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Socioeconomic causes behind alcohol and tobacco consumption in North-East India in comparison with other states of India

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ABSTRACT

The North East (NE) region of India shows much higher rates of alcohol and tobacco usage compared to the national average, particularly among women. States like Arunachal Pradesh, Manipur, Sikkim, Tripura, Meghalaya, Mizoram, and Assam consistently report high usage. Lower educational levels are associated with greater use, particularly among middle-aged individuals. Still, in some NE states, higher female literacy may also reflect greater social acceptance of alcohol among women. Poverty and low socioeconomic status lead to higher spending on alcohol and tobacco, with poorer and unemployed people often spending a larger share of their income on these products. Higher SES is sometimes linked to more frequent, but smaller, drinking; lower SES groups tend to consume larger amounts, often to cope with stress. Manual laborers, unemployed people, and Scheduled Tribe populations in the Northeast use more resources, influenced by cultural and social norms. Family habits and peer influence also raise the likelihood of use. More liberal social norms and workforce participation contribute to higher rates among NE women, and widowed, separated, or divorced women are at greater risk. Alcohol and tobacco use are closely linked. Using one raises the chances of using the other. Spending on these products often comes at the expense of healthcare, food, and education, worsening poverty and health outcomes. Socioeconomic factors such as education, occupation, income, social norms, and culture shape alcohol and tobacco use in NE India. Targeted public health efforts are needed for high-risk groups. This paper aims to estimate the impact of these factors in the Northeastern states.

KEY WORDS

Socioeconomic status; Tobacco; Alcohol; Northeast; Economic impact

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Introduction

Alcohol and tobacco use are major public health issues in India, contributing to various non-communicable diseases and early mortality. Men have significantly higher rates of both tobacco and alcohol use compared to women. Among men aged 15–49, about 53% use tobacco or alcohol, while only 7.4% of women do. Smoking and smokeless tobacco are common among men, while women mainly use smokeless tobacco products [1,2]. Cigarettes and bidis are the primary smoking products for men. Gutkha/paan masala with tobacco is the most common smokeless tobacco used by both genders. Beer is the most famous alcoholic beverage among men, followed by hard liquor [2]. Significant differences in consumption patterns occur at the district and community levels, especially among women. This shows the need for specific interventions [1,2]. Tobacco and alcohol use are generally higher in rural areas than in urban settings, particularly among older adults [3]. Both substances are linked to increased risks of hypertension, diabetes, asthma, and cardiovascular diseases.

Women who smoke, use smokeless tobacco, or drink alcohol have 16%, 8%, and 20% higher odds, respectively, of developing NCDs compared to non-users [4-7]. During the COVID-19 pandemic, tobacco and alcohol use dropped a bit. This decline was clearer among low-income, rural, male, and older groups. In urban areas, alcohol consumption went down more for males and younger people. Exposure to secondhand smoke also went down [8]. The number of new users for both tobacco and alcohol fell during the pandemic [8]. These significant differences in consumption patterns across regions and communities show the need for regular, local assessments and targeted quit programs [1,2]. Socioeconomic factors strongly influence alcohol and tobacco use in India. Patterns vary based on income level, region, education, occupation, and social group. Individuals with lower socioeconomic status, those living in rural areas, and those facing social challenges often have higher rates of both substances. To reduce these behaviors, interventions must address these inequalities and focus on groups that are at risk.

North East India holds significant socioeconomic importance for the country due to its plentiful natural resources, strategic location as a gateway to Southeast Asia, and its potential for economic growth and regional integration. However, the region faces challenges such as infrastructure gaps, underdeveloped industries, and ongoing inequalities. Improving infrastructure and leveraging its strategic location can boost economic growth, reduce disparities, and enhance India's connectivity with its surrounding regions. North East India's location is crucial for India's Act East Policy. This policy focuses on improving trade, connectivity, and cooperation with East and Southeast Asia. Better infrastructure is expected to support regional economic growth and international integration [9-11]. Since 98% of its borders are with other countries, the region has strong potential for cross-border trade and collaboration. This can drive economic development and innovation [9,11].

Alcohol and tobacco consumption are major public health issues in North East India. Cultural, socioeconomic, and demographic factors influence their patterns. This region is known for high rates of both alcohol and tobacco use, along with increased risks to health from using both substances. Men use these substances more than women. Approximately 34% of men in North East India co-use both substances, whereas only 2.3% of women do so. Underage drinking and tobacco use are

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also widespread, with alcohol more common among younger adults and tobacco use increasing with age, especially after 45 years old. Co-use is most frequent among those aged 35 and older [12,13]. Tobacco use among women is geographically concentrated in North East India, with significant hot spots in states like Manipur, Tripura, Meghalaya, Mizoram, and Assam. Alcohol use is a strong predictor of tobacco use among women [14]. Tobacco and alcohol use tend to be more common among poorer and socially disadvantaged households. Spending on these substances often displaces essential expenditures, especially food, among the poorest families [15]. Social interactions and peer groups greatly influence consumption patterns. Targeting these groups can enhance the effectiveness of interventions [15].

The cultural integration of traditional alcohol makes regulatory efforts more difficult [12,16]. Hotspot mapping and understanding sociodemographic factors can help create more effective public health policies tailored to each region. Strategies should involve raising awareness, early detection, and targeted interventions for high-risk groups [4,13,14].

Alcohol and tobacco use in North East India present significant public health and social challenges. Controlling their consumption is crucial because it contributes to higher rates of disease, economic hardship, and social inequality in the region. Both substances are closely linked to an increased risk of head and neck cancers, mainly when used together. In North East India, these substances work together to heighten the risk of high-risk HPV infections, which further raise cancer chances [17]. Use of alcohol and tobacco is particularly high in the region, with many men consuming both. Underage drinking and tobacco use are also prevalent, raising concerns about their long-term health effects [12-14,18]. Spending on alcohol and tobacco reduces household budgets for essentials like food, healthcare, and education. Poor and disadvantaged households are most impacted, often sacrificing food security to afford these substances [15]. The economic burden of purchasing alcohol and tobacco, combined with health costs from related diseases, worsens poverty, especially among the most vulnerable groups [15,19].

This paper endeavors to quantify the impact of socioeconomic factors on alcohol and tobacco consumption in the North-East Indian states.

Literature Review

Alcohol and tobacco consumption in North-East India is significantly impacted by socioeconomic factors such as education, wealth, employment status, and social group. Studies show that substance use rates in this region are much higher than the national average, with disadvantaged populations, particularly those with lower education and wealth, and members of Scheduled Tribes, being most at risk. For both men and women, poverty, illiteracy, and unemployment are strongly associated with higher rates of tobacco and alcohol use. In contrast, higher socioeconomic status tends to reduce the likelihood of consumption, though cultural factors can sometimes override this trend. Among women, greater workforce participation and higher literacy may reflect social liberalization, which can increase reported alcohol use, but overall, low socioeconomic status remains a key driver. Alcohol and tobacco use are also closely linked, often co-occurring, and both are more prevalent in geographic "hot spots" within the Northeast. These consumption patterns not only pose direct health risks but also have economic consequences, as spending on these substances can crowd out essential expenditures, such as food and healthcare, especially among people experiencing poverty. The evidence suggests that targeted interventions addressing both socioeconomic disadvantage and cultural norms are needed to reduce substance use in this region, with a focus on education, poverty alleviation, and community-based strategies.

In this literature review, we will examine selected socioeconomic factors relevant to this study, as described below.

- The Kisan Credit Card (KCC) scheme has dramatically improved the socioeconomic conditions of Indian farmers. It enables them to access affordable credit, which in turn boosts agricultural productivity, income, and quality of life [20-22]. Individuals utilizing the KCC scheme are more likely to adopt modern farming practices, access better education and healthcare, and participate in the service sector compared to those who do not benefit from it [20,23]. Studies from various states, including Odisha, Uttar Pradesh, and Haryana, reveal that KCC users report greater satisfaction with their socioeconomic conditions, higher crop yields, improved resource management, and less financial stress [20-24]. The scheme also promotes financial inclusion by bringing more farmers into the formal banking system, reducing their dependence on informal moneylenders, and lowering credit costs [25,26]. However, the scheme's impact varies by region and is influenced by factors such as education, income, land size, and access to information [24,27]. While some areas have seen significant benefits, challenges still exist in providing equal access and overcoming implementation hurdles [24,28]. Overall, the KCC scheme is recognized as a key driver of rural development and economic empowerment for Indian farmers [20-22].
- Living on alms, relying on charity or minimal social support for survival, greatly increases long-term socioeconomic vulnerability. This situation exposes individuals and households to ongoing instability, limited opportunities, and persistent hardship. People living on alms face chronic shortages of basic needs such as food, shelter, and healthcare, making them highly vulnerable to further shocks and crises [29]. Reliance on alms often results in social exclusion, as individuals must continually prove their vulnerability to access limited support, which reinforces their marginal status and lowers their ability to participate fully in society [29]. The daily disruptions and challenges of living in poverty can become normalized, making it difficult to break free from cycles of deprivation and access stable employment or education [29]. The lack of stable income and resources keeps individuals trapped in poverty, with little chance for upward mobility [29]. Navigating social security systems can be complex and stigmatizing, sometimes limiting access to the very support needed to escape vulnerability [29]. Living on alms sustains long-term socioeconomic vulnerability by entrenching poverty, restricting opportunities, and perpetuating social exclusion. Breaking this cycle requires comprehensive support systems that address both material needs and social integration.
- Household income has a significant impact on socioeconomic mobility patterns for both individuals and their generations. When household income is higher, it typically leads to greater upward mobility. On the other

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hand, lower income often leads to continued disadvantages. There is considerable intergenerational persistence in household income, children from higher-income families are more likely to remain in higher income brackets as adults, while those from lower-income families face greater barriers to upward mobility [30-33]. Mobility rates can vary by region, age, and education level. For example, in the UK, areas with lower average incomes show lower levels of both relative and absolute income mobility [30]. In the US, families headed by younger or less-educated individuals experience less upward mobility [32]. Income and Social Class: Income mobility and social mobility (movement between social classes) are closely linked, with up to 49% of intergenerational income correlations explained by social mobility. However, these patterns can diverge, and the relationship may differ by gender and classification method [34]. Economic growth and financial literacy can enhance income mobility, enabling households to capitalize on new opportunities and improve their socioeconomic status [35]. Factors such as education, family composition, and labor market changes influence the likelihood of moving up or down the income ladder [32,36].In summary, household income is a significant determinant of socioeconomic mobility, with higher income supporting greater upward movement and lower income often reinforcing disadvantage. Addressing barriers such as education and regional disparities is crucial for improving mobility.

- Government jobs usually improve employees' socioeconomic status by offering a stable income, job security, and chances for advancement. Research shows a clear link between government jobs and higher socioeconomic status. This connection can result in better well-being and increased job satisfaction. Government roles often provide more income stability and benefits compared to many private sector jobs. This results in better financial security and an improved socioeconomic status for workers [37,38]. Employees in government positions typically experience greater job satisfaction and happiness, thanks to improved income, education, and financial resources. These factors help lower stress levels and enhance overall well-being [37]. Government jobs are attractive to women, minorities, and people with higher education, which helps raise the socioeconomic status of these groups [38]. Individuals with a higher socioeconomic status often view government work more positively, indicating a cycle where government employment reinforces social standing [39]. By providing stable jobs and benefits, government positions can lower the risk of poverty and promote upward social mobility, particularly in areas or among populations with limited private sector options [38,40]. In summary, government employment plays a crucial role in enhancing the socioeconomic status of employees, providing financial stability, job satisfaction, and opportunities for career advancement. These advantages also contribute to the overall social and economic well-being, especially for underrepresented groups.
- Vehicle ownership has extensive socioeconomic effects, impacting employment, income, urban development, and social mobility. Owning a vehicle is often linked to greater economic opportunities and a better quality of life, but it can also contribute to urban issues and social inequalities. Vehicle ownership is associated with higher employment rates and more hours worked, as it improves access to job opportunities. However, while car ownership increases employment and working hours, its effect on wages is less specific when other factors are taken into account [41]. Higher household income and economic growth are strong indicators of vehicle ownership. In many regions, owning a vehicle is regarded as a symbol of prosperity and upward social mobility [42-45]. Vehicles are often seen as status symbols, especially in developing cities, and can reflect or reinforce social standing. In some situations, lower-income households usually own cars as a means of social status. Meanwhile, people with higher education may choose not to own cars [46,47]. Car ownership influences urban development by increasing the demand for road infrastructure. It also contributes to urban sprawl and traffic congestion. Compact urban layouts and good public transportation are associated with lower car ownership [43,48]. Vehicle ownership can widen social inequalities, as higher-income and centrally located households are more likely to own cars. Policies affecting vehicle costs (like fuel prices or regulations) can influence ownership rates and have implications for equity [42,48,49]. Increased vehicle ownership often leads to more congestion and pollution, particularly in rapidly growing cities [43,44]. In summary, vehicle ownership boosts economic opportunities and social mobility but also presents challenges related to urban congestion, inequality, and environmental impacts. Balanced policies are crucial for maximizing benefits while minimizing adverse effects.

Objectives of the study

To quantify the impact of different relevant socioeconomic factors on alcohol and tobacco consumption by men and women aged 15 Years and above in India and North East India at the district level.

Data collection

The entire analysis was conducted using secondary data from the Socioeconomic Caste Census, 2011, and the National Family Health Survey (NFHS-5), 2019-20. These data were collected at the district level from the National Data and Analytics Platform (NDAP). These two datasets have been merged in this platform. The Socioeconomic Caste Census (SECC) 2011 examines the socioeconomic status of rural and urban households and allows ranking based on predefined parameters. The National Family Health Survey (NFHS) provides information on population, health, and many other important indicators.

Research Methodology

The analysis was performed using a generalized additive model. Generalized Additive Models (GAMs) offer a flexible approach to statistical modeling, particularly when examining non-linear relationships between predictors and a response variable. As a versatile and effective method, a generalized additive model (GAM) extends the scope of linear regression by incorporating nonlinear interactions between variables. GAMs help analyze complex data that show non-linear patterns, such as time series and spatial data, or when the relationships between predictors and the response variable are hard to describe with simple linear functions. While traditional linear regression models assume a linear relationship between predictors and the response, many real-world situations involve non-linear, complex relationships. GAMs overcome this limitation by using smoothing functions to model these relationships flexibly. This makes GAMs a

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valuable tool for capturing data patterns that linear models might overlook.

A generalized additive model (GAM) is a generalized linear model in which the linear response variable depends linearly on unknown smooth functions of one or more predictor variables, and the focus of interest is on inference about these smooth functions [50-55].

Basic Components of a GAM

- Linear Predictors: GAMs include linear predictors, similar to traditional linear regression modeling, but they also incorporate additional components.
- Smooth Functions: GAMs employ smooth functions to capture non-linear relationships. These functions are typically spline functions or other types of smooth curves.
- Link Function: Like generalized linear models (GLMs), GAMs use a link function to relate the expected value of the response variable to the linear predictor.
- Additive Structure: GAMs are additive models, meaning that the contribution of each smooth function is additive, allowing for the modeling of complex relationships as a sum of simpler components.

It is well-known that any multivariate function can be represented as a sum and a composition of univariate functions.

$$f(\vec{x}) = \sum_{q=0}^{2n} \Phi_q \left(\sum_{p=1}^{n} \phi_{q,p}(x_p) \right)$$

However, they require highly complex functions and are therefore not suitable for modeling approaches. Thus, GAMs dropped the outer sum and ensured the function belonged to a simpler class.

$$f(\vec{x}) = \Phi \left(\sum_{p=1}^{n} \phi_p(x_p) \right)$$

Where the above is a smooth monotonic function. Writing g for the inverse of this function, this is traditionally written as

$$g(f(\vec{x})) = \sum_i f_i(x_i)$$

When this function is approximating the expectation of some observed quantity, it could be written as

$$g(E(Y)) = \beta_0 + f_1(x_1) + f_2(x_2) + \cdots + f_m(x_m)$$

This is the standard formulation of a GAM.

Analysis and interpretation

The analysis begins with the development of four generalized additive models for men and women's tobacco and alcohol consumption based on socioeconomic variables such as households with Kisan Credit Cards with a credit limit of 50000 rupees and above, households living in destitution or on alms, households with a monthly income of the highest-earning member less than 5000, households with a government salaried job, households with a government job and reporting a monthly highest income greater than 5000, households with a monthly income of the highest-earning member between 5000 and 10000, and households having a four-wheeler vehicle.

Two models have been developed for the all-India district level, and two models have been developed for the north-eastern states district level. The variables considered in this analysis are renamed as shown in Table 1 below.

Table 1. Renamed variables used for developing linear and generalized additive models.

Variables	Variables Renamed
Women Age 15 Years and Above Who Consume Alcohol (%)	V120
Men Age Group 15 Years and Above Who Consume Alcohol (%)	V62
Men Age Group 15 Years and Above Who Use Any Kind of Tobacco (%)	V78
Women Age 15 Years and Above Who Use Any Kind of Tobacco (%)	V133
Households Having Kisan Credit Card with The Credit Limit Of 50000 Rupees and Above	V26
Households With Destitute or Living on Alms	V38
Households With Monthly Income of Highest Earning Member Less Than 5000	V59
Households With Salaried Jobs in Government	V70
Households With a Government Job and Reporting a Monthly Highest Income Greater Than 5000	V92
Households With Monthly Income of Highest Earning Member Between 5000 And 10000	V95
Households Having Four Four-Wheeler Vehicles	V117

All the developed models incorporate linear models, generalized additive models (GAMs), and diagnostic checks for smooth basis dimensions within the GAM framework. The analysis also includes ANOVA-based comparisons between linear models and generalized additive models to evaluate improvements in model fit, along with an assessment of the marginal effects produced by the GAMs.

In R's statistical output, the symbols ***, **, *, ., and blank spaces shown in the "Signif. codes" line denotes the statistical significance of model coefficients based on their p-values. These symbols—referred to as significance codes—are automatically generated by R when displaying model summary tables. The interpretation of these codes is provided in Table 2.

Table 2. Interpretation of significance codes in R.

Symbol	P-value Range	Significance Level	Interpretation
***	$0 < p \leq 0.001$	0.10%	Highly significant
**	$0.001 < p \leq 0.01$	1%	Strongly significant
*	$0.01 < p \leq 0.05$	5%	Statistically significant
.	$0.05 < p \leq 0.1$	10%	Marginally significant
(blank)	$0.1 < p \leq 1$	—	Not significant

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These codes correspond to the p-values in the Pr(>|t|) column for linear models or the Pr(>|z|) column for generalized linear models. Smaller p-values indicate stronger evidence that the respective coefficient differs significantly from zero.

Socioeconomic Causes Behind Men's Alcohol Consumption: All India Districts

Tables 3, 4, and 5 present the generalized additive model, the diagnostic checks for smooth basis dimensions, and the marginal impacts of the smooth terms, respectively, for the socioeconomic factors influencing men's alcohol consumption at the All-India District level.

Table 3. Generalized additive model (GAM) for men's alcohol consumption at the all-India district level.

Family: Gaussian

Link function: Identity

Formula:

V62 ~ s(V26, bs = "cr", k = 70) + s(V38, bs = "cr", k = 70) + s(V59, bs = "cr", k = 70) + s(V70, bs = "cr", k = 70) + s(V92, bs = "cr", k = 100) + s(V95, bs = "cr", k = 70) + s(V117, bs = "cr", k = 150)

Parametric coefficients:

Term	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	22.1413	0.3869	57.22	<2e-16***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate Significance of Smooth Terms

Smooth Term	edf	Ref.df	F	p-value
s(V26)	25.912	30.312	1.22	0.196
s(V38)	8.556	10.051	4.936	0.000 ***
s(V59)	1.002	1.004	8.221	0.004 **
s(V70)	1.002	1.003	2.816	0.094 .
s(V92)	3.425	4.336	2.567	0.030 *
s(V95)	4.494	5.591	6.713	0.000 ***
s(V117)	9.372	11.328	4.347	3.02E−06 ***

Model Summary:

- Adjusted R^2 = 0.428
- Deviance explained = 47.7%
- GCV = 102.55
- Scale estimate = 93.568
- n = 625

Table 4. Check out smooth basis dimensions.

Term	k'	edf	k-index	p-value
s(V26)	69	25.912	1.032	0.785
s(V38)	69	8.556	1.045	0.865
s(V59)	69	1.002	1.045	0.863
s(V70)	69	1.002	1.032	0.803
s(V92)	99	3.425	1.044	0.868
s(V95)	69	4.494	1.031	0.78
s(V117)	149	9.372	0.97	0.175

Table 5. Marginal impact of smooth terms.

Smooth Term	x
s(V117)	−0.00003022
s(V26)	−0.00008760
s(V38)	−0.00079938
s(V59)	0.00001592
s(V70)	0.00107704
s(V92)	−0.00093322
s(V95)	−0.00007764

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Socioeconomic Causes Behind Men's Alcohol Consumption: All Northeast India Districts

Tables 6, 7, and 8 present the generalized additive model, the checks for smooth basis dimensions , and the marginal impacts of the model, respectively, for the socioeconomic factors influencing men's alcohol consumption at the district level in Northeast India.

Table 6. Generalized additive model (GAM) results for men's alcohol consumption in Northeast India districts.

Family: Gaussian				
Link function: Identity				
Formula:				
V62 ~ s(V26, bs = "tp", k = 70) + s(V38, bs = "tp", k = 70) + s(V59, bs = "tp", k = 70) + s(V70, bs = "tp", k = 70) + s(V92, bs = "tp", k = 70) + s(V95, bs = "tp", k = 70) + s(V117, bs = "tp", k = 80)				
Parametric coefficients:				
Term	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	34.476	1.148	30.02	<2e-16***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Approximate Significance of Smooth Terms				
Smooth Term	**edf**	**Ref.df**	**F**	**p-value**
s(V26)	1.026	1.052	0.739	0.389
s(V38)	1.352	1.626	11.614	0.000 ***
s(V59)	8.619	9.608	2.481	0.013 *
s(V70)	1	1.001	0.578	0.449
s(V92)	1.001	1.001	0.547	0.462
s(V95)	1.001	1.001	0.124	0.726
s(V117)	1.008	1.015	0.277	0.603

Model Summary:

- Adjusted R^2 = 0.414
- Deviance explained = 50.4%
- GCV = 155.76
- Scale estimate = 130.57
- n = 99

Table 7. Check out smooth basis dimensions.

Term	k'	edf	k-index	p-value
s(V26)	69	1.026	0.962	0.298
s(V38)	69	1.352	1.235	0.983
s(V59)	69	8.619	0.987	0.423
s(V70)	69	1	1.229	0.993
s(V92)	69	1.001	1.075	0.72
s(V95)	69	1.001	0.999	0.485
s(V117)	79	1.008	0.886	0.118

Table 8. Marginal impact of smooth terms.

Smooth Term	x
s(V117)	−0.00041293
s(V26)	0.00197915
s(V38)	−0.01608238
s(V59)	0.00006121
s(V70)	−0.00286214
s(V92)	0.00307524
s(V95)	−0.00012304

Socioeconomic causes behind women`s alcohol consumption: All India Districts

Tables 9, 10, and 11 present the generalized additive model, the checks for smooth basis dimensions, and the marginal impacts of the generalized additive model, respectively, for the socioeconomic factors influencing women's alcohol consumption at the all-India district level.

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Table 9. Generalized additive model (GAM) results for women's alcohol consumption: All India districts.

Family: Gaussian

Link function: Identity

Formula:

V120 ~ s(V26, bs = "cr", k = 70) + s(V38, bs = "cr", k = 70) + s(V59, bs = "cr", k = 70) + s(V70, bs = "cr", k = 70) + s(V92, bs = "cr", k = 100) + s(V95, bs = "cr", k = 70) + s(V117, bs = "cr", k = 150)

Parametric coefficients:

Term	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.7512	0.1999	13.76	<2e-16***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate Significance of Smooth Terms

Smooth Term	edf	Ref.df	F	p-value
s(V26)	1.949	2.461	2.384	0.082 .
s(V38)	4.97	5.791	1.169	0.334
s(V59)	1	1	0.406	0.525
s(V70)	1	1	0.432	0.511
s(V92)	1.003	1.005	0.422	0.516
s(V95)	1.004	1.007	1.432	0.232
s(V117)	24.993	29.393	7.523	<2e−16 ***

Model Summary:

- Adjusted R^2 = 0.354
- Deviance explained = 39.1%
- GCV = 26.541
- Scale estimate = 24.973
- n = 625

Table 10. Check out smooth basis dimensions.

Term	k'	edf	k-index	p-value
s(V26)	69	1.949	1.04	0.833
s(V38)	69	4.97	1.071	0.97
s(V59)	69	1	1.015	0.585
s(V70)	69	1	1.129	1
s(V92)	99	1.003	0.998	0.47
s(V95)	69	1.004	1.07	0.973
s(V117)	149	24.993	1.044	0.845

Table 11. Marginal impact of smooth terms.

Smooth Term	x
s(V117)	−3.16E−04
s(V26)	−1.90E−05
s(V38)	2.33E−05
s(V59)	1.72E−06
s(V70)	2.14E−04
s(V92)	−2.22E−04
s(V95)	−1.10E−05

Socioeconomic Causes Behind Women's Alcohol Consumption: All Northeast India Districts

Tables 12, 13, and 14 present the generalized additive model, the checks for smooth basis dimensions, and the marginal impacts of the generalized additive model, respectively, for the socioeconomic factors influencing women's alcohol consumption at the district level in Northeast India.

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Table 12. Generalized additive model (GAM) results for women's alcohol consumption in Northeast India districts.

Family: Gaussian

Link function: Identity

Formula:

V120 ~ s(V26, bs = "tp", k = 70) + s(V38, bs = "tp", k = 70) +
s(V59, bs = "tp", k = 70) + s(V70, bs = "tp", k = 70) +
s(V92, bs = "tp", k = 80) + s(V95, bs = "tp", k = 70) +
s(V117, bs = "tp", k = 80)

Parametric coefficients:

Term	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.9848	0.8318	10.8	<2e-16***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate Significance of Smooth Terms

Smooth Term	edf	Ref.df	F	p-value
s(V26)	1.006	1.011	0.435	0.512
s(V38)	1.001	1.003	7.006	0.010 **
s(V59)	8.634	9.589	3.156	0.003 **
s(V70)	7.655	8.732	1.735	0.096
s(V92)	1	1	1.247	0.268
s(V95)	1.001	1.001	0.024	0.877
s(V117)	6.116	6.776	2.387	0.0353 *

Model Summary:

- Adjusted R^2 = 0.360
- Deviance explained = 53.2%
- GCV = 94.716
- Scale estimate = 68.489
- n = 99

Table 13. Check out smooth basis dimensions.

Term	k'	edf	k-index	p-value
s(V26)	69	1.006	1.074	0.73
s(V38)	69	1.001	1.28	0.995
s(V59)	69	8.634	0.959	0.283
s(V70)	69	7.655	1.159	0.93
s(V92)	79	1	1.054	0.613
s(V95)	69	1.001	1.071	0.748
s(V117)	79	6.116	0.964	0.313

Table 14. Marginal impact of smooth terms.

Smooth Term	x
s(V117)	−0.00088960
s(V26)	0.00134901
s(V38)	−0.00854873
s(V59)	0.00006347
s(V70)	−0.00365429
s(V92)	0.00411554
s(V95)	0.00004305

Socioeconomic Causes Behind Men's Tobacco Consumption: All India Districts

Tables 15, 16, and 17 present the generalized additive model, the checks for smooth basis dimensions, and the marginal impacts of the generalized additive model, respectively, for the socioeconomic factors influencing men's tobacco consumption at the all-India district level.

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Table 15. Generalized additive model (GAM) results for men's tobacco consumption: All India districts.

Family: Gaussian				
Link function: Identity				
Formula:				
V78 ~ s(V26, bs = "cr", k = 70) + s(V38, bs = "cr", k = 70) + s(V59, bs = "cr", k = 70) + s(V70, bs = "cr", k = 70) + s(V92, bs = "cr", k = 100) + s(V95, bs = "cr", k = 70) + s(V117, bs = "cr", k = 150)				
Parametric coefficients:				
Term	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	41.6698	0.4011	103.9	<2e-16***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Approximate Significance of Smooth Terms				
Smooth Term	**edf**	**Ref.df**	**F**	**p-value**
s(V26)	6.902	8.288	3.234	0.001 **
s(V38)	24.141	28.322	5.121	<2e−16 ***
s(V59)	2.86	3.593	4.074	0.005 **
s(V70)	9.195	11.804	1.901	0.032 *
s(V92)	16.619	20.325	1.696	0.030 *
s(V95)	3.622	4.526	6.771	0.000 ***
s(V117)	2.191	2.749	23.845	<2e−16 ***

Model Summary:

- Adjusted R^2 = 0.482
- Deviance explained = 53.6%
- GCV = 112.54
- Scale estimate = 100.56
- n = 625

Table 16. Check out smooth basis dimensions.

Term	k'	edf	k-index	p-value
s(V26)	69	6.902	0.964	0.218
s(V38)	69	24.141	1.01	0.575
s(V59)	69	2.86	0.993	0.403
s(V70)	69	9.195	1.061	0.935
s(V92)	99	16.619	1.045	0.893
s(V95)	69	3.622	0.998	0.47
s(V117)	149	2.191	1.028	0.733

Table 17. Marginal impact of smooth terms.

Smooth Term	x
s(V117)	−3.54E−04
s(V26)	−1.38E−04
s(V38)	−1.32E−03
s(V59)	−9.17E−06
s(V70)	−4.00E−04
s(V92)	5.60E−04
s(V95)	−4.47E−05

Socioeconomic Causes Behind Men's Tobacco Consumption: All Northeast India Districts

Tables 18, 19, and 20 present the generalized additive model, the checks for smooth basis dimensions, and the marginal impacts of the generalized additive model, respectively, for the socioeconomic factors influencing men's tobacco consumption at the district level in Northeast India.

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Table 18. Generalized additive model (GAM) results for men's tobacco consumption in Northeast India districts.

Family: Gaussian

Link function: Identity

Formula:

V78 ~ s(V26, bs = "tp", k = 70) + s(V38, bs = "tp", k = 70) +
s(V59, bs = "tp", k = 70) + s(V70, bs = "tp", k = 70) +
s(V92, bs = "tp", k = 70) + s(V95, bs = "tp", k = 70) +
s(V117, bs = "tp", k = 80)

Parametric coefficients:

Term	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	55.1778	0.6541	84.36	<2e-16***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate Significance of Smooth Terms

Smooth Term	edf	Ref.df	F	p-value
s(V26)	13.521	14.86	0.716	0.744
s(V38)	3.757	4.175	0.932	0.388
s(V59)	1.099	1.139	1.029	0.313
s(V70)	1.265	1.339	0.084	0.922
s(V92)	1.242	1.314	0.089	0.838
s(V95)	1.318	1.447	0.02	0.948
s(V117)	42.968	46.138	1.608	0.0737

Model Summary:

- Adjusted R^2 = 0.565
- Deviance explained = 85.4%
- GCV = 127.72
- Scale estimate = 42.356
- n = 99

Table 19. Check out smooth basis dimensions.

Term	k'	edf	k-index	p-value
s(V26)	69	13.521	1.01	0.473
s(V38)	69	3.757	1.032	0.57
s(V59)	69	1.099	1.098	0.815
s(V70)	69	1.265	1.177	0.943
s(V92)	69	1.242	1.095	0.825
s(V95)	69	1.318	0.916	0.19
s(V117)	79	42.968	1.142	0.9

Table 20. Marginal impact of smooth terms.

Smooth Term	x
s(V117)	0.04296648
s(V26)	0.00714186
s(V38)	−0.01164890
s(V59)	0.00020856
s(V70)	0.00177421
s(V92)	−0.00279434
s(V95)	−0.00009671

Socioeconomic Causes Behind Women's Tobacco Consumption: All India Districts

Tables 21, 22, and 23 present the generalized additive model, the checks for smooth basis dimensions, and the marginal impacts of the generalized additive model, respectively, for the socioeconomic factors influencing women's tobacco consumption at the all-India district level.

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Table 21. Generalized additive model results: Socioeconomic causes behind women's tobacco consumption (All India Districts).

Family: Gaussian

Link function: Identity

Formula:

V133 ~ s(V26, bs = "cr", k = 70) + s(V38, bs = "cr", k = 70) + s(V59, bs = "cr", k = 70) + s(V70, bs = "cr", k = 70) + s(V92, bs = "cr", k = 100) + s(V95, bs = "cr", k = 70) + s(V117, bs = "cr", k = 150)

Parametric coefficients:

Term	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	12.021	0.3888	30.92	<2e-16***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate Significance of Smooth Terms

Smooth Term	edf	Ref.df	F	p-value
s(V26)	54.7	59.077	1.922	0.000 ***
s(V38)	19.793	23.296	3.295	0.000 ***
s(V59)	2.209	2.788	1.743	0.163
s(V70)	5.651	7.017	1.541	0.151
s(V92)	4.619	5.827	1.948	0.073
s(V95)	1.004	1.007	7.847	0.005 **
s(V117)	1.276	1.5	3.1	0.046 *

Model Summary:

- Adjusted R^2 = 0.378
- Deviance explained = 46.7%
- GCV = 110.42
- Scale estimate = 94.471
- n = 625

Table 22. Check out smooth basis dimensions.

Term	k'	edf	k-index	p-value
s(V26)	69	54.7	1.065	0.958
s(V38)	69	19.793	1.032	0.768
s(V59)	69	2.209	1.007	0.515
s(V70)	69	5.651	1.124	0.998
s(V92)	99	4.619	1.01	0.593
s(V95)	69	1.004	1.059	0.918
s(V117)	149	1.276	1.031	0.785

Table 23. Marginal impact of smooth terms.

Smooth Term	x
s(V117)	-0.00012391
s(V26)	0.00193513
s(V38)	-0.00177245
s(V59)	-0.00000231
s(V70)	0.002403
s(V92)	-0.00272972
s(V95)	-0.00005631

Socioeconomic Causes Behind Women's Tobacco Consumption: All Northeast India Districts

Tables 24, 25, and 26 present the generalized additive model, the checks for smooth basis dimensions, and the marginal impacts of the generalized additive model, respectively, for the socioeconomic factors influencing women's tobacco consumption at the district level in North East India.

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Table 24. Generalized additive model (GAM) Results for women's tobacco consumption in North East India districts.

Family: Gaussian

Link function: Identity

Formula:

V133 ~ s(V26, bs = "tp", k = 70) + s(V38, bs = "tp", k = 70) +
s(V59, bs = "tp", k = 70) + s(V70, bs = "tp", k = 70) +
s(V92, bs = "tp", k = 80) + s(V95, bs = "tp", k = 70) +
s(V117, bs = "tp", k = 80)

Parametric coefficients:

Term	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	28.148	0.224	125.7	2.34E−07 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate Significance of Smooth Terms

Smooth Term	edf	Ref.df	F	p-value
s(V26)	15.306	15.695	0.244	0.979
s(V38)	1.099	1.102	0.064	0.877
s(V59)	7.579	7.91	0.11	0.993
s(V70)	1.014	1.015	0.713	0.464
s(V92)	1.134	1.138	1.21	0.334
s(V95)	25.85	26.379	0.46	0.882
s(V117)	42.617	43.089	1.008	0.586

Model Summary:

- Rank: 503/504
- Adjusted R^2 = 0.983
- Deviance explained = 99.9%
- GCV = 144.62
- Scale estimate = 4.9674
- n = 99

Table 25. Check out smooth basis dimensions.

Term	k'	edf	k-index	p-value
s(V26)	69	15.306	1.098	0.848
s(V38)	69	1.099	1.116	0.865
s(V59)	69	7.579	1.003	0.488
s(V70)	69	1.014	1.117	0.868
s(V92)	79	1.134	1.089	0.815
s(V95)	69	25.85	1.168	0.94
s(V117)	79	42.617	1.334	0.998

Table 26. Marginal impact of smooth terms.

Smooth Term	x
s(V117)	−0.2407372053
s(V26)	0.133102585
s(V38)	−0.0190961206
s(V59)	0.000969021
s(V70)	0.015423796
s(V92)	−0.0234275454
s(V95)	−0.0235797818

Discussion

The findings from the literature and the empirical analysis show that the socioeconomic environment of North-East India greatly influences patterns of alcohol and tobacco use. The evidence shows that household wealth, education, employment status, and social identity are key factors in consumption behavior [56-58]. People from low-income backgrounds, particularly those with low education levels or who are part of Scheduled Tribes, often show higher rates of substance use. Shifting social norms and cultural traditions affect these courses. Gender roles are becoming less strict.

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This shift can reduce the protective effects typically connected to economic improvement. Results from the generalized additive model back up these findings and provide statistical detail. The analysis indicates that steady income sources, such as salaried government jobs, typically result in reduced reliance on tobacco and alcohol. However, this pattern can differ from one district to another. Owning four-wheelers, which indicates economic mobility, has a small but steady negative relationship with consumption levels.

In contrast, households that rely on charity or have consistently low incomes are more likely to have higher usage rates. This scenario reflects both financial strain and limited health awareness. The non-linear patterns found in the models also emphasize that increases in income or employment do not always lead to healthier behaviors across different regions. Gender differences are significant. Greater reported alcohol use is linked to higher literacy and increased workforce participation for women in the North-East. This phenomenon suggests that higher social independence may come with more exposure to lifestyle risks. These complexities show how modernization, empowerment, and local cultural norms interact. This leads to changes in traditional consumption patterns. Moreover, the close link between alcohol and tobacco use increases both economic and health vulnerabilities, especially in poorer communities [4,58-64]. The replacement of necessary spending, on food, education, and healthcare, with spending on alcohol and tobacco adds to socioeconomic distress in the region. Both qualitative insights from previous studies and quantitative data confirm that lower-income households face a greater economic burden from these substances. Interventions should extend beyond behavioral campaigns. They must also include structural reforms that focus on reducing poverty, improving education, and carrying out culturally appropriate awareness programs.

In conclusion, the connection between observed patterns and real results indicates that tackling substance use in North-East India needs a multi-faceted approach. Policy responses need to acknowledge that consumption is influenced by personal choices and also by strong socioeconomic and cultural factors. A good strategy should blend public health efforts with targeted social development actions. This method will encourage changes in both structure and behavior over time.

Conclusions

A range of socioeconomic determinants, including possession of Kisan Credit Cards with substantial credit limits, residence in destitution or reliance on alms, income stratification, government employment status, and ownership of four-wheeler vehicle, exert non-linear effects on tobacco and alcohol consumption among both men and women across Indian and Northeast Indian districts. In the context of men's alcohol use, the data indicate that households possessing a four-wheeler vehicle, those with members living on alms, and those reporting a moderate monthly household income (between ₹5,000 and ₹10,000) consistently demonstrate reduced alcohol consumption, in both Indian and northeastern districts. For women's alcohol consumption, the analysis identifies four-wheeler ownership as the singular variable exerting a negative association with usage rates in both Indian and northeastern states. About men's tobacco consumption, both residence in destitution and moderate monthly household income emerge as protective factors that are robust across the two regional categories. Finally, for women, a multifaceted set of factors, including four-wheeler ownership, living on alms, employment in government positions at higher earnings, and household income between ₹5,000 and ₹10,000, are each associated with diminished tobacco use, underscoring the contextually contingent and complex nature of socioeconomic impacts on health-related behaviors at the district level in India.

Disclosure Statement

The authors declare that they have no competing interests.

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