The analysis revealed that women are behind due to the patriarchal system of society where women have less chance of put forwarding their decisions or ideas. However, due to some initiatives, women now play a critical leadership role in community-led conservation initiatives. Yet, socio-cultural constraints limit their full participation in formal governance structures. One participant noted, "We inform our community about the importance of the wetland, but we often get a chance to be included in official decision-making forums."

7.1 In what ways does ecofeminism help interpret women's ecological roles and environmental agency?

Ecofeminism examines the ecological roles of women and their environmental agency at Deepor Beel, emphasizing the interconnectedness of their relationships with nature through traditional knowledge, resource management, and their resistance to environmental degradation. It positions patriarchal development as a dual oppression affecting both women and ecosystems. This perspective highlights women as key stewards through everyday activities such as water collection, food gathering, and conservation, challenging their marginalization within formal governance.

7.2 Women's Traditional Roles:

Women residing around Deepor Beel, particularly from the Karbi and Koibortra/Keot communities, are responsible for managing provisioning services such as the cultivation of rice varieties (Bau, Boro, Hali paddy), fishing, and the collection of lotus seeds or water lilies for both food and rituals, including Johong Puja, thereby integrating ecological knowledge into their cultural practices.

Ecofeminism interprets these responsibilities as nurturing extensions of women's labor, which play a crucial role in sustaining biodiversity in the face of challenges such as pollution and encroachment. These issues disproportionately impose longer collection times and health risks on women.

7.3 Environmental Action Examples:

It is found that six young women from Keotpara's fishing community formed Simang, transforming invasive water hyacinths into biodegradable yoga mats and artifacts, removing 50 tonnes of weeds over two years to restore makhana growth and employ many local women though this initiative (DST Report, 2021). The name of the mat is 'Moorhen Yoga mat' named after one of the Assam's famous bird 'Kam Sorai (Purple moorhen, a resident bird of Deepor Beel Wildlife sanctuary)'. Kumbhi Kagaz, another initiative undertaken by two young male, motive to engaged local women by creating new source of income, converts hyacinths into chemical-free paper, enhancing ecosystem services while providing livelihoods (piv.gov.in). Ecofeminism frames this as empowered resistance, retrieving agency from bans on traditional fishing that ignored women's conservation practices like seasonal net use.

7.4 Critics through radical ecofeminism and cultural ecofeminism:

7.4.1 Radical Ecofeminism Insights:

Patriarchal dominance undermines the value of both women and wetlands, such as Deepor Beel, by regarding them as resources to be exploited. This perspective reflects the urban encroachment and waste pollution that severely harm the ecosystem. Women residing in nearby villages are unjustly held responsible for overexploitation, even as urban dangers like the landfills in Guwahati continue to pose significant threats. This situation intensifies existing social hierarchies that restrict their participation in governance. Therefore, it is essential to eliminate these associations in order to empower women against institutional restrictions on traditional fishing.

7.4.2 Cultural Ecofeminism Insights:

The strong connetion that women have with nature is evident in Deepor Beel through projects such as Simang, where 38 women transform invasive water hyacinths into various artifacts, thereby rehabilitating the wetland and creating job opportunities. Organizations like Kumbhi Kagaz eliminate tons of weeds, enhancing the growth of native species and showcasing the nurturing abilities of women that are deeply embedded in traditional gender roles. These initiatives support the perspective of cultural ecofeminism, which regards women as stewards of the environment, while also addressing the economic challenges posed by fishing limitations.

7. What are the social, economic, or institutional constraints on women's participation in Deepor Beel wetland governance?:

Women participating in Deepor Beel wetland governance face multiple social, economic, and institutional constraints that limit their full involvement and influence.

8.1 Social Constraints:

Patriarchal norms limit the decision-making authority and mobility of women outside their homes, largely relegating them to informal positions within the community. According to findings from the FGD, the majority of women participants are not involved in any decision-making processes. Traditional roles of gender prescribe that women should focus on domestic responsibilities, which restrict them to actively participate in governance activities. Additionally, social stigmas and lower literacy levels further hinder women's capacity to engage confidently in public discussions or assume leadership positions within conservation organizations.

8.2 Economic Constraints:

Women in the fishing and agriculture communities of Deepor Beel frequently meet economic instability as a result of restricted access to essential resources, including credit, land ownership, and technological assistance. Although women engage in fish selling and processing, the absence of formal acknowledgment and support results in their earnings being low and inconsistent.

Moreover, the diminishing wetland and environmental degradation pose a threat to their traditional means of livelihood, further intensifying their financial dependence and susceptibility.

8.3 Institutional Constraints:

Formal governance structures and conservation initiatives related to wetlands often marginalize women from leadership and decision-making positions, prioritizing male-centric hierarchies. This institutional oversight is evident in insufficient outreach, policies that do not consider gender, and a deficiency in focused capacity-building or support for women's organizations. The absence of representation in policy-making and planning discussions hinders women's

capacity to impact wetland management strategies or obtain resources for sustainable livelihoods.

9. Conclusion and suggestions:

Women in Indigenous and local communities surrounding Deepor Beel hold specialized expertise in agriculture, medicinal plants, water management, and rituals that are essential for sustaining the wetland ecosystem. This traditional ecological knowledge plays a crucial role in biodiversity conservation and management of natural resources. These knowledge are vital for the sustainability of wetlands. Ecofeminism highlights the connection between women and nature, recognizing women's traditional roles as essential for environmental stewardship. It critiques the ways in which social and economic systems frequently marginalize both women and the environment, while also celebrating the strength of women's indigenous knowledge in restoring ecological balance. In Deepor Beel, women's participation in rituals, folklore, and everyday ecological practices reflects this viewpoint, fostering holistic and culturally grounded conservation. Despite their substantial contributions, women encounter challenges such as the loss of traditional livelihoods, encroaching development, and the erosion of cultural practices, all of which jeopardize the continuity of their knowledge.

Some of the suggestions for inclusion of the indigenous knowledge into the conservation policies are:

- Inclusion of indigenous women in all stages of conservation policy development initiated by Government, ensuring gender-sensitive and culturally appropriate participation.
- Starting of impartial partnerships between conservation authorities and indigenous communities to co-design conservation designs, strategies respecting traditional knowledge.
- Starting documentation of Indigenous Ecological Knowledge with the help of community education and integration into formal learning frameworks.
- Support initiatives promoting sustainable livelihoods aligned with Indigenous practices, such as eco-tourism and small-scale agriculture around Deepor Beel

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The Hidden Curriculum and The Nature of Conflict- Michale W. Apple

Subhamita Paul[1*], Nil Ratan Roy[1]
[1*]*Department of Education, Tezpur University, Tezpur, Assam,*
*Corresponding author
E-mail address: *subhamitapal2@gmail.com*
Contact no.: +91 9330374231

Abstract

The chapter by Michael W. Apple is entitled The Hidden Curriculum and the Nature of Conflict. It is a pioneer work in the sociology of education. The chapter is especially relevant to the researchers who study the issue of hidden curriculum, power relations, and social inequality in educational institutions. The conceptualization of the hidden curriculum by Apple is that of only norms, values, and expectations of behavior that are implicitly taught in structures of school settings, rather than explicitly taught in the formal curriculums. This chapter gives us ideas about how people learn unconsciously, understand social rules, are influenced by family and peers, and how schools help maintain existing social values and structures. Everyday school practices and formal and informal curricula combine to recreate the acceptance of the status quo of politics and economies. To scholars and educators worried about the creation of human qualities like autonomy, empathy, moral reasoning, and social justice, the chapter is a much-needed wake-up call that any meaningful educational reform cannot be achieved without considering the hidden curriculum, and not just the official curriculum.

Keywords: Hidden curriculum; power relations; social inequality; human values.

1. Introduction:

The chapter by Michael W. Apple is a seminal work in the sociology of education, which is called "*The Hidden Curriculum and the Nature of Conflict"*. According to Apple, schools are perceived as ideological locations whereby the hegemonic values are replicated in the routine practices and sessions (Apple, 2004). The chapter is especially important to those scholars who study the hidden curriculum, the relations of power, and social inequality in educational institutions. Apple defines hidden curriculum as implicit norms, values, and behavioral expectations that are deeply rooted in the structure of schools and not necessarily written in formal school curricula (Apple, 2004). These are obedience to authority, hierarchy, competitiveness and institutional compliance. According to him, schooling is a mirror of greater social and economic contradictions specifically struggles of classes, and that knowledge of education is organized in a selective way to legitimize the dominant culture and economic interests (Apple, 2004). In this sense, schools play a crucial role in preparing students for differentiated positions in the labor market. This chapter gives us ideas about how people learn unconsciously, understand social rules, are influenced by family and peers, and how schools help maintain existing social values and structures. How schools teach students about "conflict" through hidden messages in textbooks. The author points out two assumptions that school influences on conflict. The "us" vs. "them" problem is especially common when schools teach about disagreements between different social classes. Students are taught how to deal with authority of the schools. Values are at times interchanged with the norms. The reference to a comparatively specific pattern of what is expected to happen is norm and it is not optional. Value is a deemed issue of choice. For example: Discipline is a value that may be embraced in all the fields of human endeavors yet not everybody can embrace it. When a certain value is internalized by the individual, it becomes a norm by that individual in making a judgement, tastes or an option. Values are also subjective due to the decision of what kind of value an individual can enjoy.

2. Theoretical Contribution:

A major contribution of this chapter is Apple's integration of conflict theory with curriculum studies. Drawing on Marxist and neo-Marxist perspectives, Apple aligns with the reproduction theories of Bowles and Gintis (1976), who argue that schooling mirrors capitalist workplace relations. However, Apple moves beyond economic determinism by introducing the idea of relative autonomy, suggesting that schools are not merely instruments of capitalist reproduction but arenas of ideological struggle where contradictions and resistance may emerge (Apple,

2004). This position distinguishes his work from more structuralist interpretations such as Althusser's (1971) concept of education as an ideological state apparatus.

Theory	**Founder**	**Views on Hidden Curriculum**
Marxist	Karl Marx	Hidden curriculum as a mechanism through which schools reproduce class inequality.
Neo-Marxist	Antonio Gramsci	Hidden curriculum as a cultural and ideological process through which school sustain hegemony.
Correspondence Theory	Samuel Bowles & Herbert Gintis	Hidden curriculum reproduces capitalist social relations through by school norms of discipline, hierarchy and obedience.

From this standpoint, the hidden curriculum prepares students for unequal social roles by cultivating differentiated human qualities. Working-class students are socialized into discipline, passivity, and rule-following. The students of the middle classes are pushed towards leadership, confidence, and expression. This moral and character differentiation leads to reproduction of social inequality, and this seems natural and based on merit (Apple, 1979; Bowles and Gintis, 1976). In a continuation of previous studies, Apple reasons out that hidden curriculum does not only socialize students into passive subjects, but it controls conflict by providing inequality to be natural and merit based.

3. Objectives of the Study:

The present study aims to:

1. To examine Apple's conceptualization of the hidden curriculum in educational settings.
2. To analyse the role of hidden curriculum in reproducing social inequality and power relations.
3. To explore the impact of hidden curriculum on the development of human qualities such as autonomy, empathy, and moral reasoning.
4. To critically evaluate the role of schooling in maintaining or challenging the socio-economic status quo.
5. To assess the relevance of Apple's framework in contemporary educational discourse.

4. Critical Analysis:

One of the key strengths of this analysis (obj: 1 to 4) is its strong theoretical grounding. The argument Apple offers to counter the functionalist views on education as being value-neutral and consensus-based is a persuasive one. His examination of the routine activities, like grading, discipline, tracking and teacher power, is effective to show how ideology can be reproduced through run of the mill institutional mechanisms (Apple, 2004). The other strength also consists in the timeless relevance of this section. Although the arguments put forward by Apple were composed decades ago, they still apply to such problems as standardization, neoliberalism accountability mechanisms and the issue of managerial control in the educational field. Where he focused on ideology with hegemony, legitimate culture and values enter curriculum. The conflict in the society basically on intellectual and normative which are generally ignored in most of the school's curriculum. "Internal dissension and conflict in a society are viewed as inherently antithetical to the smooth functioning of the social order". This emphasis upon students as "value-transmitting" and "value-receiving" persons rather than as "value-creating person". The idea of hegemony, he argued, influences the school in a variety of ways and makes schools more than just distributors of culture, which, in its turn, are essential in the socialization of students. That is, in the process of school and classroom life, students encounter different norms and cultures in form of rules and activities that define the social life in the school.

4.1 Conceptualizing Hidden Curriculum and Human Qualities:

The hidden curriculum is defined by Apple as implicit lessons hidden in the everyday school practice as classroom management, teacher authority, assessment systems and institutional routines that convey what is cherished and rewarded in the society (Apple, 1979). These are practices that build character and dispositions of students, hence affecting the development of human qualities. The hidden curriculum tends to focus on:

- Obedience over autonomy
- Rivalry as opposed to collaboration.
- Conformity over creativity
- Success of moral reflection by means of instrumentality.

These orientations directly relate to the formation of human values such as such as ethical reasoning, self-worth, empathy, and social responsibility (Giroux, 1983; Apple, 2004). One of the reasons to realize the school quality is the hidden curriculum, since no school has identical

hidden curriculum, some schools are better in school performance or quality due to the hidden curriculum they have worked on since all schools have similar formal curriculum as regulated by the government. The school principals are key players to enhancing the quality of schools because of the hidden curriculum they cultivate in the schools, and their execution. He or she controls and organizes the structure of culture, routines, values and practices in school, into a pattern of a regular routine. The practices of hidden curriculum in schools are in two ways i.e. (a) programmed activities i.e. through school missions and extracurricular activities and (b) unprogrammed activities i.e. through the activities of teachers, Practice of school culture, creating a favorable school environment.

4.2 Conflict, Ideology and Moral Socialization:

One of the main contributions to the chapter is the idea of Apple that conflict is a part of schooling, which appears as the contradiction between the principles of democracy and institutional practice that are hierarchical. Nonetheless, the hidden curriculum plays the role of controlling and repressing conflict by normalizing the power systems, grading structures and success in competitions as natural and natural (Apple, 1979). This is a drastic process on human traits:

• Individuals are discouraged to question morally, and they should obey the rules. Subordination to performance metrics is experienced.

• Critical consciousness is substituted with the acknowledgment of institutional norms. Consequently, the process of cultivating ethical autonomy and reflective judgment, which are the most important to the process of the holistic human development, may be impaired unintentionally by schools (Freire, 1970; Apple, 2004).

4.3 Hazards to Human Qualities and Value Education:

Chapter 1 is an eloquent attack on value-neutral arguments in education by Apple. It shows that the values are ever being taught through the hidden curriculum, albeit implicitly. But such values are in most cases oriented towards efficiency, control, and productivity instead of compassion, justice, and human dignity. With respect to research of human qualities, the chapter identifies that:

- Values are acquired not by morality teaching but by institutional culture.
- The development of characters is influenced by the school power relationships.

- Humanity may be limited by the education process that values conformity over awareness.

Therefore, the covert curriculum is critical in affecting student's moral identities, social attitudes and self (Apple, 1979; Giroux, 1983). Apple has a power on its work that it manages to relate micro level practices in school with macro level structures of power and inequality. The chapter offers a sound theoretical perspective through which human qualities are viewed as being social constructions and not as ones that are selected by the individual. Nonetheless, it has a weakness associated with its rather little interest in transformative pedagogies that may undo the impact of the negative influences of the hidden curriculum. Although opposition has also been recognized, more of the focus should be made on emancipatory practices, which would reinforce the value-based and human-centered education structure.

5. **Apple's framework in contemporary educational discourse:**

This part (obj:5) engages researchers to take a critical look at the power relationship in the everyday practice of schooling instead of concentrating on formal curriculum (Apple, 2004). It endorses the application of the qualitative methods including ethnography, critical discourse analysis and narrative inquiry to reveal the concealed processes of control and domination. This is useful to educators and policymakers as it emphasizes the necessity to challenge the seemingly neutralism of such practices as assessment, streaming, and discipline that can strengthen social inequalities without intention. The concept that the formation of human qualities can never exist without the hidden curriculum of schooling is strengthened in this chapter. In that way, one can say that hidden curriculum is, what schooling does to people, or it relates to the non-academic results of schooling. As an illustration, apprenticeship to tradesmen, internships in the hospital, one-on-one music lessons and summer camp--everywhere we can find some hidden curriculum. Another critical element that appears to be vociferously strengthened using hidden curriculum is the gender roles. In case, the poor behavior and attitudes of boys are always targeted, and girls are advised to uplift their self-esteem to pass the test. Gender differentiation is extremely evident among students at a very tender age in the manner the division of labor was carried out in classrooms. As an illustration, when arranging a cultural programmed or an exhibition in school's boys are generally assigned the duties of meeting the people and packing stuffs, setting up the stages whilst girls are assigned the duties of hospitability and presentation among other tasks. The examples indicate that the hidden curriculum may be an indispensable factor in determining the conditions of

social and cultural reproduction in the educational space. Identity formation as such a strong product of hidden curriculum.

6. Connection to the Existing Literature:

The work of Apple is to extend the previous reproduction theories and critique them. Whereas Bowles and Gintis (1976) lay stress on the fact that schooling is related to the capitalistic labor relations, Apple comes out with a more refined perspective that recognizes contradictions in the educational establishments. These ideas are further elaborated on by subsequent scholars, such as Giroux (1983) that focus on resistance, critical pedagogy and student voice. The ethnographic research of Anyon (1980) also adds weight to the theoretical statements of Apple by offering empirical data on the way the social class influences the experiences in the classroom.

7. Limitations:

This is more theoretical in nature and contains little empirical classroom-based information, which can limit their applicability to practitioners interested in having practical examples (Apple, 2004). Also, although the conflict between classes is the focus of analysis, the problem of race, gender, and disability are relatively less discussed, which was later corrected by other critical theorists like Anyon (1980) and Giroux (1983). At some points, the analysis may depict students as passive subjects of ideology and thus overemphasize student agency and resistance.

8. Conclusion:

The Hidden Curriculum and the Nature of Conflict is one of the most prominent contributions to the critical education theory. Apple eloquently shows that education is political in its nature and influenced by the ideological tussles based on the wider social struggle. The absence of an empirical basis and the class-centered orientation in the chapter is, to some extent, a weakness, yet its analytical framework persists in the modern discussion of equity, power, and social justice in education. To researchers and educators who are interested in instilling human qualities of autonomy, empathy, moral reasoning, and social justice, the chapter is a sharp wake-up call in the fact that meaningful educational change needs to confront the hidden curriculum, and not only the formal syllabus.

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Human Development Challenges of Adivasi Women in Assam: A Review of Health and Educational Outcomes

Dibyasri Devi[1*]

[1*]*Research Scholar, Department of Geography, Gauhati University, Guwahati-781014, Assam*
*Corresponding author
E-mail address: dibyasridevi@gmail.com
Mobile No: +91 6000959870

Abstract

Adivasi women in Assam represent one of the most marginalized and historically excluded populations in India, facing intersecting disadvantages rooted in ethnicity, gender, poverty, and limited political recognition. Health and education, as fundamental dimensions of human development and as central pillars of Sustainable Development Goals (SDG 3 and SDG 4), remain critically inadequate among this group. This study adopts a systematic review methodology to examine the health and educational conditions of Adivasi women in Assam. Secondary data were collected from peer-reviewed articles, government reports, census publications, and policy documents, and were analysed using thematic content analysis. The study focuses on maternal and child health, nutritional status, anaemia, literacy levels, educational attainment, and the interrelationship between education and health outcomes. The findings reveal persistent disparities, including high rates of maternal morbidity, widespread anaemia, low institutional healthcare utilisation, high female illiteracy, and significant school dropout rates. Structural barriers such as poverty, spatial isolation, gender norms, and weak policy implementation further exacerbate these conditions. The study concludes that low educational attainment significantly constrains health awareness and healthcare utilisation, reinforcing intergenerational cycles of deprivation. An integrated, gender-sensitive, and culturally responsive policy framework is urgently needed to improve the human development status of Adivasi women in Assam.

Keywords: Adivasi women; health status; education; maternal health; gender inequality; human development; Assam.

1.Introduction:

The history of Adivasi communities in Assam is deeply rooted in the colonial political economy and the expansion of plantation agriculture during British rule. Unlike many tribal groups indigenous to the region, a large section of the Adivasi population in Assam comprises communities forcibly or semi-forcibly migrated from central and eastern India during the nineteenth century to serve as tea plantation labourers (Das, 2000). These communities including Santhal, Munda, Oraon, Kharia, Gond, and Ho were uprooted from regions such as Chotanagpur, Odisha, Jharkhand, and parts of present-day West Bengal. Following the British annexation of Assam in 1826, colonial administrators recruited tribal labourers through coercive practices known as the "coolie system" (Hazarika, 2002), subjecting them to high mortality, deception, and physical abuse.

Once settled, Adivasi labourers were confined to plantation enclaves and subjected to rigid social controls, becoming spatially and socially segregated from mainstream Assamese society. Colonial policies deliberately suppressed education and mobility among labourers to ensure continued dependence on plantation management (Das, 2000). This systematic denial of education and healthcare constitutes the historical foundation of persistent deprivation, most acutely experienced by Adivasi women. After independence, despite the formal abolition of exploitative labour practices, Adivasis in Assam were not uniformly recognised as Scheduled Tribes, limiting their access to constitutional safeguards, reservation benefits, and targeted welfare schemes (Hazarika, 2002). As plantation workers, Adivasi women bore a double burden demanding physical labour alongside full household responsibilities while being denied land ownership, formal education, and healthcare. These historical exclusions continue to shape intergenerational cycles of deprivation.

Against this background, the present study examines the multidimensional human development challenges faced by Adivasi women in Assam, with specific emphasis on health and educational outcomes. The study pursues the following objectives:

2. Objectives of the study:

1. To analyse the prevailing health conditions of Adivasi women, particularly maternal and child health, nutritional status, anaemia prevalence, and access to healthcare services.
2. To assess the educational status of Adivasi women by examining literacy levels, school enrolment, dropout rates, and participation in secondary and higher education.

3. To explore the interrelationship between education and health and how low educational attainment influences health awareness, healthcare utilisation, and intergenerational wellbeing.
4. To identify the socio-economic, cultural, and structural determinants shaping health and educational disparities, including poverty, gender roles, spatial isolation, and historical marginalization.
5. To critically review existing government policies and welfare schemes and to highlight implementation gaps, suggesting integrated and culturally responsive interventions.

3. Literature Review:

The existing body of literature on Adivasi women in Assam provides valuable insights into their socio-economic conditions but remains fragmented, largely sector-specific, and insufficiently gender-focused. Foundational works such as (Das, 2000) offer a broad understanding of tribal life in Assam, documenting structural inequalities in health, education, and socio-economic conditions. (Hazarika, 2002) similarly addresses persistent challenges in healthcare and educational access among tribal populations. While these works establish important historical and structural baselines, they are primarily descriptive and lack the gender-sensitive analytical depth required to understand Adivasi women's specific experiences.

More recent scholarship has moved towards focused, empirical analyses. (Boro and Saikia, 2020) identify key barriers to healthcare utilisation among tribal populations, including economic hardship, geographical isolation, and cultural mistrust of formal medical systems. Their work underscores the need for context-specific interventions that address both structural and cultural dimensions of healthcare access. Gogoi and Singh (2024) establish a strong relationship between maternal health and child wellbeing, demonstrating how poor maternal nutrition directly contributes to adverse child health outcomes including stunting and low birth weight thereby creating intergenerational health deficits. On the educational front, Doley (2022) and Gogoi (2022) document persistently low literacy rates and elevated dropout levels among tribal women in Assam, attributing these to poverty, early workforce entry, and restrictive socio-cultural norms. However, these studies generally treat health and education as separate domains, rarely examining their interdependencies or applying integrated theoretical frameworks such as (Sen's Capability Approach,1999).

A critical gap in the literature is the limited application of intersectional and human development perspectives that consider the combined influence of gender, ethnicity, poverty, and spatial isolation. Moreover, existing research often produces descriptive findings without

translating them into strong, policy-oriented recommendations. The present study addresses these gaps by adopting an integrated framework that examines health and education together, situating findings within a broader human development and capability perspective, and drawing clear policy implications for Adivasi women in Assam.

4. Database and Methodology:

The present study is based exclusively on secondary data collected from a wide range of published and unpublished sources relevant to the health and educational status of Adivasi women in Assam. The database includes peer-reviewed journal articles, academic books, and research reports focusing on tribal communities, women's development, health, and education. Official publications including Census of India reports, National Health Mission (NHM) documents, Integrated Child Development Services (ICDS) reports, Ministry of Tribal Affairs publications, and state government policy documents were extensively consulted. Credible newspaper sources and online repositories were also used to capture region-specific issues pertaining to tea garden labour, maternal healthcare, and educational access.

The study adopts a descriptive and analytical research design with a narrative review approach. Since the primary objective is to critically examine existing knowledge rather than generate primary data, a structured review of literature was undertaken, targeting works published predominantly between 2000 and 2024. Studies were selected on the basis of three criteria: (a) geographic relevance to Assam or comparable tea garden tribal contexts in Northeast India; (b) thematic focus on health, education, or socio-economic conditions of tribal or Adivasi women; and (c) methodological credibility, excluding non-scholarly, unverified, or analytically weak sources. Qualitative thematic content analysis was employed to interpret findings related to maternal health, healthcare utilisation, literacy, school dropout, gender norms, and socio-economic constraints. Comparative analysis was used where possible to assess differences between Adivasi women and the broader population. Secondary data were organised into tables to present key health and educational indicators, structural determinants, and policy interventions in a clear and structured manner. Triangulation of multiple sources was used to enhance reliability and analytical validity.

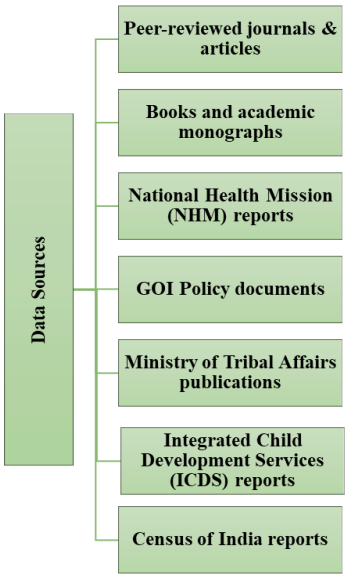

Figure 1: Systematic diagram of secondary data used in the study

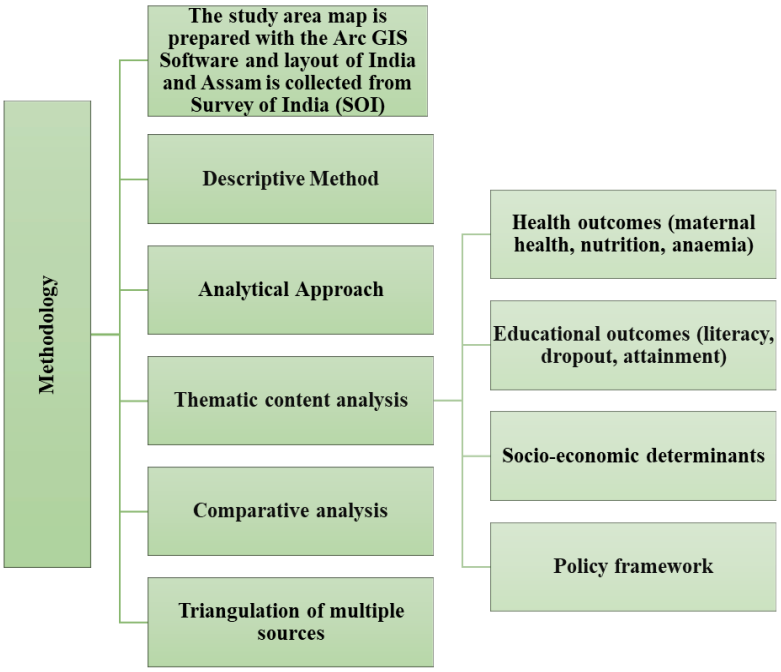

Figure 2: Methodological chart

5. Study Area:

Assam, located in the northeastern region of India between latitudes 24°N to 28°N and longitudes 89°E to 96°E, forms a crucial geographical bridge between South Asia and Southeast Asia. The state is characterised by a diverse physical landscape comprising the Brahmaputra and Barak river valleys, hill ranges, floodplains, and forested regions. Assam shares international boundaries with Bhutan and Bangladesh, and interstate boundaries with

Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, and Meghalaya. This geographical diversity significantly shapes settlement patterns, economic activities, and access to social services.

Adivasi populations in Assam are predominantly concentrated in tea garden areas, forest fringes, and rural plains, particularly in districts such as Dibrugarh, Tinsukia, Jorhat, Golaghat, and Sonitpur in Upper Assam (Das, 2000). Tea garden settlements are typically characterised by inadequate housing, poor drinking water supply, deficient sanitation facilities, and under-equipped healthcare centres. These infrastructural deficiencies have direct implications for the health and education of Adivasi women. Primary health centres in Adivasi-dominated regions frequently suffer from shortages of doctors, medicines, and diagnostic facilities, compelling women to rely on informal healthcare systems or to delay seeking treatment. Similarly, while primary schools are relatively widespread, secondary and higher educational institutions are often located far from Adivasi settlements, with additional language barriers, economic hardship, and limited parental awareness further restricting educational participation. Assam thus provides a critical regional framework for examining the intersection of ethnicity, gender, health, and education, and understanding its colonial legacy, plantation economy, and socio-political dynamics is essential for contextualising the structural inequalities faced by Adivasi women.

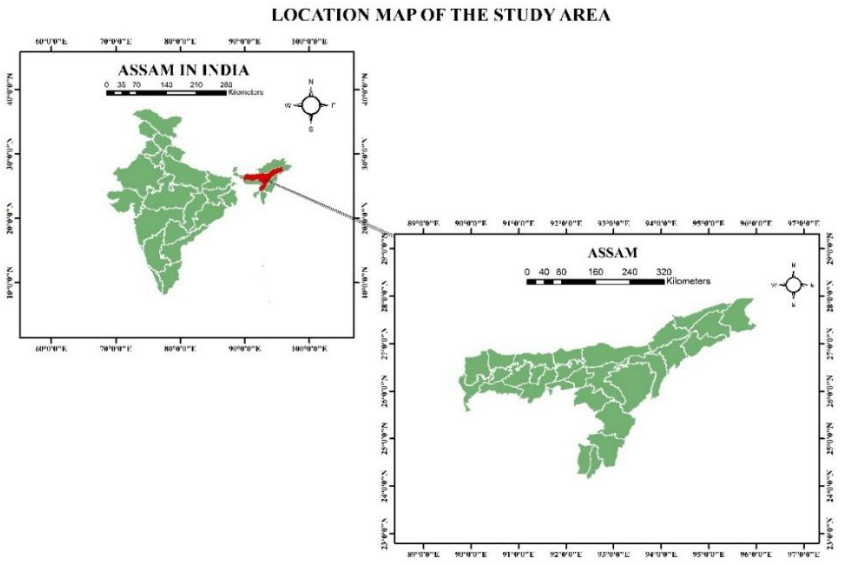

Figure 3: Map showing location of the Study Area

6. Health Status of Adivasi Women in Assam:

The health status of Adivasi women in Assam is characterised by poor nutrition, high prevalence of anaemia, limited access to maternal healthcare, and inadequate utilisation of public health services. Several studies indicate that Adivasi women suffer disproportionately from preventable diseases due to poverty, lack of awareness, and weak healthcare infrastructure (Talukdar, 2015). Tea garden areas, where a large proportion of Adivasi women reside, are marked by substandard living conditions, poor sanitation, and insufficient medical facilities.

Table 1: Major Health Indicators of Adivasi Women in Assam

Health Indicator	**Status**	**Observations**
Maternal mortality	High	Above state average
Anaemia	Very high	Linked to malnutrition
Institutional delivery	Low	Preference for home births
Antenatal care	Inadequate	Limited outreach
Child malnutrition	High	Intergenerational impact

Source: Compiled by author from various sources, including Talukdar (2015); Das (2000); Boro and Saikia (2020) & Gogoi and Singh (2024).

Maternal healthcare remains a critical concern. Many Adivasi women do not receive the recommended number of antenatal check-ups, and institutional delivery rates remain persistently low due to distance from health facilities, transportation constraints, and deep-rooted mistrust of formal healthcare systems (Boro & Saikia, 2020). The preference for home births, often attended by untrained practitioners, significantly elevates the risk of maternal and neonatal mortality. Anaemia among women of reproductive age is widespread, largely resulting from chronic dietary inadequacy, food insecurity, and limited nutritional awareness (Hazarika, 2002). These health disadvantages extend beyond individual women, with severe implications for child health including low birth weight, stunting, and elevated infant mortality thereby perpetuating intergenerational cycles of deprivation (Gogoi & Singh, 2024). Baruah (2023) further highlights significant gaps in reproductive and mental health services for adolescent girls in indigenous communities, pointing to the need for age-sensitive and culturally adapted interventions.

7. Educational Status of Adivasi Women in Assam:

Education among Adivasi women in Assam remains alarmingly low, characterised by high levels of illiteracy and elevated school dropout rates, particularly beyond the primary level. Despite government initiatives aimed at universalising education, structural and socio-cultural barriers continue to severely limit educational attainment among tribal women (Doley, 2022). Economic hardship frequently compels families to prioritise wage labour over schooling, particularly for girls, who are additionally burdened with domestic responsibilities and early marriage.

Table 2: Educational Attainment of Adivasi Women in Assam

Level of Education	**Percentage Range (%)**	**Key Constraints**
Illiterate	60-75	Poverty, lack of access
Primary education	15-25	Early dropout
Secondary education	5-10	Distance, safety issues
Higher education	<5	Economic and social barriers

Source: Compiled by author from various sources, including Das (2000); Gogoi (2022); Hazarika (2002) & Doley (2022).

Low educational attainment restricts Adivasi women's access to information, formal employment, and participation in civic and political decision-making processes. Illiteracy also limits awareness about health, nutrition, family planning, and entitlements under government welfare schemes, thereby reinforcing multiple dimensions of vulnerability (Gogoi, 2022). Studies indicate that even when girls are enrolled in school, irregular attendance and early dropout remain common due to domestic responsibilities, long distances to secondary schools, and a lack of safety and sanitation infrastructure. The near-absence of Adivasi women in higher education (<5%) reflects cumulative systemic exclusion rather than individual choice, underscoring the need for targeted, enabling interventions at each level of the educational pathway.

8. Interrelationship Between Education and Health:

Health and education among Adivasi women are deeply interconnected and mutually reinforcing dimensions of human development. Education enhances awareness regarding

nutrition, hygiene, reproductive health, and the importance of formal medical care, while good health enables consistent school attendance and improved learning outcomes. Conversely, poor health during childhood frequently leads to absenteeism and early school dropout, particularly among girls. This bidirectional relationship, grounded in Sen's (1999) Capability Approach, identifies both education and health as constitutive elements of human freedom rather than merely instrumental to economic productivity.

Table 3: Education-Health Linkages among Adivasi Women

Education Level	**Health Awareness**	**Observed Outcome**
Illiterate	Very low	Poor maternal health
Primary	Limited	Moderate improvement
Secondary and above	High	Better child survival

Source: Compiled by author from various sources, including Das (2000); Hazarika (2002) and Gogoi & Singh (2024)

Empirical studies consistently demonstrate that children born to educated mothers exhibit significantly better nutritional and health indicators compared to those born to illiterate mothers (Gogoi & Singh, 2024). Educated women are more likely to seek institutional delivery, adhere to immunisation schedules, and adopt improved feeding and hygiene practices. This interdependence highlights the necessity of integrated interventions that address education and health simultaneously, rather than treating them as isolated policy domains. Breaking the education-health poverty trap is thus central to achieving meaningful and sustainable human development among Adivasi communities in Assam.

9. Socio-Economic and Cultural Constraints:

The health and educational outcomes of Adivasi women are shaped by a complex web of socio-economic and cultural constraints that interact with, and reinforce, structural inequalities. Poverty and wage insecurity remain the most pervasive determinants, directly limiting access to healthcare, nutritious food, and schooling (Das, 2000). In tea garden contexts, low and irregular wages combined with the absence of land ownership make it difficult for families to prioritise investment in girls' education or non-emergency medical care. Cultural practices and reliance on traditional healers in some communities delay formal medical treatment,

particularly for maternal and reproductive health issues (Baruah, 2023). Gender norms that assign reproductive and household labour exclusively to women further constrain their educational participation and autonomous health-seeking behaviour.

Table 4: Determinants Affecting Health and Education

Determinant	**Impact**
Poverty	Limits access to services
Gender roles	Restrict education and healthcare
Distance	Reduces school and hospital access
Awareness	Low utilization of schemes
Cultural norms	Delay formal treatment

Source: Compiled by author from various sources, including Das (2000) and Baruah (2023)

Historical exclusion from Scheduled Tribe status has further compounded these constraints, denying Adivasi communities access to reservation-based educational quotas, scholarships, and healthcare entitlements available to other tribal groups. Spatial isolation in plantation enclaves and forest-fringe villages compounds these disadvantages, limiting physical access to secondary schools, hospitals, and government offices. Collectively, these interacting determinants constitute a structural trap that reproduces deprivation across generations and resists piecemeal or sector-specific interventions.

10. Government Policies and Interventions:

The Government of India and the Government of Assam have introduced several schemes aimed at improving tribal health and education. The National Health Mission (NHM) seeks to strengthen maternal and child healthcare in rural and underserved areas, while the Integrated Child Development Services (ICDS) targets malnutrition and early childhood development. In the educational domain, the Samagra Shiksha Abhiyan aims to universalise quality education from pre-school to Class XII, and the Tribal Sub-Plan (TSP) channels development funds towards tribal communities. The Panchayats (Extension to Scheduled Areas) Act, 1996 (PESA) provides a framework for local self-governance in tribal areas. While these initiatives have achieved some improvements in coverage, their impact among Adivasi women in Assam

remains constrained by significant implementation gaps, inadequate cultural adaptation, and limited community engagement (Ministry of Tribal Affairs, 2007).

Table 5: Major Government Schemes Targeting Adivasi Women

Scheme	Sector	Objective	Implementation Gaps
NHM	Health	Maternal and child care improvement	Weak outreach in plantation areas
ICDS	Nutrition	Reduce malnutrition and support child development	Irregular supply and understaffed centres
SSA / PMGSY	Education	Universal primary and secondary schooling	High dropout rates persist beyond primary level
Tribal Sub-Plan	Development	Inclusive growth for tribal communities	Poor monitoring and fund diversion
PESA, 1996	Governance	Self-governance and resource rights for tribals	Limited application to tea garden Adivasis

Source: Compiled by author from Ministry of Tribal Affairs (2007); Hazarika (2002)

A recurring pattern across schemes is the disconnect between policy intent and ground-level implementation. ICDS centres in tea garden areas are frequently understaffed, irregularly supplied, and physically inaccessible. NHM outreach is limited by a shortage of female health workers fluent in Adivasi languages, reducing trust and uptake. Educational schemes struggle with high dropout rates beyond primary level, partly because they do not address the economic opportunity costs of schooling for poor families. Moreover, the exclusion of many Adivasi communities from Scheduled Tribe status means that PESA's provisions for local governance and resource rights do not uniformly apply, weakening the institutional basis for community-led development.

11. Results and Discussion:

The integrated analysis presented in this study reveals that Adivasi women in Assam remain subject to systemic, multidimensional disadvantages that are deeply rooted in historical

exclusion and structurally reproduced through the interaction of poverty, gender inequality, spatial isolation, and weak policy implementation. The findings go beyond describing individual deprivations to illuminate the causal mechanisms and mutually reinforcing dynamics that link health and educational outcomes. On health, the data confirm that poor maternal and child health outcomes including high rates of anaemia, maternal morbidity, low institutional delivery, and child undernutrition are not reducible to individual behaviour but are the product of inadequate healthcare infrastructure, economic constraints, and cultural barriers to formal medical utilisation (Boro & Saikia, 2020; Talukdar, 2015). The persistence of these outcomes despite the expansion of NHM and ICDS points to implementation deficits and the failure to develop culturally sensitive, linguistically accessible outreach strategies. Gogoi and Singh (2024) provide compelling evidence that maternal health deficits directly translate into adverse intergenerational outcomes, with low birth weight and child stunting functioning as mechanisms of intergenerational deprivation.

On education, female illiteracy and dropout rates significantly exceed state averages (Hazarika, 2002; Doley, 2022), and secondary and higher educational participation remains negligible. While primary enrolment has improved under national schemes, the transition to secondary education is undermined by economic pressures, domestic responsibilities, gendered norms that deprioritise girls' schooling, and the physical distance to secondary institutions in plantation and rural settings. Critically, the study finds that the education-health relationship is deeply cyclical: higher educational attainment is consistently associated with improved health-seeking behaviour and child immunisation rates, while childhood health crises precipitate school withdrawal (Gogoi & Singh, 2024; Gogoi, 2022). This cyclical relationship constitutes a capability trap, where deprivation in one domain actively reproduces and amplifies deprivation in the other.

The application of Sen's Capability Approach to these findings underscores that the challenges faced by Adivasi women are not merely welfare deficits but fundamental constraints on human freedom and agency. Addressing these challenges requires moving beyond fragmented, sector-specific policy responses toward integrated, community-led approaches that simultaneously strengthen educational infrastructure, healthcare outreach, nutritional security, and economic empowerment. Crucially, any effective intervention must be grounded in an understanding of the specific cultural, linguistic, and historical context of Adivasi communities in Assam.

12. Conclusion:

This review demonstrates that the health and educational status of Adivasi women in Assam constitutes a critical and urgent development challenge. Despite constitutional safeguards and targeted welfare programmes, Adivasi women continue to face structural inequalities shaped by colonial history, poverty, gender discrimination, spatial isolation, and institutional exclusion. Low levels of education constrain health awareness, economic participation, and decision-making capacity, while poor health conditions undermine educational attainment and productivity a bidirectional cycle that resists single-domain interventions.

Improving female education, particularly at the secondary level, emerges as one of the most powerful levers for enhancing health outcomes and breaking intergenerational cycles of deprivation. Simultaneously, strengthening healthcare infrastructure in tea garden and rural tribal areas, ensuring nutritional security through functional ICDS centres, and improving outreach services through culturally adapted, linguistically appropriate health workers are essential complements. The review emphasises that meaningful progress requires not only increased fiscal investment but also effective implementation, rigorous monitoring, community participation, and the political recognition of Adivasi communities within the Scheduled Tribe framework. Empowering Adivasi women through education and health is not merely a welfare objective but a fundamental prerequisite for inclusive and sustainable human development in Assam. Future research should prioritise longitudinal studies, participatory action research, and qualitative methodologies that centre the voices, experiences, and aspirations of Adivasi women themselves, thereby generating contextually grounded evidence for policy reform.

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A comprehensive review on the Sagdeev Potential Approach in Nonlinear Plasma Physics

Archana Haloi[1*], Barsha Boragohain[1], Rajib kumar basumatary[1], Arunav Phukan[2]

[1*]*Department of Physics, Darrang College, Tezpur-784001, Assam*

[2]*Department of Physics, Pandit Deendayal Upadhyaya Adarsha Mahavidyalaya, Behali, Biswanath-784 184*

Assam

*Corresponding author

E-mail address: archanahaloi@gmail.com

Contact no.: 8399944563

Abstract: The Sagdeev pseudo potential method (Chen, 1984, Sagdeev, 1996, Verheest, 2000, Ahmad et al., 2013, Lakhina et al., 2014, Kian and Mahdieh, 2022) is an important theoretical tool to study strongly nonlinear wave dynamics and their structural features in astro-space plasmas environments. This method was first introduced by R. Z. Sagdeev in 1966 (Sagdeev, 1966) and he transformed the nonlinear plasma fluid equations into an energy-like equation which shows the motion of a particle in a potential field. It provides the existence and properties of nonlinear structures such as solitary waves, double layers, shock-like structures and so on. This review summarizes the fundamental concepts and basic mathematical forms of Sagdeev potential method. The physical interpretation of Sagdeev pseudo-potential and their boundary conditions for evolution of the nonlinear waves in astro-space plasma environments are also presented here. Lastly, conclusion together with applications of the technique in the various astrophysical, space and laboratory plasmas are summarised.

Keywords: Sagdeev Potential; Sagdeev Pseudo Potential method; Nonlinear waves; Solitons; Shocks; Double layers.

1. Introduction:

The study of nonlinear waves, oscillations and fluctuations in space, astrophysical and laboratory plasmas has been an importantly emerging area of research for years (Sagdeev, 1966, Chen, 1984, Verheest, 2000, Ahmad et al., 2013, Dubinov, 2022). It provides information about the energy transfer and particle acceleration; structural formation of solitons, shocks, double layers, shock fronts; formation of bounded equilibrium structures, etc. in astro-space-laboratory media (Mace and Hellberg, 1993; Shukla and Mamun, 2002; Paul et al., 2006; Lakhina et al., 2014, Kian and Mahdieh, 2022).

There are various types of waves and oscillations in astro-space and laboratory plasma environments, namely as linear, weakly small amplitude nonlinear and strongly large amplitude nonlinear waves (Chen, 1984, Verheest, 2000, Shukla and Mamun, 2002, Kian and Mahdieh, 2022). These waves, except for linear wave, may appear in the form of solitary waves, double layers, shocks-like etc. (Chen, 1984, Verheest, 2000; Lakhina et al., 2014). Many authors have studied nonlinear waves using various analytical approaches, such as the reductive perturbation technique, nonlinear Schrödinger equation approach, Vlasov equation method, and Sagdeev pseudo-potential method and so on (Sagdeev, 1966; Chen, 1984; Verheest, 2000; Shukla and Mamun, 2002; Duan et al., 2020). Among these approaches, the Sagdeev pseudo-potential technique plays a crucial role in the study of strongly nonlinear (arbitrary-amplitude) waves in astro-space plasma environments as well as in laboratory plasmas. The Sagdeev pseudo-potential method was first introduced by R. Z. Sagdeev in 1966 (Sagdeev, 1966). He showed that the basic plasma fluid equations can be reduced to a conservative energy-like equation that is analogous to the classical equation of motion in mechanics. Using this approach, he theoretically demonstrated the existence of nonlinear (arbitrary-amplitude) waves and explained their structural features, such as solitary waves (solitons) and double layers, in collision less plasmas.

Later, many authors also reported the fluctuation dynamics of these nonlinear waves and their structural features in collisional and dusty plasma media by using Sagdeev pseudo-potential technique (Chen, 1984; Verheest, 2000; Davidson, 2012). Chen (1984) and Davidson (2012) showed that the energy equation associated with the Sagdeev pseudo-potential approach becomes non-conservative in the presence of collisions. In recent decades, the Sagdeev pseudo-potential technique has been widely extended to incorporate various physical effects, such as gravity (Haloi and Karmakar, 2015; Karmakar and Haloi, 2017), magnetic fields (Kian and

Mahdieh, 2022), and bipolar dust grains (Ahmad et al., 2013; Mamun and Schlickeiser, 2015), in astrospace plasma environments. Ahmad et al. (2013) theoretically investigated the strongly nonlinear characteristics of dust-acoustic solitary waves in a dusty plasma containing opposite-polarity adiabatic dust grains and nonthermal electrons and ions using the Sagdeev pseudo-potential framework (Ahmad et al., 2013). Subsequently, Mamun and Schlickeiser (2015) studied the excitation of finite-amplitude dust-acoustic solitary waves in a bipolar dusty plasma system under the influence of gravity in the small-wavelength limit (Mamun and Schlickeiser, 2015). On the other hand, Kian and Mahdieh (2022) theoretically demonstrated the coexistence of positive- and negative-potential dust-acoustic solitary waves (DASWs) in a magnetized dusty plasma configuration by employing the Sagdeev pseudo-potential method (Kian and Mahdieh, 2022).

In this review article, we provide a comprehensive overview of the Sagdeev potential approach in self-gravitating astro-space plasma environments (Sagdeev, 1966; Chen, 1984; Lakhina et al., 2014; Karmakar, 2017; Kian and Mahdieh, 2022, Dubinov, 2022). The review covers the basic concepts and physical interpretation of the Sagdeev potential. We also discuss the boundary conditions required for the Sagdeev potential method and their role in investigating the structural evolution of strongly nonlinear waves. Finally, the applications of nonlinear wave dynamics and their associated structures across various plasma regimes, including astrophysical, space, and laboratory plasmas, are presented.

2. Basic concept and physical interpretation of the Sagdeev potential:

The Sagdeev potential method is used to study the basic concept and physical interpretation of Sagdeev pseudo-potential. It starts with the basic plasma fluid equations which are continuity equation, momentum equation and electro-gravitational Poisson's equations. The basic set of the plasma fluid equations is then transformed into a time-stationary form under the reference frame transformation, $\eta = x - \mu t$ (Sagdeev, 1966, Chen, 1984, Verheest, 2000), where μ is the Mach number (normalized by wave speed). The obtained equations are then integrating under using appropriate boundary conditions (Sagdeev, 1966, Chen, 1984, Verheest, 2000, Lahina et al., 2014, Karmakar et al., 2017, Dubinov, 2022) to reduces into an couple set of energy integral equation as

$$\frac{1}{2}\left(\frac{\partial \Phi}{\partial \eta}\right)^2 + V(\Phi) = 0 \tag{1}$$

And $$\frac{1}{2}\left(\frac{\partial \Psi}{\partial \eta}\right)^2 + V(\Psi) = 0 \qquad (2)$$

Here, Φ and Ψ are the normalised electrostatic and self-gravitational potentials, normalising by the plasma thermal potential and square of the phase (wave) speed. The terms, $V(\Phi)$ and $V(\Psi)$ are the normalised electrostatic and gravitational Sagdeev pseudo potentials. Equations (1) and (2) mean that a pseudo particle oscillates in a potential field Φ in electrostatic case w.r.t η and Ψ in gravitational case w.r.t η, respectively. In both the cases, they provide steady state (stationary) structures.

The couple set of energy equations (1) and (2) are similar to the motion of a particle in classical mechanics (Sagdeev, 1966, Chen, 1984) as

$$\frac{1}{2}mv^2 + U(x) = E, \qquad (3)$$

where, v, U and E are respectively the particle velocity, potential energy and total energy of the particle which is moving in one-dimensional plane.

The behaviours of the pseudo potential depend on the shapes of the Sagdeev pseudo potentials as follows:

1. For the existence of the solitary waves, the Sagdeev potentials (in case of electrostatic and gravitational fields) must be satisfied the following boundary conditions (Chen, 1984, Verheest, 2000, karmakar et al., 2017):

   $V(\Phi) = 0, \quad \frac{dV(\Phi)}{d\Phi} = 0, \quad at \quad \Phi = 0,$

   $\frac{\partial^2 V(\Phi)}{\partial \Phi^2} < 0, \quad at \quad \Phi = 0,$

   $V(\Phi) = 0$, $at \quad \Phi = \Phi_{max}$

   $V(\Phi) < 0$ for $0 < |\Phi| < \Phi_{max}$; and

   $V(\Psi) = 0, \quad \frac{dV(\Psi)}{d\Psi} = 0, \quad at \quad \Psi = 0,$

   $\frac{\partial^2 V(\Psi)}{\partial \Psi^2} < 0, \quad at \quad \Psi = 0,$

   $V(\Psi) = 0$, $at \quad \Psi = \Psi_{max}$

   $V(\Psi) < 0$ for $0 < |\Psi| < \Psi_{\mathbf{max}}$.

The soliton-like structure is a localized nonlinear wave. It corresponds to a bounded motion of a pseudo-particle within a potential well of the system, where the particle returns to its initial equilibrium position after reaching a finite maximum amplitude.

2. For the existence of the shock-like waves, the Sagdeev potentials (in case of electrostatic and gravitational field) must be satisfied the following boundary conditions (Chen, 1984, Verheest, 2002, karmakar et al., 2017):

$$V(\Phi)=0,\ \frac{\partial V(\Phi)}{\partial \Phi}\neq 0, \text{ at } \Phi=0,$$

$$\frac{\partial^2 V(\Phi)}{\partial \Phi^2}<0, \quad \text{at } \Phi=0,$$

$$V(\Phi)\neq 0, \text{ at } \Phi=\Phi_{max}, \text{ and}$$

$$V(\Phi)<0, \text{ for } 0<|\Phi|<|\Phi_{max}| \text{ ; and}$$

$$V(\Psi)=0,\ \frac{\partial V(\Psi)}{\partial \Psi}\neq 0, \text{ at } \Psi=0,$$

$$\frac{\partial^2 V(\Psi)}{\partial \Psi^2}<0, \quad \text{at } \Psi=0,$$

$$V(\Psi)\neq 0, \text{ at } \Psi=\Psi_{max}, \text{ and}$$

$$V(\Psi)<0, \text{ for } 0<|\Psi|<|\Psi_{max}| \text{ ; and}$$

The shock-like structures arise due to the presence of dissipative effects such as viscosity, friction, collisions, etc. in a medium. In a dispersive medium, the dissipative effects must be included in the Sagdeev framework and it resulting in a modification of the conventional Sagdeev potential formalism. The pseudo-particle gradually loses energy and settles into a new equilibrium state in that dispersive medium, leading to the formation of a monotonic and irreversible shock structure.

3. The double layers evolve if the Sagdeev potentials must be satisfied the following boundary conditions (Lakhina et al., 2014, karmakar et al., 2017):

$$V(\Phi,M)=0,\ \frac{\partial V(\Phi,M)}{\partial \Phi}=0,\ \frac{\partial^2 V(\Phi,M)}{\partial \Phi^2}<\text{at } \Phi=0,$$

$$V(\Phi,M)=0,\ \frac{\partial V(\Phi,M)}{\partial \Phi}=0, \text{ at } \Phi=\Phi_{max}, \text{ and}$$

$$V(\Phi,\ M) < 0 \text{ for } 0 < |\Phi| < |\Phi_{max}| \qquad \text{and}$$

$$V(\Psi, M) = 0,\ \frac{\partial V(\Psi, M)}{\partial \Psi} = 0,\ \frac{\partial^2 V(\Psi, M)}{\partial \Psi^2} < \text{at } \Psi = 0,$$

$$V(\Psi,\ M) = 0,\ \frac{\partial V(\Psi, M)}{\partial \Psi} = 0, \text{ at } \Psi = \Psi_{max}, \text{ and}$$

$$V(\Psi,\ M) < 0 \text{ for } 0 < |\Psi| < |\Psi_{max}| \ .$$

The double layer is a localized nonlinear structure and it corresponds to the motion of a pseudo-particle from one equilibrium point to another without returning to its original state, thereby producing a monotonic potential transition.

It is evident that the structural dynamics of strongly nonlinear waves are governed by the aforementioned boundary conditions (Chen, 1984, Verheest, 2002, Lakhina et al., 2014, karmakar et al., 2017). The Sagdeev potential method is applicable to stationary structures of highly nonlinear waves in astro-space plasmas, although its analysis is generally limited to one-dimensional systems. This method provides valuable insights into the structural characteristics of strongly nonlinear waves with arbitrary amplitudes in various astro-space plasma environments. Furthermore, the Sagdeev potential approach can be extended to multispecies plasmas, offering a clear description of the structural and fluctuation dynamics of arbitrary-amplitude, time-stationary, highly nonlinear waves.

3. Conclusion

The Sagdeev pseudo-potential method (Sagdeev, 1966) plays a vital role in exploring the time-stationary structural dynamics of strongly nonlinear waves in various astrophysical plasma environments (Sagdeev, 1966; Chen, 1984; Verheest, 2000; Shukla and Mamun, 2002; Duan et al., 2020, Dubinov, 2022), such as the interstellar medium, cosmic plasmas, the solar wind, and auroral plasmas. This method reduces the complex plasma fluid equations to a time-stationary framework, establishing a simple mechanical analogy that makes it highly effective for analyzing the structural properties of strongly nonlinear waves, despite certain limitations. It is particularly useful for investigating nonlinear wave structures such as solitons, shocks, double layers, and vortices. The method has also been extended to a wide range of plasma systems, including multicomponent, magnetized, and viscous plasmas. Furthermore, the inclusion of self-gravity has opened new avenues for understanding the nonlinear dynamics of

waves, the formation mechanisms of bounded compact objects, and energy transfer processes in astrophysical, space, and laboratory plasma.

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Life Cycle Assessment in Beer Processing System: A Review

Somir Warisa[1*], Toshinungla Ao[2], Arup Jyoti Borah[3]

[1]*Department of Botany, Assam Don Bosco University, Tapesia, Guwahati, Assam.*
[2]*Department of Botany, S. B. Deorah College, Ulubari, Guwahati, Assam.*
*Corresponding author
E-mail address: *somirwarisa@gmail.com

Abstract

Food production and consumption are essential for the survival of humans and it is common that to maintain the demand and value of the agricultural product surplus, the product is processed into a value-added product. However, production and processing are highly dependent on energy and other natural resources. Agrifood systems account of about 16.2 billion tonnes of carbon dioxide emission; therefore, it is essential to analyse the food production system to achieve the goal of sustainability. Life Cycle Assessment (LCA) is a popular technique that studies the sustainability and carbon footprint of a product system following the principles and framework of ISO 14040.This study, reviews the beer processing system and points out the hotspot of the system. A beer-producing system is a high-energy and water-consuming system, especially in the bottle manufacturing phase, which consumes about 85% of the total energy in the system. Using Polyethylene Terephthalate (PET) kegs as packing material has the least emission (64.48 kg CO_2/hl). In the beer production phase, fermentation and the maturing phase consume the maximum energy. The finding of the review indicates packaging material as the major environmental hotspot in the beer-processing system. Adoption of sustainable packaging material, renewable energy and efficient waste management can significantly reduce environmental footprint.

Keywords: Beer; Carbon dioxide; Emission; Energy; Fermentation; Life Cycle Assessment.

1. Introduction:

Food production and consumption are indispensable for human survival. Production and processing of food have evolved simultaneously with human evolution; however, production and processing systems are heavily dependent on energy resources, water, and soil, which contribute to greenhouse gas emissions, eutrophication, biodiversity loss, loss of soil fertility, water scarcity, and other environmental impacts (Huppes et al., 2006; McMichael et al., 2007).

The agricultural system accounts for the emission of 16.2 billion tonnes of carbon dioxide equivalent (CO_2eq) in 2022, which is 10% more since 2000 (Food and Agriculture Organization of United Nations, 2024). The Agrifood system consumes about 30% of total global energy production and accounts for 31% of greenhouse gas emissions (Food and Agriculture Organization of United Nations, 2025). The agrifood systems depend heavily on water availability. On the global average, about 59% of total water withdrawn is used in agriculture, and about 19% is used in industries and food processing (Food and Agriculture Organization of United Nations, 2025).

Agricultural products reach the consumer either through primary processing or secondary processing. In some cases, agricultural products or surplus agricultural products are processed into value-added products such as beer, bread, biscuits, cheese, and yogurt, while in other cases, processing isintended for preservation, like pickles or tomato sauce, etc. These processes significantly increase the market value and maintain the market demand. Any agrifoods industry is directly or indirectly related to carbon emissions; therefore, it is essential to thoroughly analyse the food production and food processing systems to achieve the goal of sustainability of the processes.

Among the processed agricultural products, beer is a very common product; it is a low-alcohol beverage prepared by brewing and fermentation. The raw material for the production is mostly barley, although other crops like maize, rice, wheat, and fruits are also used. The beer market in India is promising, with a value of INR 530.93 billion according to IMRAC Group (2025), and is projected to rise to INR 1364.63 by 2030.

Although the brewing industry has a significant role in the economy, it has a substantial impact on the environment. The brewing process requires a huge amount of water, packing material, agricultural material, and energy, which creates a burden on the environment that includes greenhouse gas emissions, eutrophication, wastewater generation, loss of soil fertility, etc. In recent times, due to anthropogenic activities, greenhouse gas emissions have increased

significantly, which has become a global challenge. The Ministry of Environment, Forest, and Climate Change (MoEFCC), Govt. of India, under the guideline of the United Nations Framework Convention on Climate Change (UNFCCC), monitors the greenhouse gas emissions and sets goals to sequester greenhouse gas for a sustainable environment by setting policies and guidelines. Therefore, evaluating the environmental performance of a beer processing system is an important subject, as it is one of the major revenue-generating industries.

Today there are several methods of analysing the product system for sustainability. One of the most popular methods is life cycle assessment (LCA). This is considered the most reliable method by the European Commission for environmental impact assessment (LCA) (Marrucci et al., 2019). It is a technique that evaluates the whole life cycle of a product process, from raw material extraction to grave.LCA is crucial in the sustainability analysis of a product, as it provides a comprehensive analysis of environmental impact (Ahmed et al., 2019). LCA can point out the hotspots of improvement, like resource consumption, waste generation and emissions, through which most sustainable methods can be adopted, thereby reducing the environmental footprint (Marrucciet al., 2024).

Although several studies have been done on the environmental impact assessment of the brewing industry, most published research is based on specific types of beer, or the data are fragmented with regard to packing material, system boundaries, functional units, etc. in addition to these most available studies are based on European countries, while studies on Indian brewing industries is very limited despite huge market in India. Therefore, a comprehensive review of available literature is essential to better understand the environmental hotspot and sustainability associated with the beer-processing system.

2. Materials and Methodology:

A systematic review of life cycle assessment of beer-processing systems was conducted from scientific literature published in various scientific journals. Published work between 2005 and 2026 was retrieved from Google Scholar, ScienceDirect and Web of Science using the keywords “life cycle assessment”, “brewing industry”, “carbon footprint”, “beer”, “environmental impact”, “brewing” and “resource management”. The retrieved literature was further screened based on the relevance of the study objective. The findings obtained from the reviewed literature were evaluated and presented based on the workflow and principles of life cycle assessment studies.

3. Principles and Framework of LCA studies:

The International Organization for Standardization (ISO) provides the principles and framework to conduct LCA with the latest principles and frameworks that are outlined in ISO 14040:2006. LCA is a standardized methodology based on the principles of ISO that evaluates the environmental impact of the product or service throughout the life cycle. LCA can be applied to different environmental and sustainability-related studies, like risk assessment, environmental performance evaluation, environmental impact assessment and environmental auditing. However, LCA excludes the economic and social aspects of the product, and it does not specify the detailed technique or methodology for each individual phase of the assessment. The intended application of LCA is considered during the goal and scope definition stage of the study (International Organization for Standardization, 2006).

The principles of LCA set the foundational guidelines for planning, conducting, and interpreting an LCA study. A life cycle assessment study takes into account a product's whole life cycle, from raw material extraction to disposal. Secondly, LCA focuses on the environmental aspects and potential impact of the product system on the environment. It is a relative approach, where the assessment is conducted with reference to certain defined functional units. Further LCA is also an iterative approach, as each phase in the LCA depends on the results of the other phases, thereby ensuring a comprehensive and consistent evaluation. Since LCA is a complex process, transparency throughout the process is essential. Moreover, LCA is also a scientific approach, which relies on natural science, international convention, or other scientific methods, and if scientific justification exists, a decision may involve value-based judgements (International Organization for Standardization, 2006).

The general framework of LCA consists of four phases: goal and scope definition, life cycle inventory analysis, life cycle impact assessment, and interpretation. In the first phase, the goal and scope are defined according to the intended application and purpose of the study. The scope defines the important methodological aspects such as functional unit, system boundary, allocation, data requirement, assumption, and limitation. During the life cycle inventory analysis, data are collected and input and output associated with each phase of the system is quantified. The life cycle impact assessment phase evaluates the potential impact on the environment based on the results obtained in the life cycle inventory phase. Finally, with the findings of the inventory phase and impact assessment phase, interpretation is done in the last

phase, and results are delivered based on the defined goal and the scope of the LCA study (ISO, 2006).

4. Common Life cycle Inventory considered in Beer Processing System:

The life cycle inventory phase depends on the definedgoal and the functional unit of the LCA study. In the assessment ofa beer processing system, the goal of the assessment may differ in system boundaries, such as cradle-to-grave, gate-to-gate, or gate-to-grave. A commonly functional unit in beer processing LCA is 1L of beer product. Most of the system boundary goals in beer processing assessment are gate-to-gate and gate-to-grave, depending on the objective of the study. The system boundary generally includes acquiring raw material, transportation, malting, fermentation, packing, distribution, and waste management. The main raw material in a beer-processing system is barley with optional adjuncts like corn, wheat, rice, or fruits, which depend on the type of beer and method of preparation. Hops and yeast are also essential components of the brewing process, and food-grade CO_2 is frequently added in commercially branded beer, which is usually excluded in traditional beers.

A beer processing system also includes several other materials and resources, including cleaning agents, filtration media, packing material, and energy inputs in the form of electricity, heat, and fuel. Water consumption is particularly high in beer processing systems, which are primarily used for cleaning purposes and sanitation that involves the use of detergent. According to several studies, approximately 5.25-7L of water is required for the production of 1L of beer (Koroneos et al., 2005).

Energy is required in multiple stages of the beer-producing system, including malting, hop processing, fermentation, filtration, packaging, distribution, and storage. Approximately 10.3-17.5 MJ/L of energy is required to produce 1 L of beer depending on the type of packaging material (Amienyo & Azapagic, 2016).

Transportation within the supply chain of beer is commonly dependent on fossil fuel-powered vehicles, which contribute to the emission of air pollutants like carbon monoxide (CO), nitrogen dioxide (NO_2), volatile organic compounds (VOC), carbon dioxide (CO_2) and sulphur dioxide (SO_2) (Koroneos et al., 2005).

Packaging material is an important component of beer processing systems and significantly determines the environmental performance of the product. Common packaging materials used in the brewing industry include glass bottles, aluminium and steel cans, polyethylene

terephthalate (PET) kegs and plastic containers. The selection of packaging material depends on several factors, such as stability of product, transportation efficiency, recyclability, storage condition and production cost. In addition to this, the choice of packaging material can significantly influence transportation cost, fuel consumption, and waste generation throughout the life cycle of the product.

In today's life cycle assessment studies, the majority of data are available as a database, which greatly minimizes time in data collection. Databases like Eco invent, Agri-footprint, and ILCD are mostly used to construct the foreground flow of a beer processing system (D'Ascenzo et al., 2024).

5. Life Cycle impact categories in Beer processing system:

The environmental impact of product system can be assessed by different methods based on the defined goal of the LCA and field of the system by using different software available for the study. Widely used software includes Simapro, OpenLCA, and GaBI. These software programs use different standard methods like CML, ReCipe, Eco-indicator 99, IMPACT, IPCC, ILCD 2011, and Environmental Footprint to analyse life cycle inventory. The application of these methods calculates the life cycle inventory and categorises the impact into different groups. Impact categories that are commonly analysed in beer processing systems are global warming potential (GWP), abiotic depletion potential (ADP), terrestrial acidification potential (AP), eutrophication potential (EP), human toxicity potential (HTP), marine aquatic ecotoxicity potential (MAEP), freshwater aquatic ecotoxicity potential (FAEP), terrestrial ecotoxicity potential (TEP), ozone depletion potential (OZP), photochemical oxidant creation potential (POCP) (Amienyo&Azapagic, 2016). In the beer processing system, GWP, AP, EP, and MAEP are considered to have the most significant impact (Salazar et al., 2023). In addition to the above mention categories, LCA can estimate energy demand and water demand and identify the hotspot for sustainability.

The brewing industry is a high-energy-dependent process. Among the energy inputs, diesel (71%) is the most consumed, followed by electricity (21.4%) and natural gas (5.3%) (Koroneos et al. 2005). Bottle manufacturing phase is the major hotspot in the beer-processing system when taken into the system boundary, accounting for approximately 85% of total input energy in the beer-processing industry. Depending on the type of material used for packing, emissions of CO_2 vary significantly. Use of polyethylene terephthalate (PET) kegs has the lowest emission potential, approximately 64.48 kg CO_2/hl. Use of glass bottles and aluminium cans

has comparatively higher emission potential, with approximately 111.30 kg CO_2/hl and 116.64 kg CO_2/hl respectively (Marrucci et al., 2024; Ruggeri et al., 2025). In addition to this use, PET kegs and glass bottles have a significant impact on natural resource depletion, ionising radiation, and photochemical ozone formation. On the other hand, aluminium cans have a significant impact on photochemical ozone formation but have a comparatively lower impact on other categories (Marrucci et al., 2024).

Considering only the brewing process that is excluding the auxiliary phase, most of the energy is consumed during the fermentation and maturation stages. Approximately 49.7 to 61.3% of total energy during the brewing process is consumed during fermentation, and about 38.6% to 50.2% of total energy is consumed during the maturation stage (Salazar et al., 2023). De Marco et al. (2016), in their study, observed that the milling of raw materials consumed more energy compared to the fermentation and maturation phases. They observed that a functional unit of 0.33 L consumes $1.83x10^{-2}$ MJ during milling and about $2.37x10^{-3}$to $4.72x10^{-3}$MJ and $2.15x10^{-3}$ to $2.80x10^{-3}$MJ during fermentation and maturation, respectively.

The beer processing system is also highly water-dependent, needed in various stages. As per the review, it observes 1.52 L (De Marco et al. 2016) to 15.1 L (Salazar et al., 2023) of water is utilized per 1 L beer product. Beer-processing systems generate significant water waste and solid waste including, surplus yeast, sludge, and spent grain. This waste can potentially contribute to water pollution, eutrophication and carbon dioxide and methane emission.

Table 1. Hotspots and potential environmental impact in beer producing system

Hotspots	Source	Potential environmental impact
Raw material production	Fertilizer, agriculture machinery, irrigation	CO_2, N_2O emission, fertilizer related acidification, Loss of soil fertility and eutrophication
Mashing wort production	Heat, water use	Eutrophication and CO_2 emission
	Boiling, fuel	CO_2 emission, fossil fuel depletion, air pollutants
Fermentation	Yeast metabolism	CO_2 emission from yeast metabolism
Maturation	Refrigeration, storage	CO_2 emission, acidification
Packaging	Manufacturing, disposal	High Global warming potential, high waste generation, resource depletion
Distribution	Transportation and fuel combustion	CO_2, NO_2, particulate emission
Sanitation	Cleaning and detergent use	water waste generation
Waste disposal	Sludge, spent grain, surplus yeast	CO2, Methane emission, solid waste generation

6. Conclusion:

For the sustainability of the system, identifying environmental hotspots is essential.From the reviewed studies, it is observed that environmental hotspots occur throughout the entire production system, including the auxiliary phase.Among all stages, themanufacturing of packaging material contributes the highest global warming potential (GWP). Of all packaging materials, glass bottles have the most significant environmental impact, accounting for approximately 55% of total packaging-related emissions, followed by steel cans with around 35%. After packing materials, the cultivation and processing of raw material also have a considerable environmental impact. This impact is primarily associated with the use of fertilizers, which contribute to eutrophication and acidification of soil and water bodies. In addition, the emission of greenhouse gases like NO_2 from fertiliser application or CO_2 from the burning of agricultural residue further increases the environmental burden. Following the cultivation phase, the fermentation and maturation stages also contribute to environmental impact, although their effects are significantly lower impact compared to manufacturing packet material and raw material cultivation.

The review study identified manufacturing of packaging material as the major environmental hotspot. Therefore, adoption of lightweight recyclable packaging materials could significantly reduce the overall environmental footprint of the beer-processing system. Further, the use of renewable energy sources and efficient waste treatment practices would greatly improve the environmental performance of the beer-processing industry.

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Society, Ideology and Socialisation: A Study of Arun and Jyoti in Vijay Tendulkar's KANYADAAN

Rishita Rani Neog*[1]
1: Department of English, Dibrugarh University, Dibrugarh, Assam
*Corresponding author
E-mail address: rishitaranineog@gmail.com
Contact no.: +918822338366

Abstract

This paper aims to reveal how profoundly culture, society, and familial systems and values influence personal identity, decisions, and transformation through a close examination of the characters of Arun Athavale and Jyoti in Vijay Tendulkar's thought-provoking play *Kanyadaan* (1983). It looks into the character of Arun through Henry A. Murray's Theory of Personality and analyse the role of family as an Ideological State Apparatus (concept by Althusser) in shaping the personality of Arun and Jyoti. Arun's behaviour characterised by violence and swings in his emotions and thoughts are result of the constant marginalisation, racial prejudices and inequality that their caste has endured. His underlying insecurities, rage, and complicated behavioural trends comes into light after his interactions with Jyoti and her family. In Jyoti, readers can see how family and its principles, values and ideologies have a crucial effect on an individual. Her journey illustrates the conflict between personal beliefs and the long-lasting effects of social conditioning. As she tries to assert her independence, the lingering influence of her upbringing and societal expectations gradually starts to clash with her idealism, exposing the frailty of individual agency in a highly stratified society. Through the lens of Personology, this paper aims to use psychological theory to gain a deeper understanding of the characters.

Keywords: Psychology, Personality, Ideological, Family, Society.

1. Introduction:

Kanyadaan by Vijay Tendulkar is a powerful exploration of the interplay between interpersonal relationships and socio-political ideologies in modern Indian society. The play confronts the liberal ideals of its time by exposing the continuous tensions between caste, politics, individual agency and ideology. Through the inter-caste marriage of Jyoti, the daughter of an upper-caste reformer, and Arun, a Dalit poet with a troubled past, undergoing series of marginalisation through generations, audiences are forced to face the harsh realities of social inequality, ideological pressures, and psychological trauma through the characters.

By portraying characters who are caught between their inherited beliefs and their lived realities, the drama highlights significant issues. One of the most important of these is whether or not individual choices can truly end oppression and the question of whether an individual is really free from ideologies which they possess or are influenced by. Tendulkar's *Kanyadaan* gives us a layered exploration of how we as members of a family and as an integral part of the society are not free from its ideals. Ideology when talked about along with the concept of development of a personality has its own important role to play. Thus, the intersection of these ideas — Ideology and Personality, provides us with a profound lens to explore how personal identity is shaped and moulded by the influence of family values and social agendas.

According to Murray, a person is shaped through numerous psychological drives like aggression, domination, need for recognition etc. He defines Personology as —

> The branch of psychology which principally concerns itself with the study of human lives and factors that influence their course, which investigates individual differences and types of personality, may be termed 'personology' instead of 'the psychology of personality,' a clumsy and tautological expression. (Murray, 2008).

Murray further emphasises on how needs shape our behaviours and how we tend to submit ourselves to those needs, resulting in them becoming important agents in shaping our personality. He goes on to describe Need as a "construct", a "force" in the brain region which organises "perception, appreciation, intellection, connotation and action" (Murray, 2008).

Althusser calls Ideological State Apparatuses as — "A certain number of realities present themselves to the immediate observer in the form of distinct and specialized institutions" (Althusser, 1971). He goes on to call family as an Ideological State Apparatus through which

children inherit certain ideologies during the process of Socialization. Culture and the society as a whole play a dominant role in shaping the ideology of a person thus forming his or her personality without any overt force in use. In the play Jyoti and Arun's marriage becomes a site where ideological mechanisms can be seen working. While Jyoti inherits an ideology of social equality, Arun is a person who is influenced by the systematic generational dominance that he and his ancestors has been enduring through ages. When Jyoti being born to upper caste parents working for the rights and equality of Dalits is trapped in her Father's dream of a caste-less India, Arun is seen to be moulded by the ideologies of his caste, silenced and suffering through ages. While he walks the path of subaltern resentment, with anger for the upper caste, she is seen being moulded by her father's liberal ideology, looking at the Dalits with sympathetic eyes. In Tendulkar's other plays like Ghashiram Kotwal too many critics have talked about the ideas of power and how power operates in different layers, just like L. Vijayananda and Dr. M. Sarat Babu's research work.

This paper tries to analyse the significant effects of ideologies in a person and how it impacts his thought processes through a study of the characters of Arun and Jyoti using Althusser's concept of Ideological State Apparatus and Murray's theory of Personality to analyse how these concepts are rather interconnected and can be studied together as one (ideologies) shape the other (personality) and provide with arguments how Caste can be seen as an ideology.

2. Objective of the Study:

This paper aims to:

1. Analyse the characters of Arun and Jyoti through the theoretical framework of Personology by Henry A. Murray and also to examine the impact of family and society on them in the light of the concept of Ideological State Apparatus by Louis Althussar.

2. Examine how ideologies shape an individual's thought process and behaviour thus having an effect on their personality.

3. Provide with textual instances which reflect the idea of caste being an ideology passed down during the process of socialisation in the family through generations.

3. Methodology:

This paper employs a qualitative approach grounded in literary theory and personological interpretation to examine the character of Arun and Jyoti in Vijay Tendulkar's *Kanyandaan* (1983). The analysis integrates Louis Althussar's concept of Ideological State Apparatus (ISA) and Henry A. Murray's Theory of Personology to explore how social institutions influence an individual's personality formation. The methodology follows an interpretative textual analysis approach through a close reading of the text, ideological mapping and personality assessment. Apart from the primary text *Kanyadaan*, the study uses a range of secondary sources like scholarly criticisms, journal articles, research papers, essays, books and other reliable online sources to collect information for consideration while using Althussar's essay: "Ideology and Ideological State Appartuses (Notes Towards an Investigation) and Henry A. Murray's text: *Explorations in Personality* as the ground for theoretical analysis.

4. Analysis:

Through the play *Kanyadaan*, the Marathi playwright Vijay Tendulkar introduces the characters of Arun Athavale, a Dalit poet and Jyoti, an educated upper caste woman born to parents who have been actively working for the cause of the Dalits and to build the society as a place where people can live freely without getting constantly targeted by the caste structures and the narratives associated with it. On the surface, although the play can be read as a narrative used to demonstrate the complexities associated with the caste structure and how the character of Nath Devalikar is someone who views the Dalits with very sympathetic eyes, the playwright can be seen giving us with enough instances to believe that the lower castes are not always innocent and free from the ideological trends that they carry with them.

This paper aims to look into the character of Arun through the lens of Personology, a Theoretical framework developed by Henry A. Murray in the 20th century, which basically argues that human beings are driven by a set of basic needs and presses which comes together to act on his or her thoughts and cause the individual to engage in some sort of action to reduce their tension or get their needs fulfilled. In this regard, we can see Arun craving for recognition (the need) and starts behaving in a rather rude manner when things go against his needs. In the particular scene where Jyoti brings him home, Arun is seen behaving not in a very polite way with his prospective mother-in-law Seva, when she questions him about his education, demeaning his worth. When Seva asks questions regarding his plans after completing his B.A,

he replies saying he has not decided on anything yet. When she says what is the use of a mere B.A he immediately answers back saying, that it is of no use at all. Here, is need for the want of recognition seems to be left unfulfilled in Seva's questioning and thus his immediate answering back which is the change in his behavourial trends.

After going on answering back to Seva, Arun gives his final answer "No problem. We shall be brewing illicit liquor" (Tendulkar, 1996) this answer leaves her dumbstruck. He goes on to say how both of them Arun and Jyoti as a married couple can work on that business of high profit and how their children can also be useful later on to help them in the profession as well. This idea challenges Seva's upper caste notions, giving her a reality check on how the lower caste actually survive. Here, the stage direction too has lot to say. The stage direction which describes how Arun is happy now seeing Seva's restlessness gives us a glimpse into the character of Arun, as someone who seeks respect and recognition, his basic needs, which when left unfulfilled leads to his changes in behaviour. This idea of Seva questioning Arun regarding his future according to critics like S. Siraguppi can be seen as "the dilapidated value of education" (Siraguppi, 2025) which can again seen as hypocrisy on the part of Seva taking into consideration her role as an activist who raises her voice for equality on the ground of caste.

According to Murray, dominance is again seen as a need which drives a person to exert control over people inferior to them. In the episode where he is brought to Jyoti's place to meet her family for the very first time, Arun gets uncomfortable in the house and perhaps with the fact that his prospective wife is an upper caste lady brought up in a luxurious environment. His lack of possession of a rich background and family history (his need) leads him to urge for dominance (change in his behaviour) over Jyoti and goes on to hurt her by twisting her hand. After he realises his doing, he says— "Sorry…Don't know what came over me. So sorry. Give me any punishments you like …I'll take it…When anyone throws a challenge at me, I lose all control…Did it hurt so much? Let me see…" (Tendulkar, 1996) Here we can see how Arun is not very conscious about him hurting his wife but readily admits how he is a person who cannot take someone throwing a challenge on him which can be again interpreted as a need for dominance.

Arun's continuous need to assert control over people around him like his in-laws and his wife through his aggressive tone, domestic violence and emotional manipulations can be seen as tools which help him fulfil his needs in different situations. Him beating his wife leaving marks on her body, behaving rudely with her can be seen as is practise of dominance on someone

inferior to him in domestic settings-his wife, a woman. In a particular episode, Arun can be seen kicking Jyoti on her stomach when she is pregnant. This act can make us realise the idea of how powerful can needs and drives be in an individual. It can have an impact to the extent that it makes a person lose all principles and values.

Murray in his work— *Explorations in Personality* (1938) talks about two different "Presses" which can be defined as external forces from the environment that acts on an individuals' internal "needs". (Murray, 2008) The character of Arun can be analysed through these presses— the Alpha and Beta presses. Alpha press (the actual, objective reality of a situation) and Beta press (the subjective or perceived reality of a situation by an individual.) "Arun's character is significantly influenced by "Alpha presses" (objective societal pressures like caste hierarchy, poverty, and discrimination) and "beta presses" his subjective interpretation of these pressures, such as viewing Jyoti's affection as condescension". (Rani et al., 2025) Arun in this regard can again be examined as someone behaving in certain ways because of his perceptions of the realities and that his perceptions might again not be accurate at all times. In this regard again the same episode of Arun visiting Jyoti's home for the very first time can be brought into discussion. The very fact that, Arun tells Jyoti how he becomes violent once he knows that someone is throwing a challenge on him itself is his perception which is not correct. It is rather his own assumption regarding Jyoti's luxurious upbringing that he somehow considered as a challenge and thus hurts Jyoti and not Jyoti directly challenging him with the matter. Through this and many other episodes throughout the play, readers can relate to how it maybe his perceptions that shapes his behavioural trends.

These perceptions can be again influenced by certain ideologies that he has built which has a lot to do with ideas that he has inherited through his family in the process of socialization. Louis Althusser in his essay, gives the concept of two types of Apparatuses— Repressive State Apparatus (RSA), which function through the use of force and violence (includes the Police, Army, courts etc.) and Ideological State Apparatus (ISA) which functions through ideologies rather than the use of force (institutions like family, churches, media etc.)

Althussar calls the ISAs as more powerful than the RSAs. In regard of this play, family acts a dominant ISA because its their values that they inherited from their family, social environment etc. during their upbringing that shapes the characters of Arun and Jyoti. The impact of social narratives and family ideals can be aptly seen in these characters in the play when in the

conversation with Jyoti in her home Arun can be seen getting restless under the concrete roof and goes on to say—

> Our grandfathers and great grandfathers used to roam, barefoot, miles and miles, in the heat, in the rain, day and night…till the rags on their butt fell apart…used to wander shouting 'Johaar, Maayi-baap! Sir-Madam, sweeper! And their calls polluted the brahmins' ears. (Tendulkar, 1996)

These are not random ideas that come to his mind but perhaps stories that he has heard from his parents or other people of the society, reflecting on the idea of the extent to which these social narratives have an impact on an individual and their thought process and how they change a person's way of looking at things. Here, readers can notice how Arun's way of looking at Jyoti's house is influenced by the stories or the discourses he has inherited through the society and primarily from his family. These discourses are instrumental in building up an idea of how luxury is something that is available to the upper-caste only and to the lower-caste. Here, Caste can again be seen as a rigid ideology surviving mostly on narratives passed on through generations.

Family considered as an Ideological State Apparatus by Althusser can be seen as an ideal force moulding Arun's behavioural trend. Growing up in a Dalit family, Arun has heard certain discourses from his family, influenced by which he has built certain ideas and ideologies that frames his needs and drives. Family as the basic unit of socialization, is the most significant factor in building the thoughts of its members and is considered as the most influential power in the process of development of a child. The very fact that this brutal system of caste and the dominance, the discriminatory practices that the upper caste practices or has been practicing since generations was introduced to him by the family, gives us a strong point in favour of how family can be rightly called as an ISA in the play and in caste settings and how through these ideas, the lower caste's attitudes towards the upper caste as ideologies gets transmitted through generations and has severe impact on the mind of people as conscious members of a certain strata of the society.

Arun can be viewed as someone having deep hatred for the upper caste and this is reflected more with his changes in behaviour around Jyoti, a symbol of upper caste for him. This hatred is again not something that he has inherited by birth but something which is shaped through the society, its narratives and family values.

Jyoti, in the play is portrayed as an upper caste woman born to parents who are seen busy working for developing India into a caste-less country. As the daughter of such progressive parents, Jyoti is not free from ideologies that she inherits from her parents. Nath Devalikar is shown as someone who does not possess any sort of negative ideas about the Dalits. He is shown as such a figure who does not even want to consider that the Dalit community for whom he has been working can possess elements of negativity too. When Seva talks to him about how rudely Arun behaved with her and her son Jayprakash and how he went on to hurt Jyoti in her house itself that too before marriage, he was not ready to listen. He goes on to say—

> Look, Seva, society cannot be transformed through words alone. We have to act as catalysts in this transformation. The old social reformers did not stop with making speeches and writing articles on widow remarriage. Many of them actually married widows… (Tendulkar, 1996)

This ideology of Nath of practicing what he has been preaching had an influence in Jyoti too. She too wanted to marry a Dalit boy not all for love but also to uphold her father's principles. Although she knew about how violent Arun is before her marriage itself, she went on to marry him to hold on to the values of equality that she has inherited from her parents. In this regard, the episode where Jyoti's parents discuss about her marriage is crucial. In that scene, when her parents along with her brother Jayprakash discuss her marriage infront of her, it is very clear how her father wants to proceed with this inter-caste marriage to prove his ideals in society. This ideology of her father lets her to accept Arun more readily. Family, the site of ideological inheritance has its role to play in shaping the thought process and ideology of Jyoti, who has nothing but sympathy to offer to her Dalit husband in her race towards equality. In her socialization process, there is seldom any sort of negativity for the Dalits, thus she could not deny Arun's proposal even after facing the reality. She can be seen as remaining positive towards her husband throughout the play.

Arun is again someone who considers domestic violence as something that is quiet normal in marriage. This idea too has to do with his upbringing, where he has seen his father beating his mother numerous times and therefore, he does not consider anything before applying force or violence over Jyoti. Jyoti who grew up in a more liberal environment, in a family which applies "democracy" rather than force during decision making faces the differences that upbringing makes after marriage. Critic P. Priyadarshini also talks about how Jyoti is someone who is not bound by patriarchy, she says in this regard: "Jyoti accomplishesher emancipation in the

domestic colonization; though the egotistical, hypocritical and authoritarian attitude of patriarchy limits women's liberty only in their sexual roles…" (Priyadarshini, 2023)

Children are shaped through the discussions in the family where its inherent ideologies are reflected, through stories that run through generations which has values to offer and ideas takes shape. As members of the family, they get moulded by the ideologies and belief systems of each other (children through their parents) and thus goes on to build their own ideologies which are quite similar to each other.

5. Conclusion:

By analysing the characters of Arun and Jyoti in Vijay Tendulkar's play *Kanyadaan*through the Theory of Personology by Henry A. Murray, and using Althusser's concept of Ideological State Apparatus (ISA) gives us an idea of the layers of interpretations that the play is open to. Through Murray's theory it reveals how a person can be driven by the needs and presses of his psychogenic core that is the very psychological factors that influence an individual's personality and behaviour. The analysis reveals that Arun's rage and violent outburst, are deeply rooted in systemic caste oppression that he and his ancestors has undergone through generations. By analysing both the external and internal factors the study thus tends to position Arun not as someone who is simply violent but as a person with layers of psychological complexity shaped through generations of marginalization and oppression.

The study also went deeper into examining how the personality of an individual is a result of inherent ideologies which they inherit through their family in the process of socialization. Family as an ISA can be seen here to be having integral role to play in the character formation of Arun and Jyoti and thus shaping their needs, emotions and way of looking at settings around them. Thus, this ISA can be seen as an integral part in personality formation and making way for their needs and drives. This study tried to analyse how caste, basically its practices and belief systems can be seen as an ideology, which passes down to newer generations. Whether it is the upper caste or the lower caste, both have their respective narratives, stories and ideologies that they tend to believe in. And these are the prime agents in shaping their core believes throughout generations.

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