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BAHIR DAR UNIVERSITY
COLLEGE OF MEDICINE AND HEALTH SCIENCES
SCHOOL OF PUBLIC HEALTH

THE EFFECT OF EXPOSURE TO CHARCOAL ON RESPIRATORY HEALTH AMONG TRADITIONAL CHARCOAL PRODUCERS IN AMHARA REGION, NORTHWEST ETHIOPIA

BY

MULUGETA TESFA GEBEYEHU (MPH IN EPIDEMIOLOGY)

JANUARY, 2026

BAHIR DAR, ETHIOPIA

BAHIR DAR UNIVERSITY
COLLEGE OF MEDICINE AND HEALTH SCIENCES
SCHOOL OF PUBLIC HEALTH

The Effect of Exposure to Charcoal on Respiratory Health among Traditional Charcoal Producers in Amhara Region, Northwest Ethiopia

By

Mulugeta Tesfa Gebeyehu (PhD Candidate)

This PhD Dissertation Submitted to the School of Public Health, College of Medicine and Health Sciences, Bahir Dar University, in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Public Health

Supervisors:

Primary Advisor: Dr. Muluken Azage (PhD, Associate Professor)

Co-advisor: Dr.Achenef Motbainor (PhD, Associate Professor)

January, 2026

Bahir Dar, Ethiopia

DECLARATION

I hereby declare that the PhD dissertation entitled Effects of Exposure to Charcoal on Chronic Respiratory Diseases, Mask Use among Charcoal Producers, and Trends, Seasonality and Forecasting of Chronic Respiratory Diseases, and Spatial, Temporal and Spatiotemporal Variations of Chronic Respiratory Disease, in Amhara region, northwest Ethiopia submitted to School of Public Health, College of Medicine and Health Sciences, Bahir Dar University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Public Health is my original work. It has not been submitted before, in whole or in part, for any degree or qualification at this or any other institution.

I affirm that no part of this PhD dissertation paper has been copied or reproduced from any other work except where due acknowledgment has been made. All sources of information, data, and ideas drawn from other published or unpublished materials have been duly cited and acknowledged in accordance with academic standards.

I also confirm that the work was conducted in line with the ethical principles and guidelines set by the Institutional Review Board of Bahir Dar University, College of Medicine and Health Sciences, including obtaining informed consent from participants and ensuring the confidentiality and integrity of the data collected.

This research is the result of my personal effort and reflects my own findings, interpretation, and conclusion, completed under the invaluable mentorship, critical insights, and continuous guidance of my supervisors, Dr. Muluken Azage and Dr. Achenef Motbinor.

Name: Mulugeta Tesfa Gebeyehu

Signature

Date 29-January-2026

ADVISORS APPROVAL

The PhD dissertation entitled Effects of Exposure to Charcoal on Chronic Respiratory Diseases, Mask Use, and Trends, Seasonality and Forecasting of Chronic Respiratory Disease, and Spatiotemporal Variations of Chronic Respiratory Disease, in Amhara region, Northwest Ethiopia submitted by Mulugeta Tesfa Gebeyehu in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Public Health at the School of Public Health, College of Medicine and Health Sciences, Bahir Dar University, Ethiopia, has been carried out under my supervision.

I have thoroughly reviewed the PhD dissertation and found that it meets the required academic standards in terms of scope, depth, methodological rigor, and relevance. The candidate has demonstrated the ability to conduct independent research, and the dissertation offers a valuable contribution to the field of study.

With this in mind, I fully approve the PhD dissertation and recommend its submission to the external examiners for final evaluation and oral defense.

Dr. Muluken Azage Signature …….. Date: 29-January-2026

Primary supervisor

Dr. Achenef Motbinor Signature …….. Date: 29-January-2026

Co-supervisor

Bahir Dar University
College of Medicine and Health Sciences
School of Public Health
Dissertation Approval

The Effect of Exposure to Charcoal Production on Respiratory Health Among Traditional Charcoal Producers in Amhara Region, Northwest Ethiopia

By: Mulugeta Tesfa

APPROVED BY THE EXAMINING BOARD

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DEDICATION

This dissertation is dedicated to my beloved wife Mrs.Muluye Molla and our lovely children Hailemichael, Kalkidan, Kirubel and Natenalel Mulugeta; this work is dedicated to you, with all my heart. Your endless love, unwavering support, constant encouragement, and the countless sacrifices you made have carried me through every challenge of this PhD study journey.

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Lastly, to my dearest friends, your encouragement has been a source of strength and light throughout this long and often challenging path. With deep love and heartfelt appreciation, I dedicate this work to each of you.

LIST OF ORIGINAL PAPERS

This PhD dissertation is based on the four original papers, which are listed here.

Paper I: Tesfa M, Motbainor A, Yenesew MA. Trends, seasonal variations and forecasting of chronic respiratory disease morbidity in charcoal producing areas, northwest Ethiopia: time series analysis. Frontiers in Epidemiology. 2025; 4:1498203.

https://doi.org/10.3389/fepid.2024.1498203

Paper II: Gebeyehu MT, Begosew AM, Teni M, Yenesew MA. Spatial, temporal, and spatiotemporal variations of chronic respiratory disease in charcoal-producing areas, northwest Ethiopia. Scientific Reports. 2026. https://doi.org/10.1038/s41598-026-40554-y

Paper III: The effects of exposure to charcoal production on chronic respiratory diseases among traditional charcoal producers in Amhara region, northwest Ethiopia. (Under review in the Journal of BMC Pulmonary Medicine with ID 447d94b1-0505-4649-9e66-998ab421fdc3)

Paper IV: Proportion and determinants of respiratory mask utilization among traditional charcoal producers in Amhara region, northwest Ethiopia:

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I am truly indebted to my parents, whose lifelong prayers, love, and values have been the foundation of all my achievements.

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Lastly, my heartfelt thanks go to my dear friends for their constant encouragement and companionship during this academic journey.

ABSTRACT

Background: Chronic respiratory diseases (CRDs) are a leading cause of global mortality and disability, with a disproportionate burden in low-and middle-income countries, particularly in Sub-Saharan Africa. In Ethiopia, the prevalence of CRDs is rising, yet these conditions remain largely neglected, especially among high-risk groups such as traditional charcoal producers who are routinely exposed to harmful smoke, gases, and particulate matter from rudimentary earth-mound kilns. However, existing studies in Ethiopia are limited in scope, largely focusing on seasonal variations or short-term pharmacological prescription data from specific locations. Consequently, there is a gap in comprehensive epidemiological research that assesses the impact of traditional charcoal production exposure on CRD morbidity and the experience of charcoal producers on personal equipment utilization, alongside investigating spatial, temporal, and spatiotemporal trends and variations of CRDs in Ethiopia, particularly in the current study area.

Objective: To assess the trends and seasonality, and spatial and spatiotemporal variations of CRD, effect of charcoal exposure on chronic respiratory diseases, and prevention practices in the Amhara region, northwest Ethiopia.

Method: A retrospective study was conducted using seven years data (2012/2013–2018/2019) on CRD cases among individuals aged ≥15 years. The data were extracted from DHIS2 monthly reports from 44 districts in Awi, East Gojjam, and West Gojjam Zones to address objective I and II, whereas a community-based cross-sectional studies were employed among adults aged ≥ 18 years using multistage sampling from randomly selected districts in West Gojjam and Awi zones for objective III and IV. For the time-series analysis, smoothing decomposition was used to explore trend and seasonality, and an ARIMA (2,1,2) (0,0,0) model was applied for forecasting, with model selection based on Bayesian information criteria. Stationarity was evaluated using line plots and the Ljung-Box Q-test. Spatial analysis included Poisson-based scan statistics via SaTScan version 10.1 to detect clusters, Global Moran's I for spatial autocorrelation, and Getis-Ord Gi* for hotspot analysis. ArcGIS version 10.8 was used for mapping. Propensity score matching (nearest neighbor, 1:3 ratio, caliper 0.05 standard deviations) was used to minimize baseline differences, followed by logistic regression to estimate the average treatment effect on the treated and overall

treatment effect. Bivariate and multivariable binary logistic regression analyses were used to identify significant risk factors for CRD symptoms and mask utilization. Model fitness was assessed by the Hosmer and Lemeshow goodness-of-fit test, and multicollinearity was checked using the Variance Inflation Factor.

Results: The annual morbidity rate of CRD has shown an increasing trend in both sexes over seven years among people aged 15 years and older from 305 (95%CI: 286,530) to 731(95%CI: 641, 1455) per 100,000 population in 2012/13 and 2018/19, respectively. Seasonal variations in CRD morbidity were also observed. The smoothing decomposition analysis depicted that the seasonal component was attributed to 44.47% and 19.16% of excess CRD cases in the period between September and November, and June to August, respectively. Forecasting with the ARIMA model revealed that CRD-related morbidity would continue to increase in the next ten years (2020-2030). The global spatial autocorrelation (Moran's I=0.2772, Z-score=3.6597, and P-value<0.001) shows a strong clustered distribution. The most likely purely spatial and spatiotemporal clusters were detected in eleven districts, and eight of these were in the Awi zone. The high LLR reflecting that the concentration of cases in this area and time period is not random but represents a true high-risk cluster. The Getis-Ord Gi hot spot analysis detected that hot spot clusters were primarily located in the northwest and southwest parts of the study area**.**

A total of 217 participants were included in the study, with a response rate of 97.1%. Of the participants, 67% were male, and the median age was 38 (IQR: 30-47) years. Exposure to charcoal was significantly associated with CRD. The average treatment effect on the treated (ATET) showed higher likelihood of CRD symptoms among producers (ATET = 0.42, $p < 0.001$). The results suggest that if individuals exposed to the charcoal had not been exposed, their likelihood of developing the CRD symptoms would have been reduced by about 42%. If all individuals were exposed to charcoal production, CRD symptoms would increase by 36.7% (ATE = 0.367, $p < 0.001$). Furthermore, the findings indicates that eliminating/reducing exposure to charcoal production emissions could prevent about 38% of respiratory disease symptoms in the community. The findings of this study also showed, old age (AOR=1.02; 95%CI: 1.01–1.03; p<0.044), engaging in charcoal production (AOR=7.72; 95%CI: 5.61–10.65; p<0.001), living in villages where charcoal production is practicing (AOR=2.52; 95%CI: 1.83–3.46; p<0.001), and engaging

in farming as an occupation (AOR=1.65; 95%CI: 1.18–2.30; p<0.004) were significantly associated with increasing the odds of CRD symptoms. Nonetheless, the odds of having CRD symptoms were decreased among men (AOR=0.73; 95%CI: 0.54–0.99; p<0.001), having more rooms in the house (AOR=0.80; 95%CI: 0.68–0.94; p<0.005), animals living in a separate room (AOR=0.57; 95%CI: 0.42–0.77; p<0.001), and houses having a separate kitchen (AOR=0.67; 95%CI: 0.49–0.91; p<0.02) compared to those houses without it.

Among 685 participants who were engaged in charcoal production, only 87(12.7%) producers utilized masks in the workplace. Having good knowledge (AOR=1.96; 95%CI: 1.20, 3.17; p<0.006), a favorable attitude (AOR=3.33; 95%CI: 2.01, 5.50; P<0.001), and engaging in combustion activity (AOR=3.19; 95%CI: 1.55, 6.54; P<0.002) were significantly associated with increasing the odds of utilizing a mask in the workplace. Conversely, older age (AOR: 0.98; 95%CI: 0.95, 0.99; p<0.045) and working for long hours in a day (AOR=0.46, 95%CI: 0.24, 0.91; P< 0.024) decreased the odds of mask utilization.

Conclusion

The study demonstrated a significant association between charcoal production exposure and increased CRD symptoms. Factors such as age, sex, occupation, number of rooms, animals living place, and place of cooking were significantly linked to CRD symptoms. Charcoal producers showed poor mask use, which was influenced by age, knowledge, attitude, type of engagement during production, and working hours. CRD morbidity increased from 2013 to 2019, with peak rates from September to November, and is projected to continue rising from 2020 to 2030. Spatiotemporal analysis showed non-random clustering of CRD cases, with hotspots in the northwest and southwest of the study area.

These findings underscore the need to improve traditional charcoal production methods and reduce exposure among vulnerable populations. Safety training is essential to enhance knowledge and attitudes toward mask use. Identified hotspot areas should be prioritized for intervention. Further research is needed to explore risk factors and health facility readiness in high-risk clusters.

Key words

CRD Symptoms, PSM, Charcoal producers, trends, ARIMA, Spatiotemporal, SaTScan

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ACRONYMS AND ABBREVIATIONS

ACF	Auto-correlation Function
AOR	Adjusted Odds Ratio
AR	Auto-regression
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
ARIMA	Auto-regression Integrated Moving Average
ATE	Average Treatment Effect
ATET	Average Treatment Effect of Treated
BDU	Bahir Dar University
BIC	Bassian Information Criteria
CI	Confidence Interval
COPD	Chronic Obstructive Pulmonary Disease
COR	Crude Odds Ratio
CRD	Chronic Respiratory Diseases
DALYs	Disability Adjusted Life Years
DHIS2	District Health Information System-2
HICs	High-Income Countries
IQR	Inter Quartile Range
KAP	Knowledge, Attitude, and Practice
LLR	Log Likelihood Ratio,
LMICs	Low-and Middle-Income Countries
MA	Moving Average

NCDs	Non-communicable Diseases
ODK	Open Data Kit
OR	Odds Ratio
PACF	Partial Autocorrelation Function
PAF	Population Attributable Fraction
PPE	Personal Preventive Equipment
PSM	Propensity Score Matching
RR	Relative risk
SDGs	Sustainable Development Goals
SMD	Standardized Mean Difference
SMD	Standardized Mean Difference
SPSS	Statistical package For Social Science
SSA	Sub-Saharan Africa
TCP	Traditional Charcoal Production
VIF	Variance Inflation Factor
WHO	World Health Organization

CHAPTER ONE: INTRODUCTION

1.1. Introduction

Chronic respiratory diseases (CRDs) are among the most commonly reported health problems in people exposed to harmful pollutants, particularly in areas where biomass fuel use is common. Exposure to traditional charcoal production are frequently exposed to risky pollutants during production activities. This exposure poses a serious health risk, particularly to their respiratory system, due to the inhalation of toxic chemicals(1). In low-and middle-income countries, including Ethiopia, charcoal production activity is performed using the traditional technology (earth mound kilns), which exposes producers and communities living around to the harmful substances(2). In many informal small-scale sectors, the use of personal protective equipment among workers is limited, and awareness of exposure to pollutants remains low. Moreover, diseases often exhibit seasonal and geographic variation, necessitating studies that explore their temporal and spatial distribution.

In Ethiopia, where charcoal plays a key role in energy source, economy, and rural livelihoods, there is limited research that explores how exposure to charcoal production is affecting charcoal producers' respiratory health. Even less is known about how respiratory problems vary over time and across different areas, or how personal protective measures are being used in real-life field settings.

This dissertation aims to address these gaps by examining the relationship between exposure to charcoal production and respiratory diseases among traditional charcoal producers. It brings together four related but distinct papers. The first examines the trends, seasonal variations, and forecasting of respiratory diseases. The second demonstrated the spatial, temporal, and spatiotemporal distribution of respiratory illnesses across different districts. The third explores the health effects of participating in charcoal production on the respiratory system. The fourth investigates the extent of personal protective equipment (mask) use among traditional charcoal producers in work place and the factors that influence their practices. Together, these four papers provide a comprehensive picture of the health risks linked to engaging in the traditional charcoal

production activity and offer insights that can support better protection and policy interventions for the traditional charcoal producers and community living around the production areas.

1.2. Background

Chronic respiratory diseases are diseases of the airways and the other structures of the lungs(3). They are among the most common non-communicable diseases (NCDs)(4) leading to death and disability, up to 6.7% of all NCDs in 2019 (3). Asthma and chronic obstructive pulmonary disease (COPD) are the most common types of CRDs(5). Asthma is a heterogeneous disease, usually characterized by chronic airway inflammation. It is defined by the history of respiratory symptoms such as wheeze, shortness of breath, chest tightness, and cough that vary over time and in intensity(6). COPD is a common, preventable, and treatable disease that is characterized by persistent respiratory symptoms and airflow limitation that is due to airway and or alveolar abnormalities usually caused by significant exposure to noxious particles and gases(6). Both asthma and COPD are types of lung diseases and are classified as obstructive respiratory diseases (7, 8).

Chronic respiratory diseases develop gradually as a result of continuous exposure to harmful environmental and occupational factors such as smoke, dust, and air pollutants. When these substances are inhaled, they irritate and damage the lining of the airways, making it more sensitive and less able to protect itself (9, 10).

This repeated injury triggers the body's defense system, leading to ongoing inflammation in the lungs. At the same time, these exposures increase oxidative stress, which further damages lung cells and worsens the inflammatory response. As a result, the airways begin to produce excess mucus, and their ability to clear it becomes impaired(11-13).

The Global Burden of Disease 2019 report shows that asthma is the leading CRD, affecting 262.4 million people, causes 96% of global asthma-related deaths and 84% of disability-adjusted life years (DALYs) in low- and middle-income countries, followed by COPD, which affects over 212 million adults worldwide (11). The number of COPD cases globally among those aged 25 years and older will increase by 23% from 2020 to 2050(14)

Among causes of respiratory disease-related morbidity and mortality, use of biomass fuels has a substantial proportion (15-17). Globally in 2018, nearly 4 million people a year died prematurely from illness attributable to household air pollution, and around 53% of these deaths were related to respiratory health problems(18).

Globally, 2.8 billion people were dependent on biomass fuel, including charcoal, in 2020, and this is expected to continue increasing in the coming decades since the demand is rising and it also helps as a means of income(19). Worldwide, the production of wood charcoal fuel is increasing from 36.7 to 54.9 million metric tons from 2000 to 2022, respectively, and Sub-Saharan Africa cover 65% of the world's charcoal production with Nigeria, Ethiopia, Ghana, Tanzania, and Madagascar being among the top producers (20). In developing countries, more than 90% of people depend on the energy derived from charcoal for cooking and heating(21). Charcoal consumption in the majority of Sub-Saharan Africa (SSA) is expected to double by 2030(22). The projections show how important charcoal will be in the coming decades in SSA(20), and by 2040, there will be a 200 percent rise in the number of primary charcoal consumers compared to 2020(23). Due to the high demand for wood charcoal in developing countries due to its low-cost energy source(20, 23, 24), it serves as an employment and income return in many developing countries(25-27); hence, it is critical to assess and develop long-range charcoal policies to prevent health impacts on producers and the community at large.

In Ethiopia, as of the 2016 EDHS report, 93% of households use some type of solid biomass fuels, including charcoal for cooking(28, 29). Among the top ten charcoal-producing countries from Africa, Asia, and South America, Ethiopia ranks 3rd (contributing 8%), producing charcoal in these regions, and the annual consumption of charcoal in Ethiopia rose from 944,598 tons in 1961 to 4,416,051 tons in 2017(26).

Charcoal is obtained through the process of partial combustion of wood, carbonization (pyrolysis), and emits a combination of health damaging air pollutants such as carbon monoxide (CO), sulfur dioxide (SO2), polycyclic aromatic hydrocarbons (PAH), volatile organic compounds (VOC), nitrogen dioxide (NO2) and respirable particulate matters (PM2.5 and PM10)(2, 30). Likewise, the charcoal production process has a health risk due to exposure to gases, smoke, and dust, a black

powdery residue that disperses quickly into the air and can also act as a carrier for other hazardous pollutants, both organic (PAHs) and inorganic (trace metals), and leads to respiratory illnesses (31).

The level of pollutant gases and PM emissions depends on the type of technology used for the production, which in tropical countries is commonly made in traditional earth and pit kilns. (30)

Similarly, in Ethiopia, it is produced using the traditional earth mound kiln, due to its lower cost, and this could expose charcoal producers as well as the community at large to various health problems(1). However, the experience of people using personal protective devices to prevent and minimize the health effects is minimal in their occupational exposures (32), and these challenges could make them more vulnerable to the harmful effects of charcoal production. Despite the risks, there are very few studies conducted in rural Ethiopia that focus specifically on respiratory health outcomes related to traditional charcoal production exposure.

Exposure to biomass smoke pollutants such as carbon monoxide (CO) may cause sub-acute intoxication, since CO is very effective and competitive with oxygen for binding sites on haemoglobin and leads to a reduction of oxygen to blood tissues, including the sensitive brain blood tissues(33).

Occupationally related hazards are attributed to a wide range of health effects (34). Every year, 2.9 million workers lose their lives due to occupational accidents and diseases, with many more suffering from debilitating work-related injuries and chronic conditions globally(35).

The safety and health conditions at work of the informal sector workers become a challenge due to the unsafe and unhealthy conditions in which they often work (36). Occupational health and safety monitoring activities are usually practiced in the formal sectors, and early prevention of health effects is regularly assessed(37). Nevertheless, this opportunity is lacking in the informal sectors, including the traditional charcoal producers, since these groups of workforce are used to working in conditions that are not safe for their health(38, 39). Research highlights the potential of PPE in reducing workplace injuries, with studies indicating that more than 90% of incidents can be mitigated through the proper implementation of PPE(40). Studies showed that Knowledge and attitude toward PPE use may vary across different occupational subgroups (41, 42)

Diseases do not occur uniformly throughout the year; rather, their occurrence fluctuates over time due to a range of temporal factors. Understanding the trends and seasonality of chronic respiratory disease is essential for timely public health interventions. Analyzing trends over time can also inform policymakers about the effectiveness of control measures and identify emerging risks. Moreover, developing accurate forecasting models can provide health authorities with predictive insights that support early warning systems, efficient resource planning, and targeted interventions.

There is a global interest in depicting geographic disease distribution and determining trends in time to acquire key information about disease burden(43, 44). The distribution of diseases is not uniform over space or time. Diseases vary spatially, with certain geographical areas consistently experiencing higher or lower burdens than others. This spatial variation may be driven by differences in contributing factors. Investigation of possible disease clustering is fundamental to epidemiology to detect the high-risk population(45). Yet, there is still limited local evidence showing how charcoal production exposure directly affects respiratory health, and the dynamics of CRD in such contexts remain scarce in low-resource settings, and the informal sector remains underrepresented in the existing literature especially in Ethiopia. This study aims to fill that gap by providing a multidimensional analysis that combines epidemiological, behavioral, temporal, and spatial perspectives in these communities.

1.3. Statement of the problem

Chronic respiratory disease-related morbidity and mortality are increasing and becoming challenges for the health-care systems due to their frequent exacerbations(3, 46). They have been considered a major public health problem and will remain a challenge within the 21st century(47). From the WHO African region in 2015, among all causes of disease conditions, productivity loss accounts for 37.12% and 9.18% due to NCDs and respiratory conditions, respectively(48). In Ethiopia, approximately half of all deaths are attributable to NCDs and injuries(49).

In 2021, an estimated 468.3 million people globally were living with CRDs, and accounted for 4.4 million deaths and 108.5 million DALYs were reported(50). According to the global burden of disease (GBD) study in 2017, CRDs have a significant contribution to the increase in increasing of NCDs by 22.7% from 2007 to 2017(4). Worldwide, between 1990 and 2017, DALY rates attributed to communicable diseases decreased by 41·3%, but on the contrary, it increased by 40·1% for non-communicable diseases, with a 14.5% increase due to CRDs (8). In 2019, CRD accounted for 103.5 million DALYs globally, representing about 4.1% of the total global burden of diseases(51). Generally, CRD lowers the quality of life of the affected people(52, 53).

Disproportionately, the high burden of the global morbidity and mortality attributed to CRDs resides in low-and middle-income countries (LMICs)(15, 16), with more than 50% of CRD cases living in LMICs or deprived populations(54). This accounts for a significant proportion of premature deaths, next to cardiovascular disease (3). Similarly, Ethiopia had an unacceptably high rate of early readmission for acute exacerbations of asthma and COPD (17).

Despite a recent reduction in CRDs related to smoking being reported in developed countries, it is increasing in developing countries due to biomass fuel use and other pollutants (55) (56). In 2016, ambient air pollution alone caused some 4.2 million deaths, while household air pollution from cooking with polluting fuels and technologies caused an estimated 3.8 million deaths in the same year. More than 90% of air pollution-related deaths occur in LMICs, mainly in Asia and Africa, followed by the Eastern Mediterranean region, Europe, and the Americas (57).

Most urban people (90%) use charcoal as the primary cooking fuel (58). Globally, close to 50% of the deaths from COPD in developing countries could be attributed to biomass fuel smoke (59). Charcoal workers in 3rd world nations are exposed to higher levels of wood smoke (60). Biomass fuel smoke creates major occupational and environmental health risks, especially in low-resource settings where access to clean energy alternatives is limited. This risk is expected to worsen in charcoal producers. Although basic personal protective equipment (PPE) is the primary option for these risk populations, its utilization among biomass fuel users or charcoal producers remains considerably low. Moreover, the persistence of occupational health risks among informal workers suggests a critical gap between policy provisions and implementation, particularly in extending regulatory coverage, enforcement, and occupational health services to informal economic sectors. Currently, there is limited evidence whether exposure to the traditional charcoal production activities affect respiratory health or how regularly producers use mask while producing charcoal. In addition, there is limited information on the trends, seasonal, spatial and spatiotemporal variations of CRD in the local context. Without this evidence, it is difficult to design effective ways to protect people from the health problems attributed to exposure to charcoal production and living in the surrounding areas. Thus, this study aims to assess the effect of exposure to traditional charcoal production on chronic respiratory diseases, mask use, trends and seasonality, and spatial and spatiotemporal variations of CRD in Amhara region, northwest Ethiopia.

1.4. Significance of the study

This study is significant because it contributes to the existing body of knowledge by generating new evidence on the issue under investigation. The findings of this study will broaden understanding of the problem and will provide practical, evidence-based insights to support better planning, prioritization, and decision-making, especially in shaping public health policies and allocating resources to address the identified public health concern. In addition, the study will assist in raising awareness about health risks and protective factors, empowering people who could support to take preventive actions and participate more actively in health-related decisions that affect their lives.

Overall, the findings are particularly useful for workers and their families. By understanding the health risks they face and the periods when these risks are higher, they can take practical intervention to protect themselves. This can help reduce illness, lower medical costs, and improve their overall quality of life and productivity. In the long run, this also supports better economic and social stability for households.

For the health system, the study provides helpful information for planning and preparedness. Knowing the trends and seasonal patterns of CRDs allows health facilities to anticipate increases in cases and respond more effectively. The forecasting component adds further value by helping predict future burdens, while the spatial analysis helps identify areas that are more affected. This makes it easier to target resources and interventions where they are most needed, ultimately reducing the overall burden on the healthcare system.

Policymakers and program planners can also benefit from these findings. The study highlights the need to improve access to clean and affordable energy sources, promote safer and more efficient charcoal production technologies, and strengthen occupational health and safety measures, especially for self-employed workers in the informal sector who are often overlooked. The information on where and when risks are highest can also support more targeted and practical policy decisions. Moreover, the study will also serve as a scientific reference for future research.

1.5. Rationale of the study

Nearly half of CRD-related deaths in developing countries are linked to biomass fuel smoke, underscoring the significant global respiratory health and it remains a challenge within the 21st century(61), Despite, the World Health Organization (WHO) recognizes preventing and controlling of CRDs as a global priority and key to achieving the Sustainable Development Goals(SDGs), the risk factors that leads to these diseases such as tobacco smoke, air pollution, (both indoors and outdoors), work place dust, fumes from burning of biomass, harmful chemicals are still on rise specially in LMICs(29, 62, 63).

In many urban areas, up to 90% of the population depends on charcoal as their primary cooking fuel, resulting in widespread exposure to biomass smoke. This dependence is further reinforced by the limited availability of affordable clean energy alternatives in low-resource settings, increasing both household and occupational exposure(64). Population growth and the growing demand for biomass fuel and charcoal production in the coming years will increase the pressure placed on rural communities. Charcoal production is expected to double in 2030 (22). In LMICs, including Ethiopia, charcoal production activity is performed using the traditional technology (earth mound) kilns, and leads charcoal producers to be exposed to high concentrations of wood smoke during production processes, placing them at elevated risk of chronic respiratory diseases (CRDs)(1).

Though literature establishes relationship between the use of biomass fuels and health problems, few studies have assessed the direct respiratory health effects of exposure to the traditional charcoal production or investigated PPE use among charcoal producers. While the use of PPE is a key strategy to reduce inhalational exposure, the actual utilization of PPE (mask) among charcoal producers remains poorly documented. Moreover, there is a lack of epidemiological evidence on the temporal (trend and seasonal variations), spatial (geographic clustering), and spatiotemporal distribution of CRDs within the local context, hindering the development of targeted public health interventions.

Therefore, this study aims to assess the effect of exposure to traditional charcoal production on chronic respiratory diseases, mask use, trends, seasonality, forecasting, spatial, and spatiotemporal

variations of CRD in Amhara region, northwest Ethiopia. This can help to generate epidemiological evidence, which could help to design prevention strategies in the regional and national effort.

CHAPTER TWO: LITERATURE REVIEW

A comprehensive review of existing literature from reputable journals, reports and policy documents was undertaken to support and contextualize the four interrelated research papers compiled within this dissertation. The reviewed literature includes sociodemographic and economic variables, personal and behavioural related variables, environmental, occupational, trends, and spatial perspectives on respiratory health, with a particular focus on chronic respiratory disease.

The first paper examines the trends, seasonality, and forecasting of respiratory diseases. The second paper investigates the spatial, temporal, and spatiotemporal distribution of chronic respiratory disease. The third paper looks at the effect of exposure to traditional charcoal production on chronic respiratory disease. The fourth paper focuses on the use of personal protective equipment (mask) among charcoal producers.

Together, these bodies of literature underscore the complex and interrelated factors that shape respiratory health. They form a solid basis for the studies included in this dissertation and emphasize the importance of integrated, evidence-based strategies for the prevention, monitoring, and targeted intervention.

2.1. The burden of chronic respiratory diseases

Chronic respiratory diseases (CRDs) are among the major non-communicable diseases(61), and the leading cause of death globally in 2019(51). It was the third leading cause of death, next to cardiovascular disease and cancer(65). Chronic respiratory diseases (CRD) are neglected diseases in Sub-Saharan Africa (SSA), although prevalences are significantly rising, and could adversely affect attaining targets 3.4 and 3.8 of the agenda for SDG, which specify that premature mortality must be reduced by one-third from NCDs by 2030 in Sub-Saharan Africa(66, 67). In Ethiopia, NCDs cause a significant health burden, accounting for 13 million disability adjusted life years (DALYs), while NCD-related mortality represented 43% of all deaths in Amhara in 2019 (68).

Studies have shown that asthma and COPD are the most common types of CRDs(61, 69). The global burden of diseases (2019) report also suggested that asthma is the most common CRD

globally, affecting 262·4 million people in 2019, with LMICs contributing 96% of global asthma-related deaths and 84% of global DALYs, followed by COPD affecting 212·3 million adults(3). Globally, the number of COPD cases among those aged 25 years and older will increase by 23% from 2020 to 2050(14).

CRDs are accompanied by symptoms such as chronic cough, phlegm, wheeze, shortness of breath, and chest tightness (32, 70), and it significantly challenges healthcare services due to repeated hospitalization attributed to its frequent exacerbation (46, 71). Subjects with asthma had higher all-cause hospitalization and mean yearly all-cause hospital days compared with subjects without asthma, which adversely affects the patient and family due to the high treatment cost (71). Chronic respiratory diseases can lead to significant chronic morbidity and loss of economic productivity, which burdens patients, families, and health systems similarly(72). Because of this, CRD negatively affects adults' quality of life, affecting them socially, emotionally, and physically, and decreasing productivity (73-75).

CRD has increased in recent years, and those exposed to risk factors related to occupational exposure may suffer more from CRD(76, 77). Although smoking was the leading cause of deaths and DALYs from CRDs worldwide, air pollution and occupational risks also made a significant contribution in LMICs(3, 78). Occupational exposure to particulate matter, gases, and fumes contributes to 15.6% global DALY's due to COPD(79). The most common cause for CRD in Sub-Saharan Africa is due to severe household and occupational exposures, while in other LMICs associated with industrial and urban pollution(80). Unsafe working environments expose workers to harmful substances, which are leading risk factors for CRD(76). Similarly, charcoal production activity exposes charcoal producers and the local community to smoke and dust, which could be attributed to respiratory health diseases (25, 81).

Because of the rapid growth of urbanization and the rise in the price of modern energy sources such as electricity, liquefied petroleum gas, and kerosene, dependence on charcoal is increasing (82). Hence, it is critical to assess and develop long-range charcoal policies to prevent health impacts on producers and the community at large.

2.2. Trends, seasonal variations, and forecasting of chronic respiratory disease

Globally, deaths due to CRDs increased from 1990 to 2019 (54) and accounted for 7% of all forms of global deaths (83), and LMICs contribute to over 85% of all CRD cases(84). The burden of CRD will continue to affect hundreds of millions of people globally, with disproportionate growth in low- and middle-income regions through 2050 (14). The existing CRD burden is huge and much earlier than the predicted ranking by 2030 (85). The World Health Organization has identified the prevention and control of CRDs as an urgent development issue and essential to the achievement of the SDGs (86). In Ethiopia, among all modifiable risk factor-attributed deaths and DALYs of NCDs, chronic respiratory diseases contribute 41%, next to cardiovascular diseases(68). Ethiopia has adopted a WHO "Best Buys" intervention to achieve the SDGs' goals and is presently executing a National Strategic Plan for the Prevention and Control of Major Non-communicable Diseases in 2020(87).

The number of COPD cases among those aged 25 years and older will increase by 23% from 2020 to 2050 globally, and the number of cases in LMICs will be expected to be more than double that of high-income regions(14). Higher morbidity is common in asthma disease than in COPD, but mortality is higher in COPD than in asthma cases(88). Understanding these diseases helps address a substantial portion of the CRD burden among adults.

Seasonality has been demonstrated for several clinical conditions where symptoms and mortality increase in winter; for example, cardiovascular disease (89), pulmonary embolism (90), COPD exacerbations, and hospitalizations related to COPD (91, 92), are most common in winter. Furthermore, other studies have shown that seasonal variations in asthma and COPD morbidity rates and hospitalizations were higher in the cold and pollen seasons (93-95). Although respiratory diseases have seasonal patterns, season-specific inflammatory potentials may vary from region to region (96).

A time series is a sequence of observations taken sequentially over time (97). Time series data analysis is a valuable tool for assessing the occurrence of disease at various points in time since trends and seasonal variations impact the functioning of the health system, including CRD treatment and care(98). There are some studies in Ethiopia on the seasonal differences in the

occurrence of asthma and COPD. Nevertheless, earlier research on the seasonal fluctuations in asthma or COPD morbidity rates in Ethiopia was limited to particular sites for shorter periods and was based on single-pharmacologic prescription studies (99-101).

Moreover, low self-care practice is common in most of the patients in northwest Ethiopia, which accounted for 42.3% of uncontrolled asthma (102). This is also true at the country level in Ethiopia, where 45% of asthma cases experienced uncontrolled asthma (103). Thus, it is important to understand trends and seasonal variations for asthma, COPD, and CRD in the region to target and prioritize prevention efforts. Likewise, forecasting for these diseases also helps to generate information to forewarn health institutions, healthcare providers, and decision-makers of the need for prudent decisions about resource allocation. Therefore, this study aimed to investigate the trend, seasonal variations, and forecasting of CRD, asthma, and COPD morbidity in the region using seven years of data. The results will be very helpful in planning the health care system and developing preventative methods to manage and control CRD, especially in regions where large-scale charcoal production is practiced.

Trends of CRD

The Global Burden of Disease (GBD) Study 2019 shows that from 1990 to 2019, the number of people dying from CRD increased by about 28.5%, and the number of people living with the disease rose by nearly 40%(54). The GBD 2021 analysis of COPD reveals that while age-standardized incidence and mortality rates have declined, the total disease burden has continued to rise, largely due to population growth and aging(104). However, absolute cases, deaths, and DALYs increased, driven by population growth and aging, and men consistently showed higher age-standardized rates (48). Between 2000 and 2016, a multi-country study analyzing CRD mortality trends found that CRD deaths dropped by about 23% in high-income countries and 36% in middle-income countries, suggesting that the higher baseline mortality in middle-income countries contributed to their more pronounced decline in mortality rates(105). Similarly, a study done in China to show the trends of CRD revealed that the number of CRD cases increased by 39.5% from 1990 to 2017(106). A study using WHO mortality data from 46 countries found that global asthma death rates stayed about the same between 2006 and 2012(107). Similar patterns have been observed in Brazil analyzed long-term mortality data were analyzed and found

that while some regions showed a decline in CRD deaths, others reported an upward trend(108). Similarly, a retrospective study conducted in Iran examining respiratory disease trends from 2011 to 2018 revealed an upward increase in mortality due to respiratory diseases(109). These differences point to the influence of local factors, such as environmental exposures, health service availability, and population demographics.

Seasonality of CRD

Chronic respiratory diseases such as asthma and COPD show significant seasonal variations, with asthma cases peaking in autumn and COPD cases highest in winter(110). The findings of a study conducted in the United States, which analyzed data covering a four-year period, revealed a clear seasonal variation of asthma exacerbations, peaking during the winter months and declining in the summer, and no significant differences in exacerbation rates between males and females(111). This suggests that seasonal factors, rather than sex, play a dominant role in influencing asthma exacerbation patterns. Likewise, another study done elsewhere demonstrated that asthma admissions peaked during winter and were lowest in summer(112). Correspondingly, a study examining the impact of seasonal biometeorological conditions on asthma and COPD hospital admissions found clear seasonal variation in disease flare-ups; in winter, poorer air quality driven by higher PM2.5 and PM10 levels was linked to more exacerbations, while in summer, discomfort from meteorological conditions contributed to increased hospital admissions(113). Congruently, the findings of a study done elsewhere reported that the number of daily admissions showed an increasing trend, and the seasonal fluctuation was obvious, with more daily admissions in winter and spring than in summer and autumn(114). Notable seasonality patterns were observed in COPD hospitalizations and emergency visit rates in the overall cohort(115).

Forecasting of CRD

An analysis of Global Burden of Disease data from 1990 to 2021 predicts that age standardized incident rates for asthma will stay high worldwide between 2022 and 2050(116). Most of the increase is expected to happen in lower middle and low SDI areas like South Asia and parts of Sub-Saharan Africa, and the rise will likely be bigger among women(104). A GIS-based study of respiratory disease cases admitted to hospitals in Bangladesh demonstrated significant spatial and

temporal disparities in disease occurrence(117). A study from Ontario, Canada, found that the prevalence of COPD was expected to rise to 12.7% in 2024, compared to the rates observed between 2011 and 2014(115). Likewise, another study projecting the future burden of COPD hospitalizations found that the number of people admitted with COPD could increase by 210% between 2010 and 2030(118).

2.3. Spatial, temporal and spatiotemporal distribution of chronic respiratory disease

Africa has a huge burden of CRD(119), as compared to other NCDs, which is underestimated and neglected(120). One-third of Ethiopians have NCDs, and CRDs are among the most common diseases with increasing public health challenges (49, 71, 121). Addressing chronic diseases is integral to the 2030 Agenda for sustainable development (122). Environmental exposure to tobacco smoke, indoor air pollution, and chemicals are important risk factor for COPD (29, 62, 123). Other studies have been investigating the impact of frequent long hours of exposure to smoke released from the incomplete combustion of wood, which leads to lung function impairment(124, 125). A previous study showed that major clusters of high COPD hospitalization were observed in areas near high emissions of pollutants(126).

Investigation of possible disease clustering is fundamental to epidemiology to detect the high-risk population(60). Ethiopia is working by following the WHO's global action plan to prevent and control NCDs by the year 2025(87). There is also a global interest in depicting geographic disease distribution and determining trends in time to acquire key information about disease burden (43, 44). Previous epidemiological studies of CRD morbidity in Ethiopia have mainly focused on the prevalence of the disease(127, 128). The population who engaged in charcoal production, which is believed to be a risk factor of CRD, is substantially increasing. However, spatial, temporal, and spatiotemporal variations of CRD have not yet been well explored in charcoal production areas, although the information from the spatial, temporal, and spatiotemporal studies will undoubtedly help to guide policymakers in implementing an appropriate intervention in affected areas properly on time. Thus, this study was performed to determine the spatial, temporal, and spatiotemporal variations of CRD among adults in northwest Ethiopia from 01 July 2012 to 30 June 2019.

An earlier study done on spatial patterns of CRDs, including asthma and COPD, reveals substantial geographic disparities in incidence, prevalence, and mortality(129). A nationwide spatial study conducted in China exhibited marked variation in COPD prevalence across cities, even after adjusting for age and smoking(130). Likewise, mapping studies examining COPD distribution across Africa, Asia, and Australia demonstrated clear geographic differences in disease rates between regions(131). A study conducted in South Australia revealed that both COPD and asthma

cases were not randomly distributed throughout the study region, but exhibited obvious geographic aggregation(132). Consequently, research conducted in China using data from 2014-2020 clearly shows that asthma, COPD, and other chronic respiratory diseases are not evenly spread(133). The spatial difference in illness and death rates may vary from place to place due to factors such as living conditions, income levels, urbanization, environmental quality, and healthcare access.

Identifying temporal variation in CRD morbidity rates may provide insights about disease patterns and thereby inform research, policy, and clinical care. Previous SaTScan analysis in the Taiwan study detected spatiotemporal clusters of COPD mortality from 2000–2012 using SaTScan with a Poisson model, maximum cluster population size of 50%, and a one-year temporal window(134). A study conducted in Pakistan also showed evidence of spatiotemporal clustering of respiratory infections(135). Another study conducted in the Memphis metropolitan area over 11 years (2005–2015) identified statistically significant spatiotemporal clusters of childhood asthma(136).

2.4. Effect of exposure to charcoal production on chronic respiratory diseases

In addition to the provision of energy, charcoal production is an important economic activity, providing a considerable amount of employment and serving as a source of livelihood for most rural households(27, 137). In Ethiopia, as of the 2016 Ethiopian Demographic and Health Surveillance report, 93% of households use some type of solid biomass fuels, including charcoal for cooking(28). However, in most developing nations, including Ethiopia, charcoal production is carried out using traditional methods, earth mound kilns, which expose workers to harmful substances, and it has been a growing concern due to its threat of chronic respiratory diseases(1). Charcoal is produced through the partial combustion of wood (pyrolysis), which emits numerous noxious pollutants, including particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide, methane, and carcinogenic organic air pollutants, which in turn affect human health(2). The level of pollutant gases and PM emissions depends on the type of technology used for the production. Using improved kilns for charcoal production reduce in emission of pollutants ranging from 46% to 57.9% for CO2, 29.4%–56.6% for CO, 61.7%–86.1% for NO, 56.6%–86.2% for NOx, 41%–62.8% for SO2, and 35.7%–57% for CH4(137). However, in tropical countries is commonly made in traditional earth and pit kilns(30).

Charcoal producers and people living near the production areas can be exposed to these harmful pollutants due to their long-term exposure during their production periods and residence. Previous epidemiological studies have shown the public health impact of biomass fuel and respiratory health(138, 139).

2.5. Factors associated with chronic respiratory disease symptoms

Based on existing literature, the risk factors for chronic respiratory diseases can be generally summarized into the main categories such as socioeconomic and demographic factors, personal and behavioral factors, family-related factors, and work and environment-related factors.

Socioeconomic and demographic characteristics

People with lower socioeconomic status often experience more severe asthma and are more likely to be hospitalized, which increases the risk of dying from the disease (140). Individuals with higher levels of education and those with higher incomes were less likely to develop chronic lung diseases(141). This might be because the majority of people in this group are less likely to be engaged in working conditions that are exposed to pollutants. Previous studies have shown that people living in rural areas were more likely to have chronic respiratory diseases than those in urban areas (142, 143).

A community-based study conducted in Ethiopia found that older adults had significantly higher odds of developing chronic respiratory diseases than younger adults (140, 144, 145). This might be because long-term exposure to harmful environmental factors, biomass fuel use, or occupational factors over the years can gradually damage the lungs and affect respiratory health. The global trends of mortality and DALY rates for chronic respiratory diseases varied by age, sex, region, and disease pattern(83).

Many studies from LMICs have shown that women are at a higher risk of developing CRD than men (146-149), because most of the time they are exposed to biomass smoke from cooking and indoor fuel use a major risk factors. On the contrary, other studies have shown that men are more likely than women to develop chronic respiratory diseases (150). This is mostly because men are more often employed in jobs where they are regularly exposed to harmful substances like dust, fumes, silica, coal dust, and industrial chemicals.

Personal and behaviour-related factors

Individuals who had ever smoked cigarettes were much more likely to experience chronic respiratory symptoms than those who never smoked(151). Similarly, evidences indicate cigarette

smoking is recognized as the most important risk factor for COPD(29, 152). Studies provide strong evidence that heavy or long-term consumption of alcohol is a major risk factor for various respiratory diseases(153, 154). Chronic respiratory diseases in adults usually develop as a result of a combination of long-term exposures and existing health conditions. Conditions such as cardiovascular diseases, metabolic disorders like diabetes and obesity(155). Respiratory infections, including tuberculosis, pneumonia, can increase vulnerability by weakening lung function and reducing immune defense(156). Likewise, HIV infection may contribute to ongoing airway inflammation and repeated injury to the lungs(157)

Family-related variables

Studies have shown that individuals with a family history of chronic respiratory diseases had significantly higher odds of developing chronic respiratory symptoms(151). In line with this, another study revealed that the odds of having CRD were significantly higher among participants with a family history of the disease than among those without a family history(158). This may be because genetic factors can influence their chances of developing chronic respiratory symptoms (159). Similarly, a study conducted elsewhere suggests that hereditary factors and genetic susceptibility play a significant role in the development and progression of chronic respiratory conditions, such as asthma and COPD(160). Furthermore, another study conducted on family-related issues also showed that among children who had two family members with asthma, the highest asthma risk was identified when both parents had asthma compared to those children who had one family member with asthma(161).

Working conditions and other environmental-related variables

Occupational exposures are a major but preventable cause of chronic respiratory diseases(162). Similarly, epidemiological studies suggest that occupational exposure can be a major contributor to the development of COPD(49). A case control study conducted among pharmaceutical factory workers, environmental and occupational related factors such as working department, total working hours per week, training on respiratory health, and energy used at home did not show a significant association with chronic respiratory symptoms. However, work experience (service years) showed an association with the development of chronic respiratory symptoms (151). This

could be because factories usually follow strict health and safety rules that limit how many hours people can work. A community-based study conducted in Ethiopia also found that having an unimproved floor, using firewood as a cooking fuel, and cooking in a room without a window were significant determinants of respiratory symptoms(139). A cohort study also revealed that the proximity of an animal farm to people's living residences has a significant contribution to CRD(163).

2.6. Occupation related hazards

Occupational related hazards are attributed to a wide range of health effects (164, 165). Every year, millions of workers lose their lives due to occupational accidents and diseases, with many more suffering from debilitating work-related injuries and chronic conditions globally(166, 167). Illness due to occupational injury leads to long-term absenteeism from work, which in turn reduces productivity(168). Disability adjusted life years attributable to unsafe work conditions were estimated to be 180 million in 2019, with an associated economic loss of 5.8% of global GDP(35). Furthermore, work-related injuries and diseases have substantial psychosocial and economic consequences for the affected individuals and their families(169, 170). Among the major work-related mortality, one-third of the total work-related deaths (31%) were due to circulatory diseases, while malignant neoplasm contributed 29%, respiratory diseases 17%, and occupational injuries contributed 11%(35). By 2030, the United Nations aims to significantly reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination(171).

The safety and health conditions of workers in the informal sectors become a challenge due to the unsafe and unhealthy conditions in which they often work (172). Occupational health and safety monitoring activities are usually practiced in the formal sectors, and early prevention of health effects is regularly assessed(173). Nevertheless, this opportunity is lacking in the informal sectors, including the traditional charcoal producers, since these groups of workforces are used to working in conditions that are not safe for their health (172).

Charcoal production and usage are linked with adverse health outcomes(1). The production takes place with partial combustion(pyrolysis), which can emit quantities of PMs, CO, NOx, SO2, HF, formaldehyde, phenol, acetic acid, xylene, and toluene(81). In addition, the production has been

undertaken using a traditional method, the earth mound kiln (174). Because of these situations, the working conditions of charcoal producers are unsafe; nevertheless, little attention is paid to these hazards. Particulate matter concentrations that can be easily inhaled and penetrate the lungs. Specifically, particulate matter with a diameter less than 2.5 μm (PM2.5) can be easily inhaled and penetrate the tracheobronchial region that includes the trachea and bronchi, and with a diameter of less than 1.0 μm (PM1.0) can reach the alveolar region in the lungs(175). Particulate matter can also act as a carrier for other hazardous pollutants, both organic (e.g., PAHs) and inorganic (e.g., trace metals)(31).

The hierarchy of occupational hazard control from the most effective to the least effective can be described as elimination, substitution, engineering control, administrative control, and personal protective equipment (PPE) use(176). The use of PPE is one of the approaches for preventing exposure to hazards that could result in injuries and illness among workers across various working settings, including those engaged in the informal sectors (177), like the traditional charcoal production sector.

Although there are several studies on PPE use among workers in health care settings(178, 179), textile(180), chemicals(39), and cement(181) factories, flower farming(182), and others small-medium enterprises like welders(183), there is limited evidence about practice of PPE(mask) use, knowledge, attitude toward production exposure and determinants of practice of mask utilization among charcoal producers.

Therefore, this study aimed to assess the utilization of mask use and factors associated with its utilization. Understanding the level of mask utilization and factors associated with it among these exposed populations is crucial to understanding the current situation to prevent further exposure to harmful pollutants attributable to the production process. Furthermore, this study would help in identifying potential opportunities for collaboration with key partners in and out of government to prevent occupation related diseases and injuries among workers in this informal sector.

2.7. Mask utilization among workers in workplaces

Research highlights the potential of PPE use in reducing workplace injuries, and more than 90% of incidents can be mitigated through the proper implementation of PPE(184). Even though the use of PPE in the workplace significantly reduces the risk of injuries and illness, many workers, particularly in the informal sectors, small-scale, and temporary work environment fail to use PPE consistently(185).

Across various studies in Ethiopia, Ghana, Saudi Arabia, and global reviews, the use of PPE among small-scale industry workers was found to be low. In a study conducted in Harar town, Ethiopia, among small-scale industry workers, only 4.3% possessing adequate PPE, and only 7.7% had received any form of occupational safety training(186). Similarly, a cross-sectional study done in Ethiopia among smallholder farmers showed that only 6.9% of them use masks during pesticide preparation and utilization in the workplace (39). In Ambo, Ethiopia, just under half of workers used PPE (187), while a study done in Hawassa, among woodworking only 19.6% used PPE frequently(38). In small workshops in Jeddah, Saudi Arabia, the use of specific PPE items ranged from just 11% for safety shoes to 50% for welding shields(188). Similarly, findings from Ghana suggest that 78% of the small-scale miners do not use the appropriate PPE(189). A global review of small- and medium-sized enterprises also showed that only 12% of employers provided PPE, and fewer than two-thirds of workers used it properly(40). The low utilization of PPE was due to a lack of availability, training, and supervision being common problems.

On the contrary, around 42% and 55% large-scales factory workers in Ethiopia used PPE properly(190, 191). This shows that workers in the formal sector tend to use PPE more in workplaces than those in small-scale industries. This is probably because they usually get PPE from their employers, have regular supervision, and receive ongoing training that keeps safety practices in check.

The proper use of PPE, supported by adequate knowledge and a positive attitude, is essential in preventing work-related injuries and illnesses. Studies showed that knowledge and attitude toward PPE use may vary in many workplaces across different occupational subgroups (192). For instance, earlier studies have shown that the use of PPE varies from 10 to 82% and depends on various

factors such as; lack of knowledge and unfavorable attitude(193), lack of access (194), its discomfort at work(195), working time(187), and behavioural related factors(180, 191) are among the reasons for non-use of PPE at work place. Another study conducted in Nansana Municipality, Uganda, found that although most welders in small-scale metal workshops had a high level of knowledge (61.4%), the majority (68.7%) held negative attitudes toward it, and only 37.1% reported good PPE practices (183). Furthermore, a study conducted among textile workers in Karachi, Pakistan, showed that 77% had good knowledge, but only 21% reported safe practices(42).

2.8. Factors associated with mask use among charcoal producers

Sociodemographic characteristics

Studies have shown that younger workers use PPE less often, while older workers understand the risks and use it more consistently(184, 190). Similarly, a cross-sectional study in Nigeria reported that workers over 35 years old were 1.8 times more likely to use PPE compared to the young age groups(196). Gender differences influenced PPE utilization, with male workers often reporting higher PPE use compared to females, partly due to gender-specific roles and PPE availability (42, 197). Results from several studies revealed that people are more likely to use PPE if they are better educated and are strongly influenced by training on PPE use and awareness of workplace hazards (180, 198, 199). In contrast, the results from Ghana small-scale miners revealed that proper use of PPE did not show statistical significant association with sociodemographic characteristics (such as sex, age, education, and major activities engaged in) (189).

Working conditions

Workers who had worked less than eight hours a day were more likely to use PPE safely than those who didn't(42). Work experience was also observed as a significant factor in PPE use, and workers with more years of experience were more likely to consistently use PPE in the workplace(191). During their long period of work experience, they have often received training and experienced real-life incidents that reinforce the importance of PPE(200).

Knowledge and Attitude

Earlier studies have shown that workers in small- and medium-sized industries are more likely to use PPE when they have good knowledge, a positive attitude, and work in a place with a strong safety culture compared to those who do not(40, 178, 183).

PPE availability, affordability, and comfort

A scoping review on PPE use in long-term care settings showed that supply shortages and the cost of PPE acquisition are the key barriers to use (201). Furthermore, earlier studies also explained that workers were less likely to use PPE in workplaces when the PPE is a poor fit and causes

discomfort, emphasizing the importance of designing PPE that addresses proper fit for users(202).

2.9. Conceptual framework

The conceptual framework for this study is developed to illustrate the potential relationships and pathways through which various factors may influence the outcome of interest. This framework was constructed based on existing literature, theoretical models, and empirical findings relevant to the health condition under investigation. The variables included in the framework are categorized into five main domains: sociodemographic and economic characteristics, environmental exposures, occupational conditions, family-related influences, and personal or behavioral factors **(Figure 1)**

By organizing these variables within an integrated framework, we aim to better understand their independent and combined effects, guide analytical strategies, and support the interpretation of results. This framework will also serve as a foundation for identifying intervention points and informing public health policies and practices aimed at reducing disease burden and improving health outcomes.

Conceptual Framework

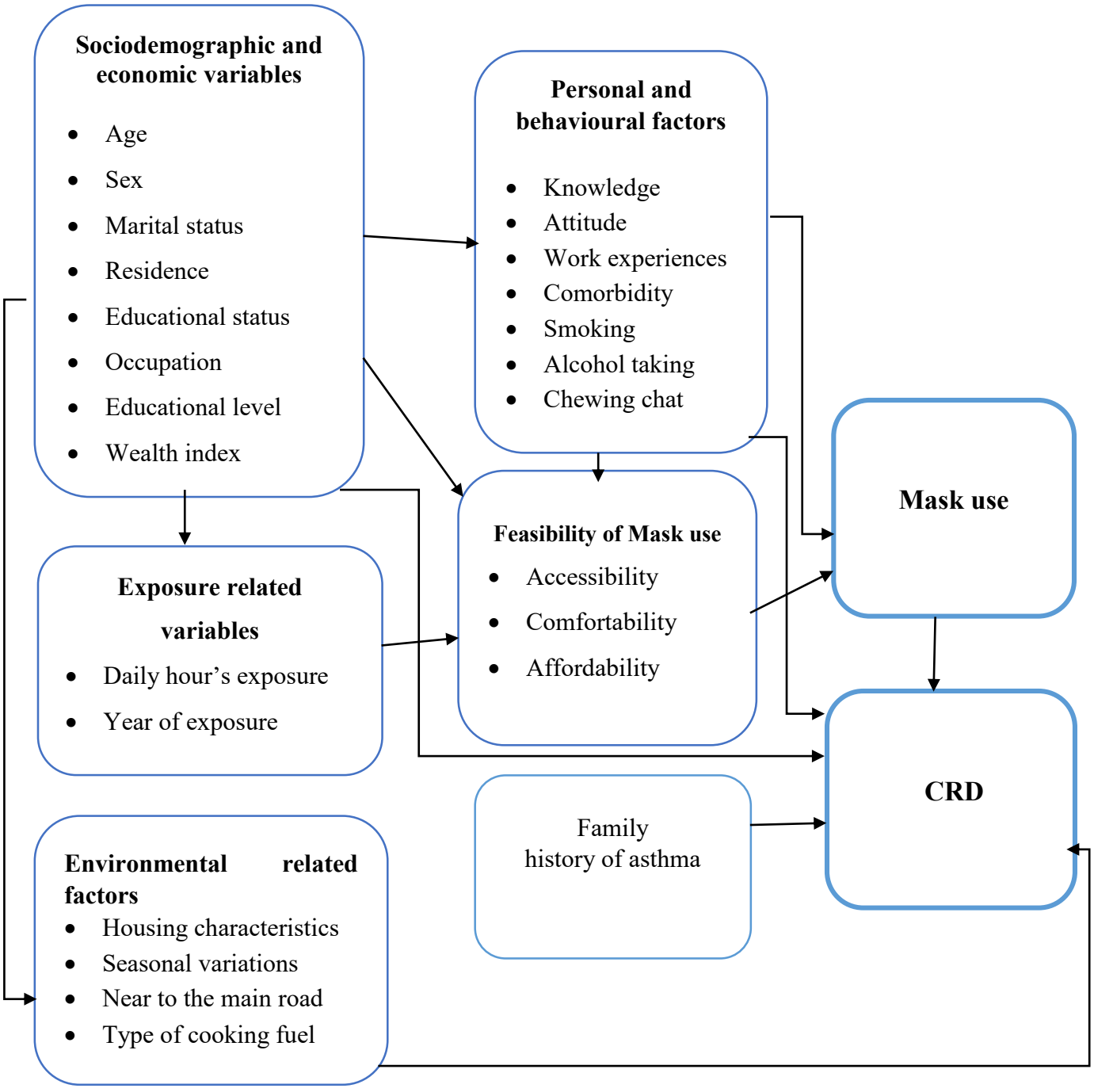


Figure 1: Conceptual framework of factors affecting respiratory health and mask utilization among study participants adapted by reviewing from the existing literatures.

2.10. Research questions

To guide this study and make sure it stays focused, clear research questions were developed. These questions are designed to help explore the main goals of the research and dig deeper into the important issues. By answering them, the study will provide meaningful insights and a better understanding of the topic. The following research questions will direct the scope and focus of the investigation:

- What are the trends and seasonal patterns of chronic respiratory diseases over the past seven years in the northwest, and what are the projected patterns in the near future?
- How does the burden of chronic respiratory diseases change spatially and spatiotemporally in northwest Ethiopia, and are there specific areas or time periods with particularly high clusters?
- Does exposure to charcoal increase the risk of developing chronic respiratory disease?
- To what extent do traditional charcoal producers use personal protective equipment (mask), and what determining factors influence their mask utilization?

CHAPTER THREE: OBJECTIVES OF THE STUDY

3.1. General objective

To assess the effect of exposure to charcoal on chronic respiratory diseases, mask use, trends and seasonality, and spatial and spatiotemporal variations of CRD in Amhara region, northwest Ethiopia

3.2. Specific objectives

- To analyze the trend, seasonality and forecasting of chronic respiratory disease in northwest Ethiopia (Objective I)
- To examine the spatial, temporal and spatiotemporal patterns of chronic respiratory disease in northwest Ethiopia (Objective II)
- To determine the effect of exposure to traditional charcoal production on chronic respiratory diseases (Objective III)
- To determine the proportion of mask use among traditional charcoal producers and to identify factors associated with mask use (Objective IV)

CHAPTER FOUR: METHODS AND MATERIALS

This section explains how the four studies in this dissertation were carried out. It gives an overview of the philosophy and methods used, including the types of study designs, target populations, sources of data, and the different analytical tools used to answer each research objective. To examine the possible causal association between exposure to traditional charcoal production and CRD symptoms, the propensity score matching technique was used to balance the observed confounders. To understand how workers protect themselves from harmful pollutants at work place, a cross-sectional study looked at the utilization of masks among traditional charcoal producers. A retrospective time-series analysis was used to explore how CRDs have changed over time and to forecast future patterns. Finally, a spatial, temporal, and spatiotemporal analysis was carried out to map where and when CRD cases have been most common in the region. Data for the various components were obtained through both primary data collection and secondary sources. Study populations varied by objective, encompassing community members, occupational groups, and patients presenting CRD symptoms. Different statistical and geospatial tools were used to analyze the data, depending on the specific objective. The use of diverse integrated methodological approaches provides a comprehensive understanding of both the direct and underlying contextual factors that influence CRD symptoms, supporting more evidence-based public health planning and targeted interventions.

4.1. The research philosophical paradigm

The research is guided by the principles of the post-positivist philosophical paradigm. Post-positivism assumes that reality exists independently, but it can only be understood imperfectly and probabilistically. Therefore, knowledge is considered tentative and developed through evidence-based scientific inquiry, while recognizing the presence of bias and error in the research process(203). It generally focuses on identifying explanatory associations or causal relationships through quantitative approaches, where empirically based findings from large sample sizes are favored. In this regard, generalizable inferences and replication of findings have been principles guiding positivist science(204).

Overall, the chosen paradigm reflects the study's aim to generate reliable, evidence-based insights from existing data. The integration of multiple quantitative methods allows a comprehensive understanding of the research problem, estimating treatment effects, identifying trends over time, and mapping spatial variations while maintaining objectivity and methodological rigor. This philosophical foundation ensures that the study's findings are both scientifically credible and practically relevant for decision-making in the health sector.

4.2. Study Design

A retrospective time–series study was employed to conduct studies under objectives I and II. A community-based cross-sectional study design was employed (Objectives III and IV). The design was chosen since it allows for the assessment of the causal association of exposure to traditional charcoal production on CRD symptoms among adults (by comparing exposed and non-exposed groups) under natural settings, using the propensity score matching (PSM) technique to balance the measured confounders between the exposed and unexposed groups (Objective III). The ideal method of determining the causal treatment effect is by carrying out randomized controlled trials (205). However, randomization is often challenged by ethical concerns and feasibility; i.e., it is unethical to randomize individuals to potentially harmful exposures(206). Likewise, randomized controlled trials cannot be applied to study the effect of exposure to TCP on CRD symptoms for ethical and practical reasons. Nevertheless, when randomization is not feasible or unethical, an observational study under natural settings using PSM analysis can be done to assess the causal associations. (207). This study design was also chosen to assess the determinant factors for the outcomes of the study (Objective III and IV).

4.3. Study setting and period

The study was conducted in the three zones (East Gojjam, West Gojjam and Awi) of Amhara region. The three zones are among the thirteen administrative zones of the Amhara National Regional State, located in the southwest of the Amhara region, Ethiopia **(Figure 2).**

Debre Markos is the town of East Gojjam zone, located at 300km from Addis Ababa, the capital city of Ethiopia, and 265km from Bahir Dar, the capital city of Amhara Region. Finote Selam is

the town of West Gojjam, located 389 km from Addis Ababa, through Debre Markos, and 176 km from Bahir Dar. While Injibara town is the administrative center of Awi zone, which is located 447 km from Addis Ababa and 118 km from Bahir. Geographically, East Gojjam is located at 9.900°00′ North latitude and 38°30′ East longitude. West Gojjam is located at 11°09′ North latitude and 37°14′ East longitude, and Awi zone is located at 11°00′ North latitude and 36°40′ East longitude.

Based on projections from the 2007 Census by the Ethiopian Statistic Society, East Gojjam had a population estimated at about 2,845,753, with 1,408, 325 males and 1,437,428 females in 2023. The zone covers around 14,004.47 square kilometers, giving it a population density of about 203.2 people per square kilometer. West Gojjam had a population estimated at about 2,755,600, with 1,383,472 males and 1,372,128 females in 2023(208). The zone covers around 13,312 square kilometers, giving it a population density of about 158 people per square kilometer. Awi zone had a population of about 1,328,104, comprised of 665,606 males and 662,298 females. It covers an area of 9,148 square kilometers, with a population density of around 107.44 people per square kilometer.

The study area is well-known for its massive wood charcoal production, and it is one of the areas where large quantities of charcoal are transported to Addis Ababa annually (209). For instance, only in Mecha district (one of the districts located in the study area), around 164648.2 tons of charcoal was produced from 2014 to 2018 **(**25**)**. Charcoal production is one of the major sources of households' livelihoods, as a means of generating income (210). Despite its advantage in resolving the shortage of high-energy demand and serving as a source of income, the process of producing charcoal, as well as its use, exposes workers and nearby communities to various harmful pollutants, which in turn affects human health, notably the respiratory system **(**211**)**.

The study area climate has four seasons: summer (a rainy season in Ethiopia from June to August), spring (September to November), Bega/winter (a dry season in Ethiopia lasting from December to February), and autumn (March to May) (212).

The data extraction was done from October to December 2022 using DHIS2 quarterly reported CRD cases to the zones during 2012/13-2018/19 (Objective I and II), and community based data

collection time was from December 10/ 2022 to February 05/ 2023 (Objective III and IV). and consideration was given to bronchial asthma and COPD cases in the analysis since these are the most prevalent types of CRDs (106, 213).

Study Area Map

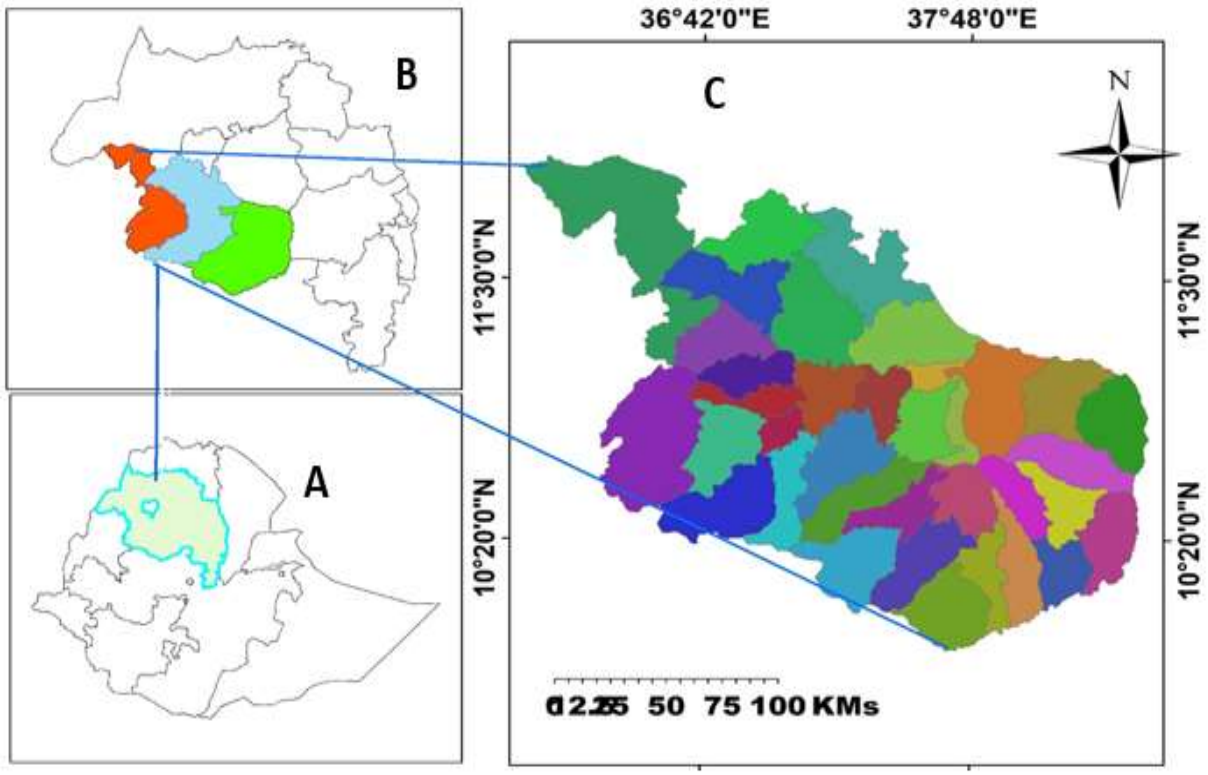


Figure 2: Map of the study area in Amhara region, northwest Ethiopia. A- shows a map of Ethiopia; B- shows a map of the Amhara Regional State, and C- shows districts in the three zones (Awi, East, and West Gojjam zones)

4.4. Population

Source population

The source population was all people who were 15 years and older living in East Gojjam, West Gojjam, and Awi zone who visited the health facilities in the three zones (Objectives I and II), and all adult people aged 18 years and above living in the West Gojjam zone and Awi zone (Objective III), all adult people aged 18 years and above engaged in charcoal production processes and living in the West Gojjam zone and Awi zone (Objective IV).

Study population

The study participants were all adults' aged 15 years and older living in East Gojjam, West Gojjam and Awi zone who visited health facilities during the seven-year period (2012/13-2018/19) (Objectives I and II). For Objective III and IV, adults aged 18 years and above included exposed and non-exposed to TCP, and residing in the randomly selected districts of Awi zone and West Gojjam zone. Participants included in the charcoal producers group if the individuals engaged in charcoal production activities for at least one year before the data was collected, and those labeled as non-producers if individuals had not been involved in charcoal production (Objectives III and IV).

4.5. Variables

Outcome variable

Presenting at least one CRD symptoms (1=Yes, 0=No) (Objective III)

Respiratory mask utilization (1=Yes, 0=No) (Objective IV)

Exposure (treatment) variable

Engaging in traditional charcoal production (1=Yes, 0=No) (Objectives III and IV)

Control (independent) variables

Control variables that potentially confound the relationship between exposure to traditional charcoal production and chronic respiratory symptoms, and factors affecting mask utilization were

chosen in accordance with existing literature (Objectives III and IV). These variables include sociodemographic and economic characteristics, personal and behavioural factors, family-related variables, knowledge, attitude, and environmental-related factors. Variables likely to affect both the presentation of CRD symptoms and exposure to the TCP are included to predict the propensity to be exposed to traditional charcoal production.

4.6. Inclusion and Exclusion Criteria

All records documented in the DHIS2 during the study period (2012/13-2018/19), and with complete information on key study variables (e.g., diagnosis, demographic data) were included in the study, whereas, records with missing or incomplete data on major study variables (e.g., missing diagnosis or outcome information) were exclude (Objectives I and II).

For objectives III and IV, the inclusion criteria considered individuals with at least one year of work experience in the traditional charcoal production in one or more of the activities, such as combustion, carrying and packing, and those complete the questionnaire. The exclusion criteria include individuals who were seriously ill and couldn't respond to questions (Objectives III and IV).

4. 7. Operational definitions

Chronic respiratory symptoms: The development of one or more of the symptom/s such as chronic cough, phlegm, wheezing, shortness of breath, and chest tightness(128). Symptoms-based respiratory questionnaires are a valuable tool for screening of respiratory symptoms in resource-poor and rural settings (214).

Chronic cough and phlegm were defined as cough and sputum production occurring on most days of the week (≥4 days/week) for at least 3 months in a year(128, 215).

Wheezing: A condition causing a wheezy or whistling sound during inspiration/ expiration during the last 12 months apart from that caused by a cold or acute upper respiratory infection(128).

Chest tightness: chest pain that kept off work with phlegm during the last 12 months(128).

Shortness of breath/breathlessness is grouped into five levels, and anyone who presented with level 1 or higher symptoms in the last 12 months was considered to have shortness of breath(216).

- Grade 0: No breathlessness except with strenuous exercise.
- Grade 1: Breathlessness when hurrying on the level ground or walking up a slight hill during the last 12 months.
- Grade 2: Walking slower than people of the same age on the level because of breathlessness or need to stop for breath when walking at own pace or level during the last 12 months.
- Grade 3: Stopping for breath after walking about a certain distance or a few minutes on the level ground during the last 12 months.
- Grade 4: Too breathless to leave the house or breathless when dressing or undressing during the last 12 months.

Engaging in traditional charcoal production was assessed by asking participants if they were involved in TCP activities (combustion, packing, and/ or carrying) for at least one year, likely to be associated with significant exposures to particulates or fumes attributed to the CRD symptoms (217).

A participant is considered a traditional charcoal producer if he/she is participated in one or more of the activities, such as combustion, packing, or carrying/transporting of charcoal, for at least one year.

Knowledge - Participants' level of knowledge was assessed using ten structured questions, each having a binary response, 1= Yes and 0= No. This gave each participant a total possible score between 0 and 10. To determine the overall level of knowledge, we used Bloom's cut-off criteria by converting each score into a percentage. Based on this, scores of 80% or above were considered a high level of knowledge, 60-79 as a moderate level of knowledge, and below 60% as a low level of knowledge (190). However, for the final report, those participants whose score 60% and above were considered as having good knowledge.

Attitude - Participants' attitude level was assessed using 10 questions, each based on a 5-point Likert-scale ranging from 1=strongly disagree to 5=strongly agree. This gave a total possible score between 10 and 50 for each respondent. To determine the overall attitude level, we used Bloom's cut-off criteria. Based on this method, each respondent's total score was converted into percentage, and scores of 80% or above were categorized as a positive attitude, scores 60-79% as a moderate

attitude, and scores <60% as a negative attitude (190), and for the final report, those participants whose score 60% and above were considered as having positive attitude.

PPE use- In this study, PPE use was assessed based on whether participants reported using any type of mask while they were at the workplace (charcoal production sites).

Utilization was assessed through a self-reported yes/no response, indicating whether they wore a mask during work activities.

4.8. Sample size and sampling procedure

Sample size determination

For objectives I and II, the study included all people who were 15 years and older with records on asthma and COPD reported in the three zonal health departments' DHIS2 database over a seven –year period (2012/13-2018/19).

To determine sample size for **objective III,** we calculated by using a double proportion formula with an assumption of 95% confidence interval and power of 80%, 5% acceptable margin of error and 32% and 23.5% proportions of ever wheezing among women exposed and unexposed exposed to biomass smoke respectively(218) and design effect of 2 and by taking 10% for non-response rate, Therefore, total sample size for study participants was 2237 adults. The 2:1 ratio was taken for non-producers to producers.

$$n=(Z_{\alpha/2}+Z\beta)^2*[p_1(1-p_1)+p_2(1-p_2)/(p_1-p_2)]^{\,2} * DEFF$$

Where:

- $Z\alpha_{/2}$ is the critical value of the normal distribution at $\alpha/_2$ (for a confidence level of 95%, **α** is **0.05** and the critical value is 1.96), α = type I error (level of significance)
- **Zβ** is the critical value of the normal distribution at **β** (for a power of 80%, β is 0.2 and the critical value is 0.84), β = type II error (1- β = power of the study) and power is the probability of getting a significant result

- **P_1** and **p_2** are the expected sample proportions of the two groups.
- **P_1 - p_2** is the expected difference in proportion
- Design effect (**DEF**) of two is used

For objective IV, we aimed to estimate the proportion of mask use among the target population and identify associated factors with it. To calculate sample size, we used EPI Info™ 7 STATCALC. For the proportion, we applied the single population proportion formula, using a PPE use proportion of 30% from the previous study(219), with a 95% confidence level, 5% margin of error, a design effect of 2, and a 10% non-response rate. A total of 710 individuals were estimated to have participated in this study. For the associated factors, we used the two population proportion formula, by considering a variable on availability of PPE as factor for utilization of PPE at work place reported from the earlier study; assuming proportion of outcome (PPE use) among exposed 73.5%, proportion of outcome (PPE use) among unexposed 50% and ratio of unexposed to exposed 0.17, odds ratio of 1.7 (220), 95% confidence level, 80% power, along with a design effect of 2 and 10% non-response rate, and the calculated sample size was 630. However, finally, we took the larger 710 estimated for the proportion.

$$n=(Z_{\alpha/2})^2*p(1-p)/d^2 * DEFF$$

Where:

- n = required sample size
- Zα/2 = standard normal value at the desired confidence level (e.g., 1.96 for 95% CI)
- p = estimated proportion of the outcome (from previous studies or assumptions)
- d = margin of error (precision), usually set at 0.05

Sampling procedure

We included all the records available during the study period, i.e., it was based on a census of the data, rather than on a selected sample **(Objective I and II).** By doing so, we were able to capture the full picture of the situation without leaving out any relevant cases. A multi-stage sampling technique was employed to select study participants **(Objectives III and IV).** First, districts from the two zones were identified based on their practice of charcoal production. Second, eight districts (four from each zone) were selected randomly from each zone, and 30% of kebeles were selected randomly from the respective districts. Households were selected using a systematic random sampling technique, and one adult person from each household was randomly selected. At the household level, the data collectors identified the person as a charcoal producer or non-producer **(Figure 3).**

Sampling procedure

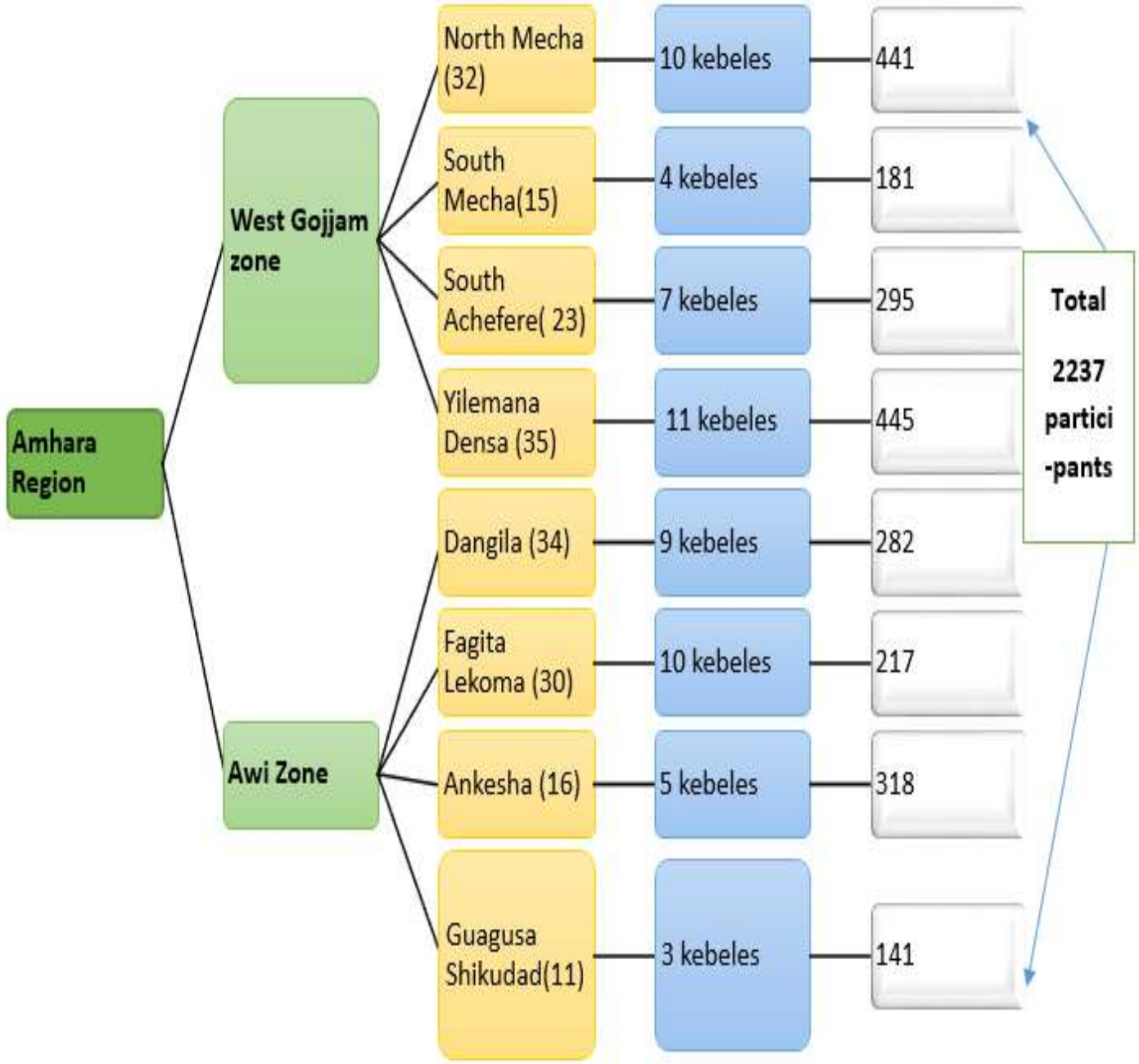


Figure 3: Schematic presentation of sampling procedures to select study participants in the districts of West Gojjam and Awi Zones, Amhara Region, Ethiopia

4.9. Data Collection

Data were obtained retrospectively from the three zones of the Amhara region that are compiled through the DHIS2 data management system and reported between 2012/13 and 2018/19. Seven years of data from 44 districts (18, 11, and 15 districts were from East Gojjam, Awi, and West Gojjam Zones, respectively) were included in the analysis. We considered bronchial asthma and COPD cases in our analysis since these are the most prevalent types of CRDs(221-223) (Objectives I and II). There is an integrated health information system from the bottom up through the HMIS. Health-related data based on the recommended WHO guideline ICD codes for chronic lower respiratory diseases (J40-J47)(224) are compiled at the district level and reported quarterly to the Zone Health Department offices, then the Regional Health Bureau, and finally to the Federal Ministry of Health. Data were collected by health management information system officers from October to December 2022. The projected population data on adults aged 15 years or older for 44 districts specified continuously over the seven years were obtained from the Bureau of Finance and Economic Development, Amhara Regional National State. All cases were regarded as discrete episodes, even if a patient could have revisited during this period.

The study used community-based primary data collected by trained data collectors with face-to-face interviews using smartphones pre-installed with the Kobo Toolbox (ODK) application. The interview-administered questionnaire was prepared in English and translated into Amharic, and then back-translated to English by experts to ensure validity (Objectives III and IV).

The information on CRD symptoms was collected based on earlier studies (6, 70, 101, 225, 226) with a few modifications. Symptoms-based respiratory questionnaires are also a valuable tool for identification, screening, and diagnosis of respiratory illnesses in resource-poor and rural settings (70, 128, 227). Occupational exposure-related questions were adapted from earlier studies (127, 196, 228, 229). Eight BSc nurses, health officers serving as data collectors, and two MPH supervisors participated in the data collection.

4.10. Data quality control

The first version of the questionnaire was reviewed by six clinicians from Debre Markos Referral Hospital in the field to check how each item is clear and relevant. The item relevance was rated based on a 4-point scale, with 1 indicating “not relevant” and 4 indicating “highly relevant.” The item-level Content Validity Index (I-CVI) ranged from 0.50 to 1.00, whereas as the overall scale-level CVI (S-CVI) was 0.82. Based on expert feedback, questions with I-CVI values below 0.70 were revised(230). After these improvements, the final questionnaire showed good content validity. In addition, the internal consistency of the questionnaires was assessed using Cronbach’s alpha, and the overall alpha coefficient was 0.809, indicating good reliability.

To ensure data quality, a standard questionnaire was used, and data collectors and supervisors received one-day training about the objective of the study. Data were collected using smartphones with the KoboToolbox (ODK) application. Using this tool made the process smoother, improved completeness, reduced errors, and enhance overall reliability of the collected information. The data extraction tool was prepared based on the DHIS2 registry format. The data extraction guideline was prepared and pretested for its fitness to account for the required information before actual data collection.

The data collectors were informed and trained about the objective of the study and how data extraction is carried out in the data collection procedure. After extraction, the data were checked for completeness and consistency by the principal investigator daily. Cross-checking was also done with the quarterly and annual reports of the districts and the Amhara Regional State Health Bureau records. The data were carefully entered into Microsoft Excel for further cleaning and analysis. Initially, the dataset was screened for inconsistencies, such as duplicate records, outliers, and incorrect or misformatted entries. Errors were corrected through standardized transformations, including removing duplicate entries and correcting formats (e.g., age category formats). The number of CRD cases together with their district was carefully geocoded based on address information from registers and using X and Y-coordinates. All district attributes were properly recorded and cross-checked before analysis. The data collection process is continuously supervised by the supervisors and principal investigators to ensure completeness and consistency.

Additionally, a pre-test was conducted on 5% of the respondents living outside the study area before the actual data collection began.

4.11. Data management and processing

We carefully managed the data to ensure accuracy and completeness before starting the analysis. The annual morbidity rates for COPD, asthma, and CRD per 100,000 people were determined for each year. Multiple subgroup analyses were performed; the first group included CRD, which included both asthma and COPD; the second group included asthma, and the third group included COPD. Excel 2019 was used to demonstrate the trend and calculate seasonal components of CRD, and SPSS version 27 was used to undertake the forecasting analysis (objective I). An attribute table for districts was prepared in Excel by including location ID, name of districts, number of CRD cases, sex, and population of the district, and all the CRD records are geocoded based on their X and Y-coordinates of each district where CRD cases were residing (objective II).

After data collection, the information was exported to Microsoft Excel for cleaning and coding. SPSS version 27 was employed to clean and edit data imported from Excel, which contains data from the Kobo Toolbox. The data were first cleaned to ensure that only valid observations were included in the analysis. Any missing or invalid data points were handled appropriately by imputation based on the nature of the dataset(231). STATA version 17 was employed for further analysis (Objectives III and IV).

4.12. Data Analysis

Descriptive statistics

Descriptive statistics (mean, standard deviation, median, and interquartile range) were used to summarize continuous variables, while categorical variables were presented as frequencies and percentages. The results are supported by visual representations like tables and graphs.

Inferential statistics

The inferential statistical analyses were performed to estimate the effect of exposure to traditional charcoal production and to assess risk factors associated with CRD symptoms and mask use.

Propensity score matching (PSM) analysis was employed to evaluate the impact of exposure to traditional charcoal production on CRD symptoms by considering Rosenbaum and Rubin's recommendations to estimate causal effects from observational data(232). The PSM works by creating a new control group through the selection of control subjects who share a similar propensity for treatment as the exposed subjects. The analysis involved several key steps, including propensity score estimation, matching, covariate balance assessment, effect estimation, and sensitivity analysis. In addition, a multivariable logistic regression model was used to assess factors associated with CRDs besides the risk of exposure to TCP and factors associated with mask utilization in the workplace (Objective III and IV)

4.12.1. Trend, seasonal variations and forecasting analysis

Trend and seasonal variations analysis

The center of the moving average was plotted to observe seasonal and annual fluctuations and trends of CRD morbidity (118) in the study area. A smoothing technique was used to reduce data variability that might occur in time series as a result of irregularities and seasonality to observe trends and the seasonal distribution of CRD. Smoothing was performed based on the moving average window method (using a four-quarter window) (233). Excel 2019 was used to demonstrate the trend and calculate the seasonal components of CRD.

Forecasting

The intrinsic feature of time series data is that, typically, adjacent observations are dependent (97). The nature of this dependence among observations of time series is of considerable practical interest. Autoregressive Integrated Moving Average (ARIMA) model (2, 1, 2) (0, 0, 0) was employed to forecast CRD for the next ten years using data from 2013-2019, where (2, 1, 2) is a stationary part of the model and (0, 0, 0) is a seasonal part of the model. The ARIMA model is a typical statistical technique capable of finding a fitting function in an iterative way through the Box-Jenkins procedure. The ARIMA model uses the autoregressive parameters (AR), the number of differencing passes(d), and moving average parameters (MA) to describe the series in which a pattern repeats seasonally over time (234). Before forecasting, the stationarity of our time-series data was assessed with a line chart, P-P plot, and Ljung-Box Q-test. We consider the differencing

of (d=1) to transform the data to be stationary. To determine the time lags for the current observation, the autocorrelation function (ACF) and partial autocorrelation function (PACF) were used to estimate the auto-regression (AR) and moving average (MA) models. The Box and Jenkins method was used to determine the ARIMA model (97); identification of stationarity, estimation of the AR and MA models graphically using ACF and PACF correlograms, and diagnosis and checking the model. After the identification of the ARIMA model, it was checked using the Bayesian information criterion (BIC) to evaluate the goodness-of-fit of constructed models, and a model with a BIC value of 15.67 was chosen to select the best ARIMA model to forecast CRD. SPSS version 27 was used to undertake the forecasting analysis.

4.12.2. Spatial, temporal and spatiotemporal analysis

For objective IV, Ethiopian administrative regions' shapefile, district-level polygon map, and geographic coordinates were obtained from the publicly accessible DIVA-GIS database (http://www.diva-gis.org/gdata), and spatial data layers were created in ArcGIS 10.8. Spatial, temporal, and spatio-temporal analysis was employed using the Poisson model. The data represent all CRD cases (bronchial asthma and COPD cases) registered from 44 districts of the three zones between 01 July 2012/13 and 30 June 2018/19 and archived in the Zonal Health Department offices. An attribute table for districts was prepared by including location ID, name of districts, number of CRD cases, sex, and population of the district, and all the CRD records are geocoded based on their X and Y-coordinates of each district where CRD cases were residing. The SaTScan software version 10.1 was used to detect the randomness of CRD distribution over space and time among adults aged 15 years and above, and cluster maps with CRD cases were plotted using ArcGIS version 10.8.

Spatial autocorrelation analysis

Spatial autocorrelation (global Moran's I) statistic was employed to assess whether the spatial pattern expressed CRD cases is clustered, dispersed, or random in the study area(235). The significance of Moran's I is identified based on the Monte Carlo method, which simulates the distribution according to random data. Moran's I value lies between +1 and -1, and when its value is greater than zero and p-value < 0.05 shows clustering, while Moran's I value of zero shows no

spatial autocorrelation (the pattern is random) and less than zero shows the pattern is dispersed. The local Moran' I and Getis-Ord Gi analyses were also done to locate the local cluster after detecting the global Moran' I. The local Moran' I describes spatial clustering of observations in high or low rates and outliers, and the Getis-Ord Gi statistic identifies local spatial clustering patterns, either "hot spots" (spatial clusters of high values) or "cold spots" (spatial clusters of low values). The statistical significance for local Moran's I and Getis-Ord Gi was determined via hypothesis testing using standardized z-scores calculated for each observation and significant p-values. A spatial weight matrix was used to specify the spatial dependence between neighboring districts. Neighbors were defined using the first-order queen's polygon contiguity (i.e., districts sharing common borders and vertices were considered neighbors(236, 237). ArcGIS was used to explore the distribution of CRD cases in terms of their geographic relations.

Spatial clusters

We used Kulldorff's SaTScan software version 10.1 to employ the spatial, temporal, and spatiotemporal scan statistics to depict the purely spatial, temporal, and spatiotemporal clusters as described previously(236) using the attribute table prepared for districts. Kulldorff's scan statistics also help to calculate the log-likelihood ratio (LLR), and relative risk (RR) and provide a p-value using Monte Carlo Simulations. In this SaTScan statistics, the Poisson model was employed, where the number of cases is compared to the background population data and the expected number of cases in each unit is proportional to the size of the population at risk(236). The observed CRD cases were compared with the expected cases inside and outside of each window and the risk ratios were estimated based on the Poisson distribution. The null hypothesis of the spatial scan statistic states that CRD is randomly distributed throughout the districts and that the expected event count is proportional to the population at risk. The purely spatial clusters were selected based on the likelihood ratio and p-value <0.05. The LLR was calculated to assess the statistical significance of the detected clusters, while the relative risk (RR) quantified how much higher the CRD risk was inside the detected cluster compared to outside. Monte Carlo simulations were used to evaluate the statistical significance of the clusters by comparing the observed LLR with LLRs generated under the null hypothesis. The maximum number of permutations for the Monte Carlo simulation was set to 999 to assess the sensitivity of significant locations to the number of permutations, p <

0.05(238). The scanning window was a circle in the purely spatial pattern, and the upper limit for the maximum purely spatial was set to be 50% of the population at risk, which is important to detect both small and large clusters. For each circle, the rejection of the null hypothesis is based on a likelihood ratio statistic. The p-value was calculated through Monte Carlo hypothesis testing, by comparing the rank of the maximum likelihood from the real data set with the maximum likelihoods from random data sets. To evaluate the statistical significance of the most likely cluster, the 999 random replications of the data set are generated under the null hypothesis. For each location and size of the scanning window, the alternative hypothesis is that there is a higher risk within the window as compared to outside.

Under the Poisson assumption, the likelihood function for a specific window is proportional to:

$$\left[\frac{c}{E(c)}\right]^{c}\left[\frac{C-c}{C-E(c)}\right]^{C-c} I(Z)$$

Where:

- **C** is the total number of cases
- **c** is the observed number of cases within the window and
- **E[c]** is the expected number of cases within the window under the null hypothesis. Note that since the analysis is conditioned on the total number of cases observed,
- **C-E[c]** is the expected number of cases outside the window**.**
- **I(Z)** is an indicator function.

In this context, Z represents a candidate spatial (or space-time) cluster, defined by a scanning window of varying size and location that moves across the study area. Each Z includes a set of geographic units (e.g., districts) and the observed and expected number of cases within that window. An indicator function I(Z) is used to control which types of clusters are evaluated in the analysis. When SaTScan is set to scan only for clusters with high rates, I( ) is equal to 1 when the window has more cases than expected under the null hypothesis, and 0 otherwise. The opposite is true when SaTScan is set to scan only for clusters with low rates. When the program scans for

clusters with either high or low rates, then I( )=1 for all windows(239). The excess hazard (the ratio of observed to expected cases greater than one) for each district was calculated by dividing the observed cases by the expected cases and plotted using the geographic information system (GIS). The expected number of cases in each area under the null hypothesis was calculated using the following formula: **E[c]= *p**C/P**, where **c** is the observed number of cases and ***p*** is the population in the location of interest, while **C** and **P** are the total number of cases and population, respectively. SaTScan also identifies secondary clusters in the data set in addition to the most likely cluster and orders them according to their likelihood ratio test statistic. Secondary clusters are computed, based on the degree of overlap allowed in the cluster circles, and include the option of no geographical overlap(236).

Temporal clusters

A purely temporal cluster analysis scanning was performed to detect the temporal clusters of CRD cases with high rates, representing the whole geographic area, but with a one-year time aggregation length. The temporal scan statistic uses a scanning window, a time interval that moves in one dimension. The upper limit for the maximum was specified to be 50% within the study period for purely temporal cluster analysis. To identify clusters, a likelihood function was maximized across all locations and times. The maximum likelihood indicates the cluster is least likely to have occurred by chance (primary cluster). The p-value is obtained through Monte Carlo hypothesis testing. For purely temporal analyses, only the most likely cluster is reported.

Space-time clusters

The space-time scan statistic was employed to detect clusters in both space and time. The time of the space-time cluster analysis was set to the time frame from 2012/13–2018/19. The space-time scan statistic was defined by a cylindrical window with a circular (or elliptic) geographic base and with a height corresponding to time. The base is defined exactly as for the purely spatial scan statistic, while the height reflects the time of potential clusters. The cylindrical window is then moved in space and time so that for each possible geographical location and size, it also visits each possible time interval, where each cylinder reflects a possible cluster. Thus, this method enables simultaneous detection of the location and time of a cluster occurrence. A likelihood ratio was

calculated for each space-time window to indicate to what extent the rate of cases inside the area is higher than expected. Monte Carlo hypothesis testing is then used to indicate the significance level of specific space-time windows. For each space-time window, the likelihood ratio was calculated to determine whether the rate of observed cases inside the area was higher than expected cases. By considering the number of observed and expected cases inside the window, the software identifies and assesses the statistical significance of space-time clusters. The Monte Carlo simulation technique is used to estimate the p-value. The maximum number of permutations for the Monte Carlo simulation was set to 999 to assess the sensitivity of the significant locations to the number of permutations. This means that SaTScan will generate 999 random permutations of the data to compare with the real data. The cluster with the maximum LLR was defined as the most likely cluster (a cluster with the highest LLR test means a cluster least likely to have occurred by chance). Likewise, for purely spatial analysis, in space-time analyses, SaTScan also identifies secondary clusters in the data set in addition to the most likely cluster and orders them according to their LLR test statistic. A standard of no geographical overlap and a hierarchical cluster type were selected to report secondary clusters (separation of clusters). Statistical significance for the presence of clusters was reported when the p-value was < 0.05. A discrete Poisson-based model was used to analyze annually reported CRD cases following the Poisson distribution(236).

4.12.3. Propensity score matching analysis

Propensity score estimation

A logistic regression model was employed to estimate the propensity score for each individual using a treatment dummy (engaged in TCP) as the dependent variable and the other covariates as the independent variables (control)(240). The propensity score is defined as the probability of being exposed to TCP, given a set of observed covariates, and its objective is to create a balanced sample where exposed and unexposed individuals have similar characteristics(206). The Receiver Operating Curve (ROC curve) was used to evaluate how well the estimated propensity scores distinguish between exposed and unexposed groups.

Propensity score matching

Propensity score matching (PSM) analysis was performed to reduce selection bias with the potential confounders between the exposed and unexposed groups. The ideal way of determining the causal treatment effect is by carrying out randomized controlled trials(205). However, due to its ethical and practical reasons, it is difficult to manipulate study subjects by assigning them to the treatment (i.e., exposure to TCP) to estimate its impact on CRD symptoms(241). Nevertheless, Rosenbaum and Rubin(206, 242) proposed the PSM method to minimize the imbalance in participant characteristics between treatment (exposed) and control (non-exposed) groups by considering the confounding between the two groups. We used nearest-neighbor matching with a 1:3 ratio and a caliper width of 0.05 standard deviations of the logit of the propensity score.

Balance assessment in matching

Standardized Mean Deviation

To assess the effectiveness of the matching, the balance of covariates before and after matching was evaluated using standardized mean differences (SMD), percentage bias, percentage bias reduction, t-tests, and variance ratio comparisons(243).

Love plot

In addition, the Love plot is also used to assess the balance between exposed and unexposed individuals by examining the standardized percentage bias across covariates before and after matching graphically. The vertical line at zero on the x-axis serves as a reference point, indicating perfect balance. The post-matching values are mostly expected to fall within the ±10% range, suggesting improved balance.

Sensitivity analysis

Sensitivity analysis assesses the robustness of effect estimates to unobserved confounders(206). Causal inferences from non-experimental studies are inevitably threatened by unmeasured confounding, as the assumption of no unmeasured confounding can never be directly tested. Since propensity score matching cannot account for unmeasured confounders, we performed sensitivity analysis using Rosenbaum's Bounds gamma(1 1.2) to justify how robust the estimated treatment

effects (e.g., ATE, ATET) were to hidden bias from unmeasured confounders in our study and would not need to influence the treatment assignment to change our conclusions about the treatment effect(240).

Effect estimation

To address potential confounding, we employed propensity score matching to create a balanced comparison between those who were exposed to the traditional charcoal production (treated) and non-exposed (control) adults. After implementing the propensity score matching, to assess the causal effect of exposure to TCP in presenting of CRD symptoms, we estimated the two treatment effect parameters: the Average Treatment Effect on the Treated (ATET) and Average Treatment Effect (ATE) with their methods(232).

Average Treatment Effect on the Treated (**ATET**) measures the average effect of treatment specifically among those who are actually exposed to TCP. The basic formula for ATET is:

$$\mathbf{ATET} = \mathbf{E(Y1|T = 1) - E(Y0|T = 1)}$$

Where:

- Y (1) - is the potential outcome (CRD symptoms) for the exposed (treated) individuals,
- Y (0) - is the potential outcome for the unexposed (controlled) individuals, and
- T=1- indicates treatment assignment (i.e., exposure to TCP).

Average Treatment Effect (**ATE**) represents the average impact of the exposure across the entire population if all individuals in the sample had exposed. The basic formula for ATE is:

$$\mathbf{ATE} = \mathbf{E(Y(1) - E(Y(0)}$$ (206).

In addition, we computed the population attributable fraction (APF) using ATE to estimate the proportion of CRD symptoms burden in the population that could be attributed to exposure to the traditional charcoal Production.

The formula used(244):

$$PAF = \frac{[pe * ATE]}{Risk\ population}$$

Where:

- *Pe* - prevalence of the exposure in the population
- ATE - average treatment effect
- Risk population - overall prevalence of the outcome in the population

4.12.4. Multivariable binary logistic regression analysis

Multivariable logistic regression analysis technique was employed to address the research questions that emphasized factors associated with CRD symptoms, in addition to assessing the effect of exposure to traditional charcoal production on chronic respiratory disease symptoms (Objective I), and factors associated with respiratory mask utilization among traditional charcoal producers (Objective II).

To assess risk factors associated with CRD symptoms, candidate variables for the final multivariable logistic regression model were selected based on a p-value < 0.25 in the bivariable analysis(245). A multivariable logistic regression model was then employed to identify factors independently associated with CRD symptoms among adults. The strength of association between each independent and dependent variable was reported using adjusted odds ratios (AORs) with 95% confidence interval. Statistical significance was determined at a 5% significance level (P<0.05). Variables with p-value < 0.05 in the final model were considered statistically significant risk factors for CRD symptoms. The Hosmer-Lemeshow goodness-of-fit test was used to assess the adequacy of the final multivariable logistic regression model, and the test has shown p-value of 0.391, indicating that the model fit the data well. This test evaluates whether the predicted probabilities from the model align with the observed outcomes. Multicollinearity among the predictor variables was assessed with VIF for all predictors and found to be below 10, indicating that multicollinearity was not a concern in the final model.

4.13. Ethics approval and consent to participate

This study was approved by the Ethical Review Board (IRB) of the College of Medicine and Health Sciences, Bahir Dar University, and a support letter was also secured from the Amhara Public Health Institute to the respective administrative zones where the study was conducted. Informed verbal consent was obtained from all participants after the objectives of the study were explained to them before the study began. Participation in the study was completely voluntary. Participants had the right to ask any questions and could withdraw from the study at any time without providing a reason, and without facing any anger or negative consequences. Participants who were found to have serious health issues were kindly advised to visit the nearest health facility for proper care. Privacy and confidentiality of the data were maintained by using respondent codes instead of names, and data were secured through encrypted folders. The information collected was used solely for this study.

CHAPTER FIVE: RESULTS

5.1. Trends, seasonal variations and forecasting of chronic respiratory diseases (Objective I)

5.1.1. Trends of asthma, COPD, and overall CRD

The trend of CRD has clearly shown an increase from 2012/13 to 2018/19. The average number of CRD cases during the seven years in the three zones was 30942(95%CI: 19133, 42750). The yearly average CRD morbidity rate was 460.5 (95% CI: 302, 619 per 100,000 population per year, p trend<0.001) during the study period in the three zones. The overall CRD morbidity rate showed an increasing trend from 305 in 2012/13 to 731 per 100,000 population in 2018/19, which translates to an overall increase of 139.7% over the seven years, and the average annual relative increase of 13.3% per year from 2012/13 to 2018/19.

Among the two common CRD respiratory diseases, the number of asthma cases always occupied first place every year and accounted for 90.5% of the total CRD cases from 2012/13-2018/19. The overall average of asthma cases during the seven years was 28008(95%CI: 17208, 38808) in the three zones. The annual average rate of morbidity was 417 (95% CI:277,562 per 100,000 population per year, p trend<0.001). The trend of asthma morbidity rate increased from 275.6 to 661 per 100,000 population in 2012/13 and 2018/19, respectively, which translates to an increase of 139.8%.

Similarly, the COPD morbidity rate also varied from 29.3 in 2012/13 to 69.7 in 2018/19 per 100,000 population, representing a 137.9% relative increase. The yearly average of COPD cases was 2933(95%CI: 1841, 4025) per 100,000 population per year (p trend<0.001) during the seven years in the three zones **(Figure 4).** The majority of asthma (58.6%) and COPD (54.9%) were reported in the 30-64-year-old group **(Table 1).**

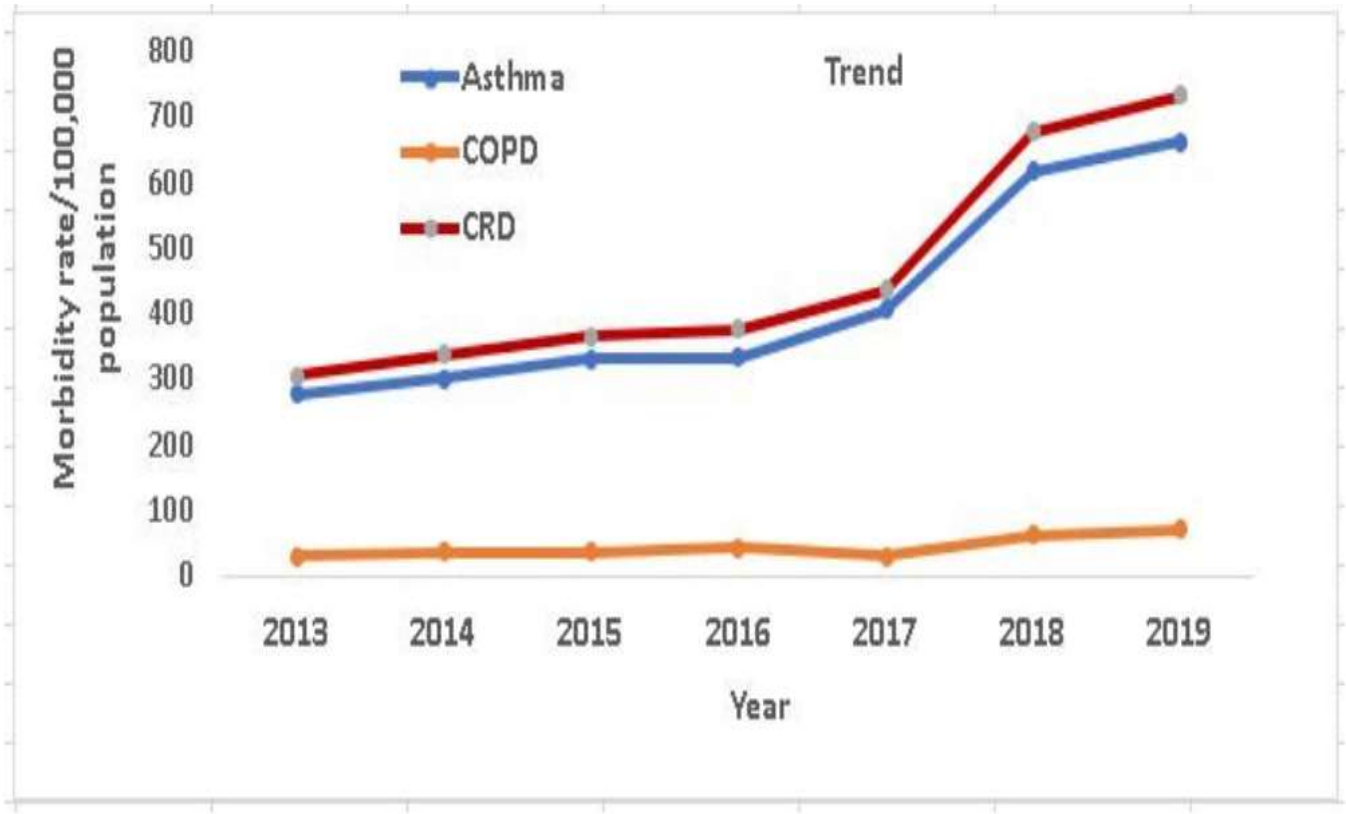


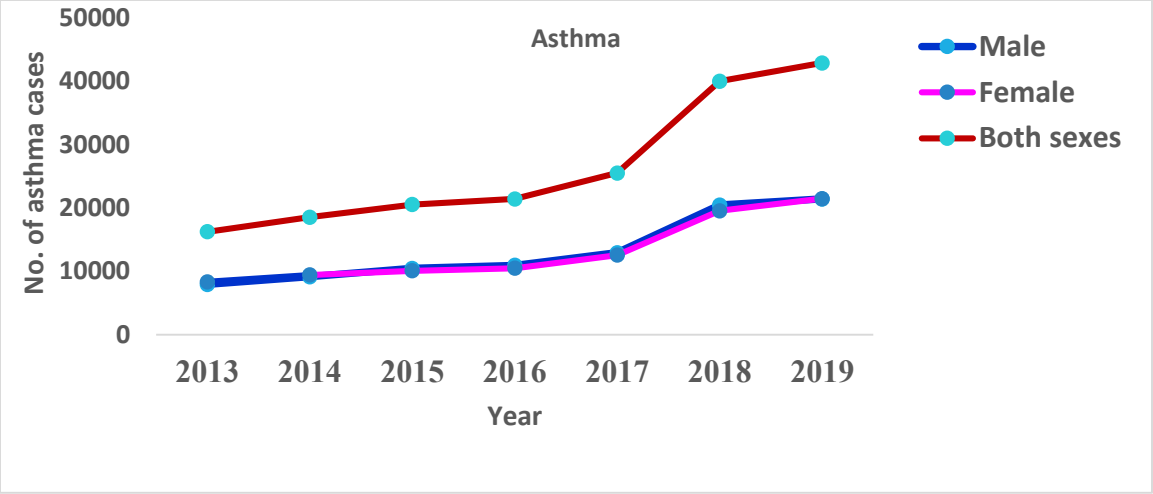
Figure 4: The trends of asthma, COPD, and CRD morbidity rates/100,000 population from 2012/13 to 2018/19 in Amhara Region, northwest Ethiopia

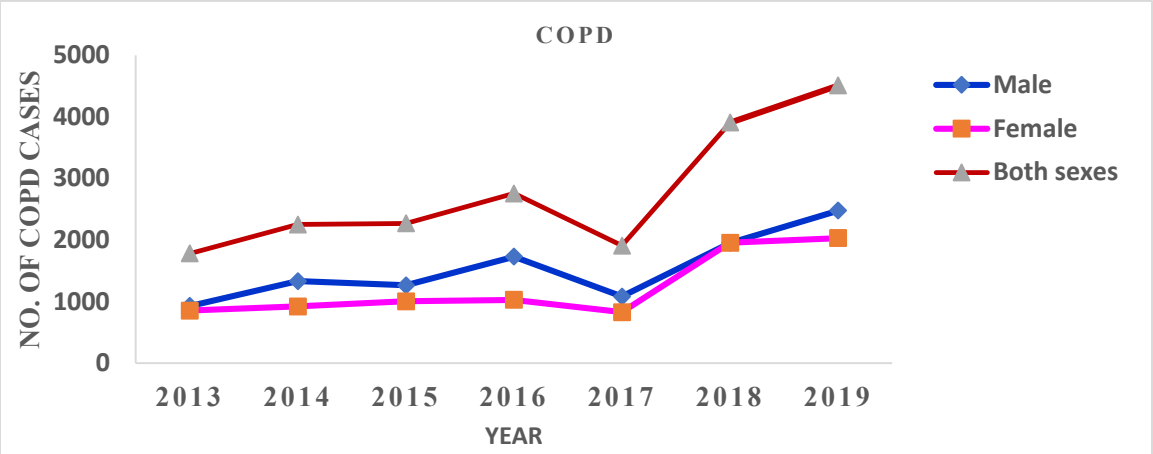
Table 1: Summary statistics for asthma, COPD, and CRD morbidity in Amhara region, northwest Ethiopia, 2012/13-2018/19

	2012/ 2013	2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	Average No. of cases (95%CI)/100,000 population
No. of cases in both sexes in three zones								
Asthma cases								
Male	7925	9143	10468	10939	12931	20455	21417	14226 (95%CI: 8614, 19837)
Female	8839	9485	10263	10584	12423	18621	21318	13782(95%CI: 8575, 18990)
Total	16764	18628	20731	21523	25354	39076	42735	28008(95%CI: 17208, 38808)
COPD cases								
Male	928	1331	1264	1728	1081	1953	2477	1639(95%CI: 1093, 2185)
Female	853	920	1005	1027	828	1954	2030	1294(95%CI: 721, 1867)
Total	1781	2251	2269	2755	1909	3907	4507	2933(95%CI: 1841, 4025)
CRD cases								
Male	8853	10474	11732	12667	14012	22412	23894	15865(95%CI: 9798, 21933)
Female	9692	10405	11268	11611	13251	20575	23348	15076(95%CI: 9322, 20830)
Total	18545	20879	23000	24278	27263	42987	47242	30942(95%CI:19133, 42750)

Age distribution of asthma and COPD cases			
CRD cases	**15-29 years**	**30-64 years**	**>=65 years**
Asthma			
Male	23321	53166	16791
Female	23183	55220	13130
COPD			
Male	2260	5811	2691
Female	1810	4825	1982

The morbidity rates due to asthma and COPD persistently increased in both sexes from 2012/13 to 2018/19 **(Figure 5).** The number of male to female cases of asthma, COPD, and CRD was proportional across the seven years, even though the proportion of male cases was slightly higher. However, there is a difference in the relative percent change of asthma and COPD cases in both sexes during the study period. A relative percent change of 70% and 58% was detected in male and female asthma cases, respectively. In the same pattern, a relative percent change of 67% and 38% was noted in male and female COPD cases, respectively. Overall, from 2012/13 to 2018/19, an increase in the trend of CRD in both males and females was observed across the three zones.





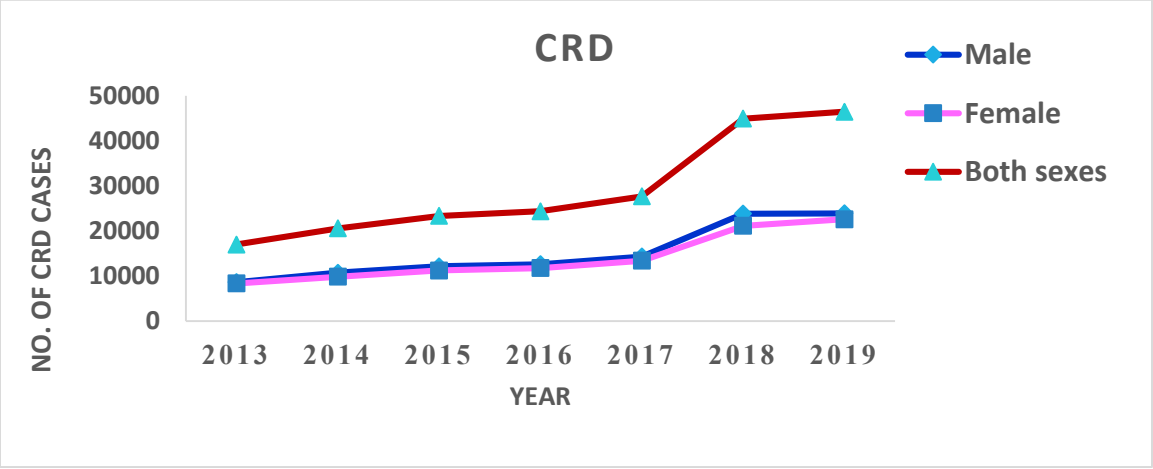


Figure 5: The morbidity rates due to asthma and COPD in both sexes from 2013 to 2019 in Amhara region, northwest Ethiopia

The morbidity rates attributed to asthma, COPD, and CRD showed variations across the seven years in three zones **(Figure 6).** The yearly average morbidity rates of asthma, COPD, and CRD for Awi from 2013 to 2019 were 594.7 (95% CI: 382.6, 806.8), 46 (95% CI: 20, 71.8), and 640 (95% CI: 407, 873) per 100,000 population, respectively. Indeed, the relative percent change in asthma, COPD, and CRD morbidity rates from 2013 to 2019 was also 58.2%. 11.3% and 56.7% respectively.

The yearly average morbidity rates of asthma, COPD, and CRD for WGZ from 2013 to 2019 were 389(95%CI: 285, 493), 46(95%CI: 31, 62), and 427(95%CI: 305, 550) per 100,000 population, respectively. Concomitantly, the relative percent change of asthma, COPD, and CRD morbidity rates from 2013 to 2019 were also 6.4%, 97%, and 7.2%, respectively.

The yearly average morbidity rates of asthma, COPD, and CRD for EGZ from 2013 to 2019 were 365 (95% CI: 209, 522), 40 (95% CI: 25, 55), and 406 (95% CI: 245, 569) per 100,000 population, respectively. Similarly, the relative percent change of asthma, COPD, and CRD morbidity rates from 2013 to 2019 was 66%, 10%, and 65.8%, respectively. The peaks of yearly asthma, COPD, and CRD would reach in 2017 and need further investigation.

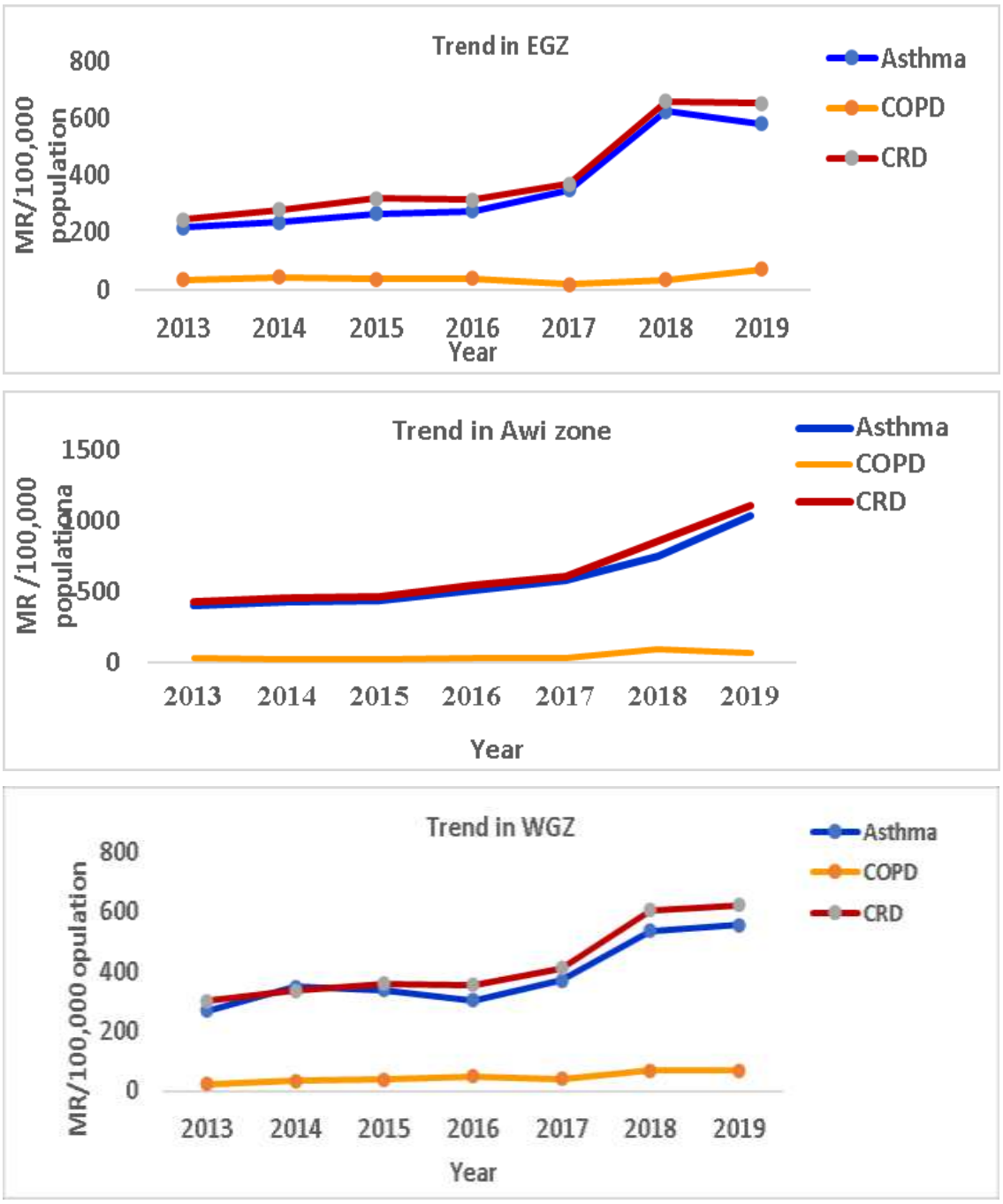
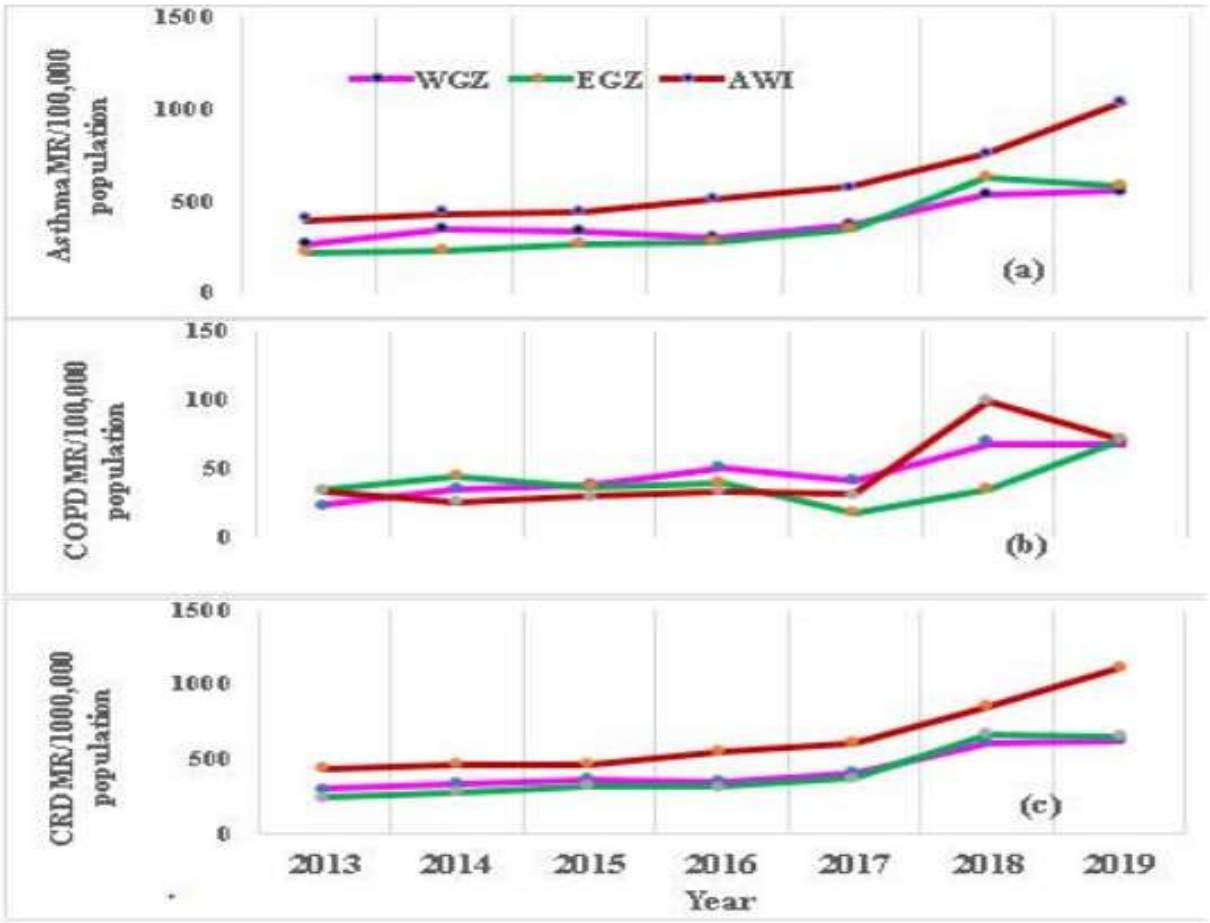


Figure 6: Trends of asthma, COPD, and CRD during 2013-2019 in three zones of Amhara region, northwest Ethiopia

Overall, the trends of asthma, COPD, and CRD morbidity rates during the study period are increasing year-to-year across the three zones **(Figure 7).** The morbidity rate from chronic respiratory disease varied greatly among the three zones. The highest cumulative average CRD morbidity rate during the seven years increment was observed in the Awi zone, at 4508.8 per 100,000 population, followed by West Gojjam, at 3005.8 per 100,000 population, and East Gojjam, at 2905 per 100,000 population. However, there was some overlap between the East and West Gojjam zones in CRD morbidity rates in the year 2018.



Morbidity rates of Asthma (a), COPD (b) and CRD in three zones

MR- Morbidity rate, WGZ-West Gojjam zone, EGZ-East Gojjam zone, Awi-Awi zone

Figure 7: Trends of asthma, COPD, and CRD morbidity rate per 100,000 population in people aged 15 years and older in the three zones of Amhara region, northwest Ethiopia, 2013-2019

5.1.2. Seasonal variations of chronic respiratory disease

Asthma, COPD, and CRD have clearly shown seasonal patterns in the three zones during the study period. The proportions of summer, spring, winter, and autumn CRD cases were 59189 (29%), 71944 (35%), 39297 (19%), and 33764(17%), respectively. The months from June to August and September to November had a higher morbidity rate for asthma compared to the remaining months of the year. A peak was observed for COPD from September to November and December to February compared to the rest of the months of the year. This seasonal pattern was detected throughout the seven years.

Calculating a moving average at specific intervals smooths out the data by reducing the impact of random fluctuations. The result of smoothing using the moving average indicated that the seasonal component attributed to 41.47% (with a seasonal index value of 1.4147) and 19.16% (with a seasonal index value of 1.1916) of excess CRD cases in the period between September and November and June to August, respectively, above the cycle mean. However, in the period between December and February and March to May, on average, 28.8% and 34.76 % below the base of the cycle mean, respectively. The observed ascending trend is statistically significant ($p<0.001$) **(Figure 8)**.

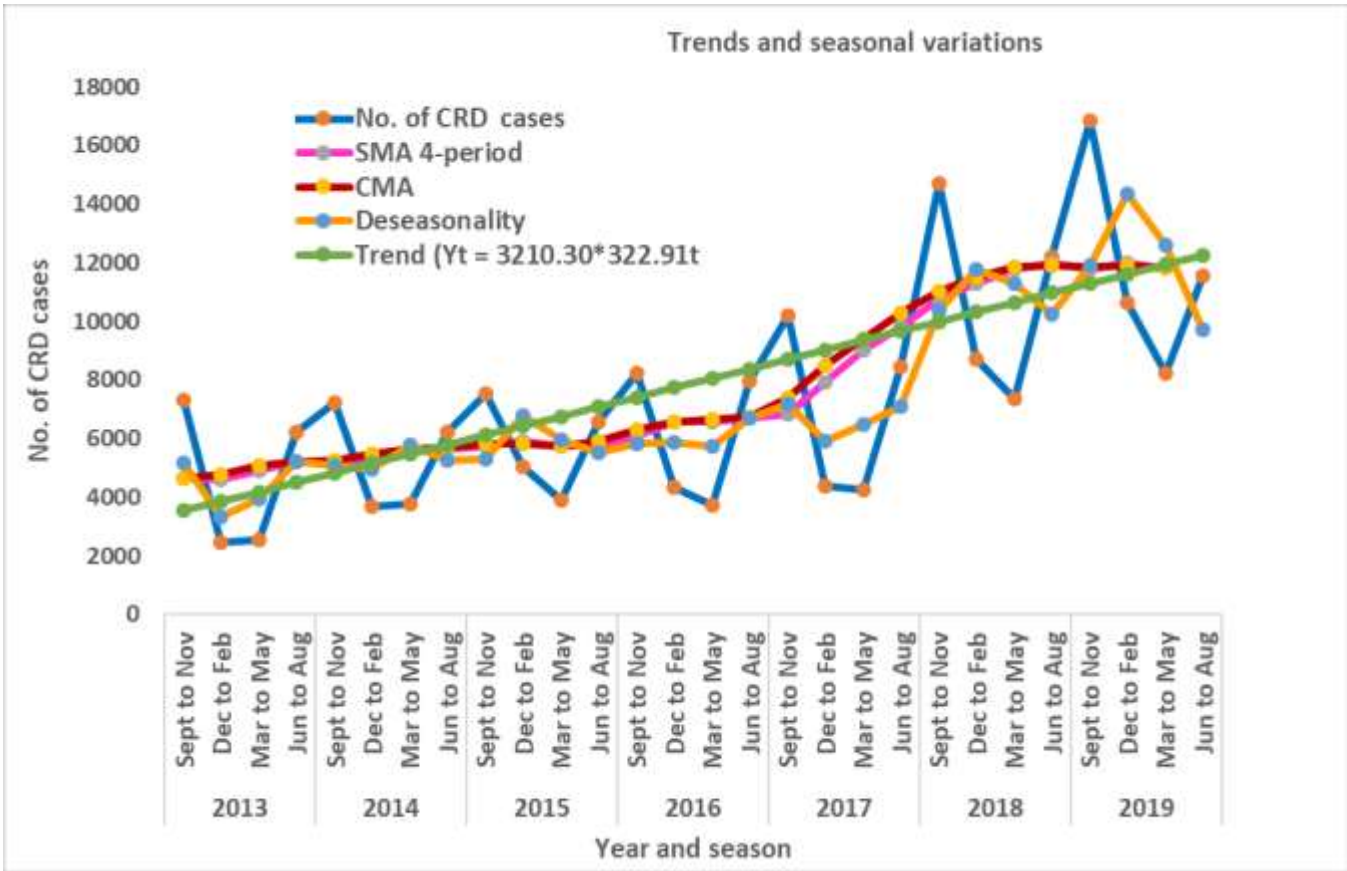
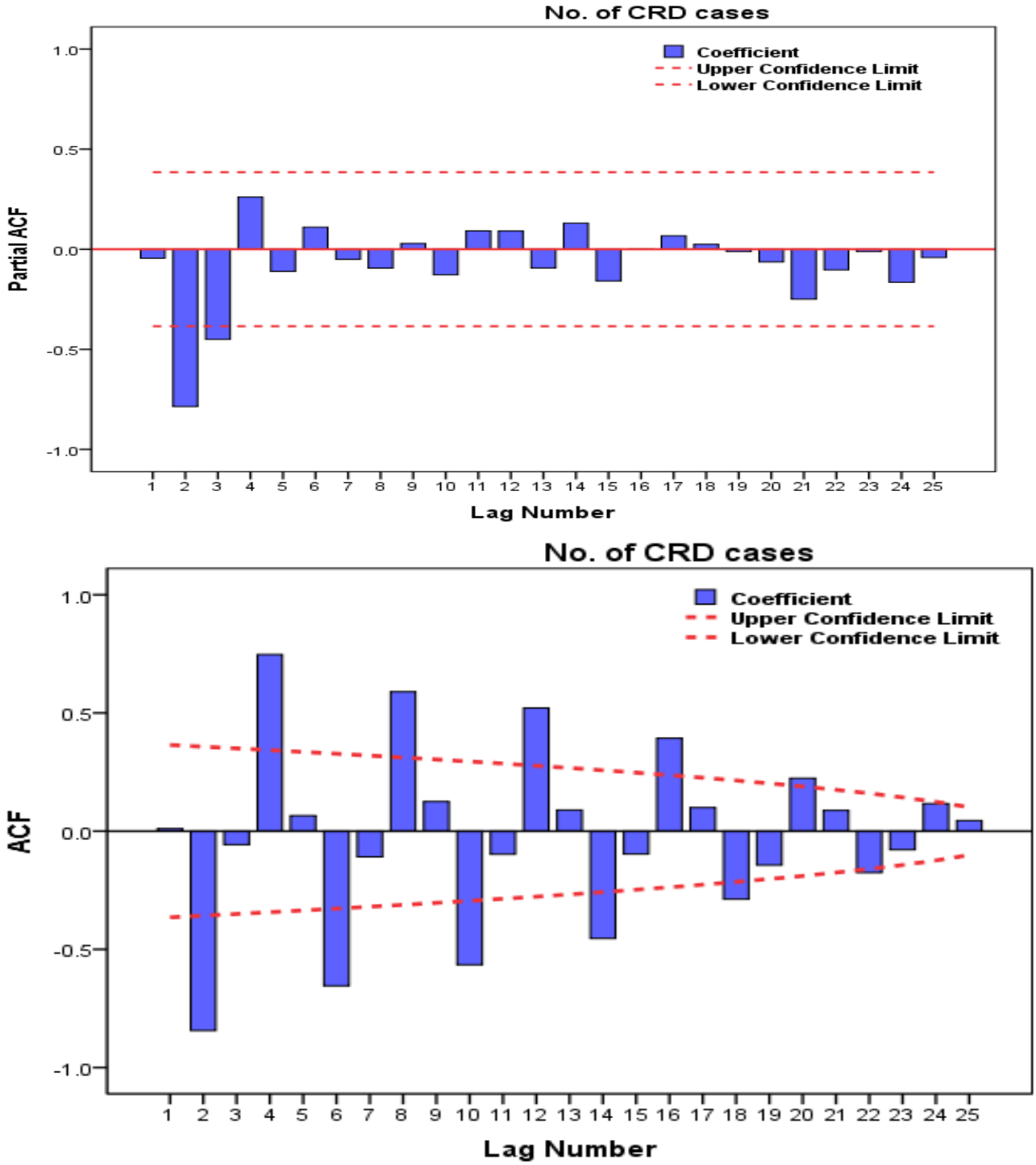


Figure 8: Trends and seasonal variations of CRD morbidity in people aged 15 years and older in Amhara region, northwest Ethiopia

5.1.3. Forecasting of chronic respiratory disease

The trend of CRD was forecasted for the next ten years (2020-2030) based on the 2013-2019 data. Since the data clearly showed a trend and seasonality, we used differencing to maintain the stationarity. The ARIMA model (2, 1, 2) (0, 0, 0) was utilized to forecast the CRD pattern based on the values estimated from the ACF and PACF plots **(Figure 9**). The result from forecasting revealed that in the next ten years, the trend of CRD will increase by 38 % from 2020 to 2030 **(Figure 10).** Similarly, the trend of asthma and COPD will increase by 41.4% and 39.9% from 2020 to 2030, respectively.



ACF- Autocorrelation function PACF- Partial autocorrelation function

Figure 9: ACF and PACF plot of CRD cases during 2013-2019 with transformation of at differencing of one (d=1)

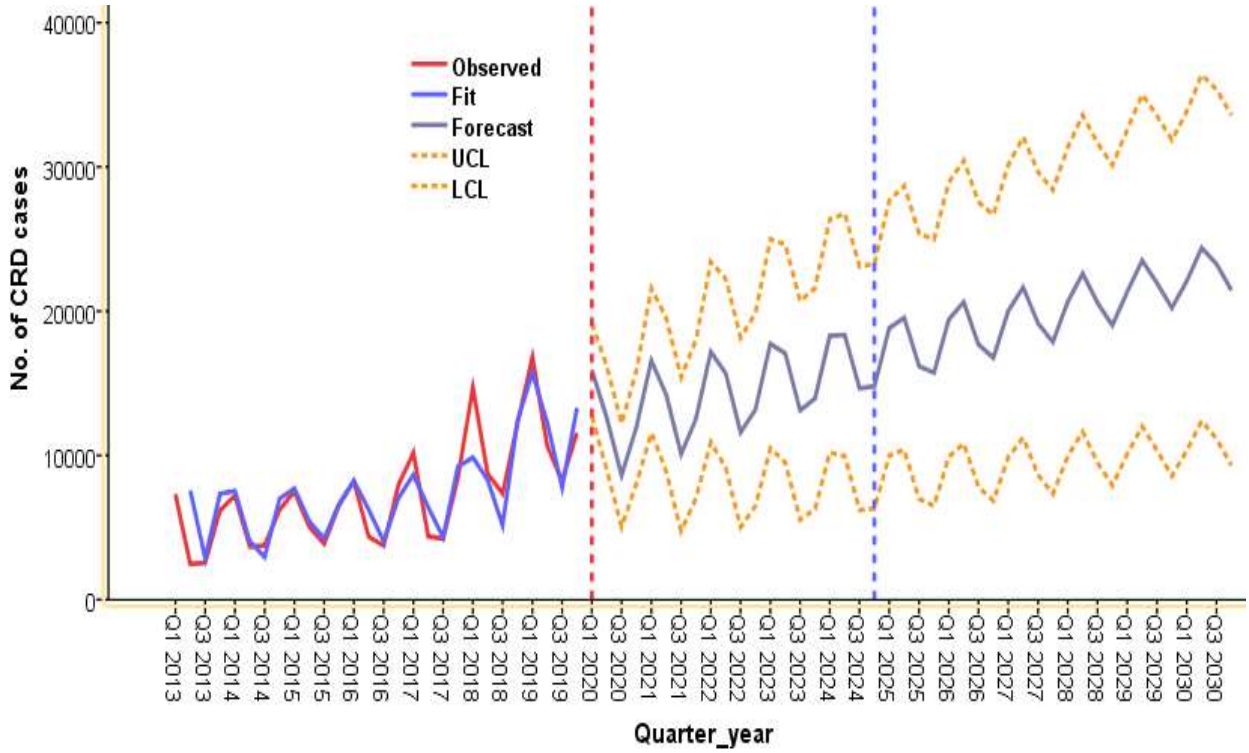


Figure 10: Forecasted CRD for the next ten years (2020-2030) using data from 2013 to 2019 in the three zones of Amhara region, northwest Ethiopia

5.2. Spatial, temporal and spatiotemporal variations of chronic respiratory diseases (Objective II)

5.2.1. Distribution patterns of CRD cases

During the seven years (2012/13 to 2018/19), a total of 204,190 CRD cases were reported from 44 districts in three zones of the Amhara region, and the overall morbidity rate was 4641 (95%CI: 3903, 5379) cases per 100,000 population at risk. Asthma accounted for 90.5% of the total CRD cases in 2019. Chronic respiratory disease shows no substantial sex differences, with the rate among males slightly higher, accounting for 51%. The annual morbidity rate increased from 305 (95%CI: 286, 530) per 100,000 populations in 2012/13 to 731 (95%CI: 641, 1455) per 100,000 populations in 2018/19, indicating an annual morbidity rate change increase of 139.7%% **(Figure 11).**

The CRD morbidity rate was 6508(95%CI:2933,10,082), 4208(95%CI:1714,6702), and 3202 (95%CI:1852,4552) per100,000 population in Awi, West Gojjam, and East Gojjam zones, respectively.

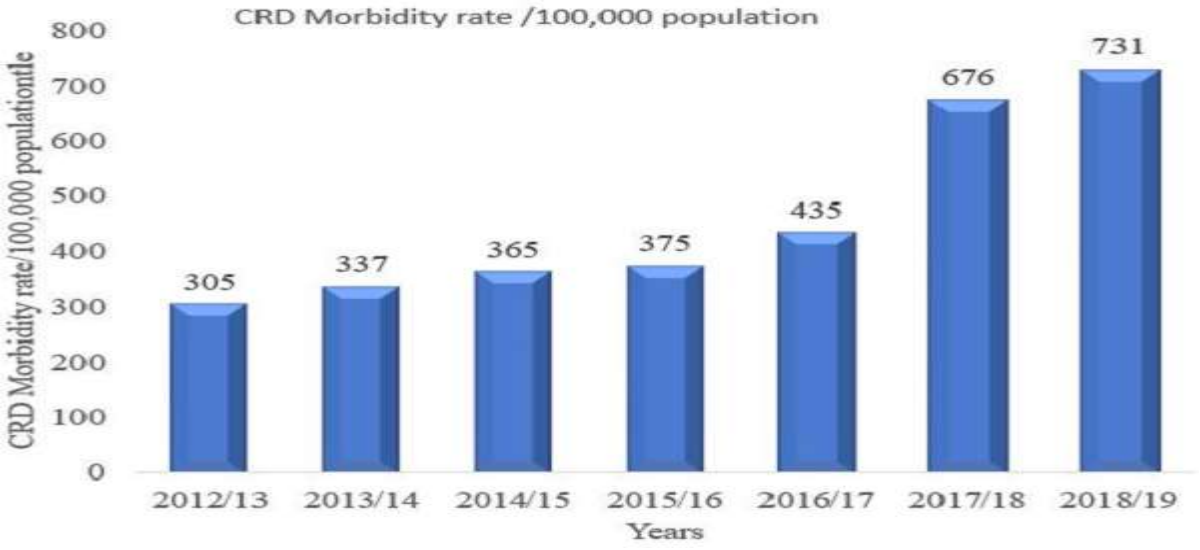


Figure 11: Annual CRD morbidity rate per 100,000 population among those aged 15 years and above in Awi, East, and West Gojjam zones, northwest Ethiopia, from 2012/13 to 2018/19

Across all districts, for seven years, a significantly higher morbidity rate (19967/100,000 population) was reported in Dangila town (Awi zone), while the lowest was observed in Gonji Kollela district (West Gojjam) (746/100,000 population). Besides, the distribution patterns of adult CRD morbidity rates varied across years and districts. The highest morbidity rate(7314/100,000 population) was reported in Dangila town in 2018/19, followed by Finote Selam town (4275/100,000 population) in 2018/19, and Mota town (3626/100,000 population) in 2017/18, while the lowest was observed in Yilmana Densa district (62/100,000 population at risk) in 2015/16 **(Table 2).**

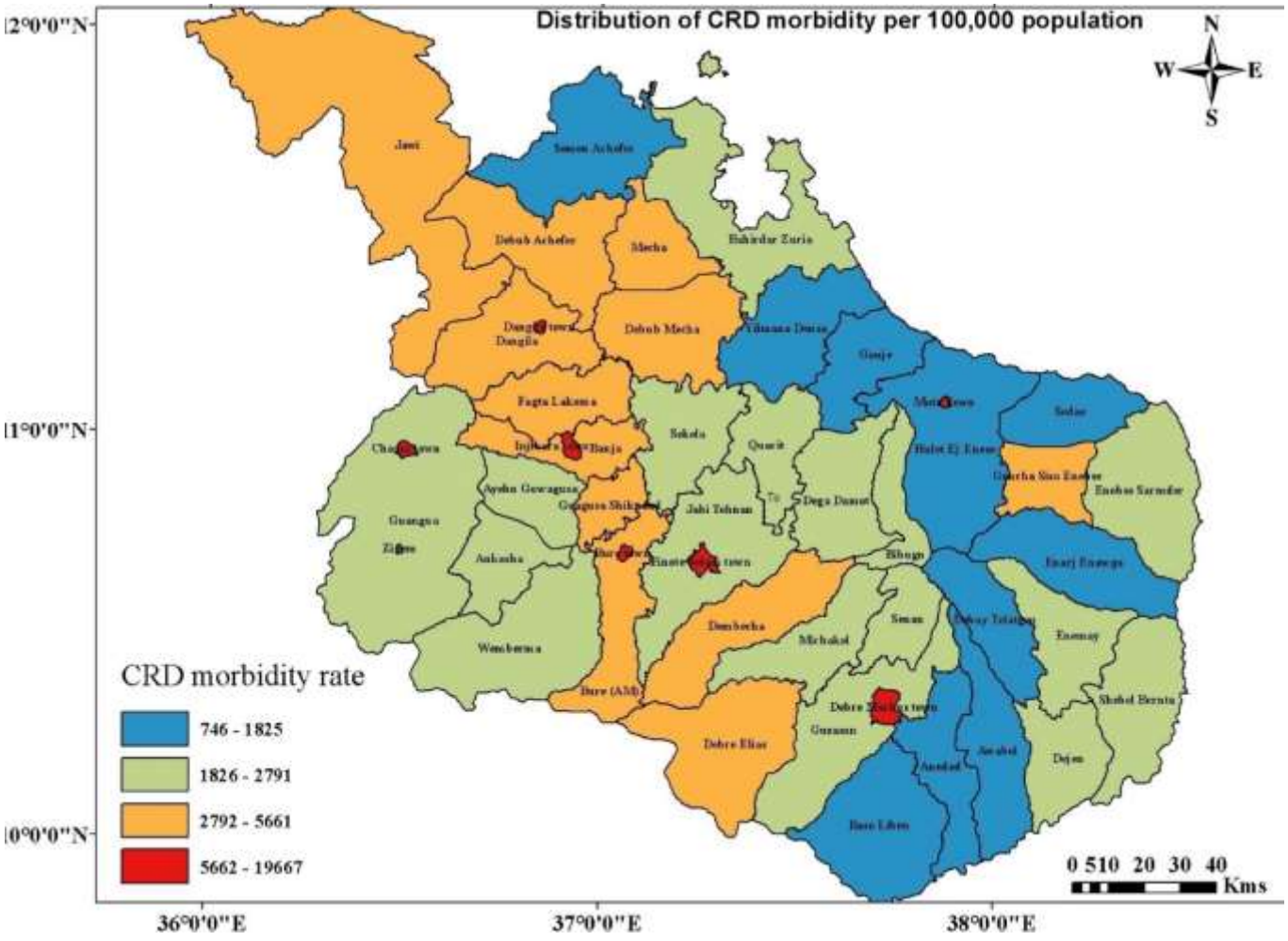


Figure 12: Spatial distribution of CRD morbidity rate per 100,000 population in districts of the three zones, 2012/13-2018/19

Table 2: Annual CRD morbidity rates per 100,000 population at the district level in the three zones of Amhara region, northwest Ethiopia, 2012/13-2018/19

Districts	2012/ 2013	2013/ 2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019
Aneded	171	200	316	207	256	147	111
Ankasha	284	134	298	440	469	238	458
Awabel	105	191	203	190	275	297	411
Bahir Dar Zuria	345	138	393	363	347	422	481
Banja	311	329	305	286	449	1447	1241
Baso Liben	124	172	178	197	241	219	620
Bibugn	200	155	221	206	369	130	739
Bure Zuria	428	609	564	423	630	301	444
Burie Town	1220	1368	1800	2334	2287	2037	2700
Chagni Town	1265	1311	1288	1450	1210	2501	2202
Dangila Town	1309	1993	1660	1895	2303	2993	7314
Dangila Zuria	428	400	513	738	796	782	451
Debay Tilatgin	133	102	152	168	233	167	384
Debre Elias	475	739	1638	777	659	476	887
Debre Markos Town	1488	1639	983	1398	1109	1258	2456
Debub Achefer	685	708	386	547	493	1229	969
Dega Damot	257	122	187	279	316	504	642
Dejen	236	259	257	338	323	233	646
Dembecha	455	610	809	656	694	563	655
Enarji Enawga	146	187	114	296	249	430	385
Enebse Sar Midir	135	199	302	271	128	1037	679
Enemay	251	215	348	254	270	713	393
Faggeta Lekoma	441	474	352	374	489	863	685
Finote Selam Town	1677	1953	1749	709	1641	3822	4275

Goncha Siso Enbebse	149	191	226	201	329	1893	310
Gonje Kolela	96	107	105	127	66	100	145
Gozamin	251	135	284	396	344	409	367
Guagusa Shikudad	591	508	558	563	583	691	867
Guangua	247	324	253	274	375	467	790
Hulet Ej Enese	97	96	154	272	267	242	280
Injibara Town	998	1631	1625	1716	1547	2240	1189
Jabi Tehnan	168	261	171	228	350	643	731
Jawi	362	442	355	440	427	625	1897
Machakel	173	320	332	390	461	184	577
Mecha	260	367	491	451	516	780	752
Motta Town	418	858	548	500	785	3626	3076
Quarit	206	252	133	170	325	471	417
Sekela	182	189	181	183	215	580	486
Semen Achefer	84	134	134	170	136	179	223
Shebel Berenta	292	138	200	156	258	811	603
Sinan	205	164	159	162	313	423	632
Wemberma	286	282	410	404	454	347	190
Yilmana Densa	104	141	84	62	109	419	336
Zigem	226	248	330	251	377	890	1051

5.2.2. Spatial autocorrelation analysis

Spatially, the distribution of CRD cases was non-random (global Moran's I=0.277148, Z-score =3.6597, p<0.001), indicating that the distribution pattern of CRD morbidity was clustered (**Figure 13**). Since the global spatial autocorrelation showed clustering, we employed further analysis to identify spatial cluster features with high or low values (cluster and outlier analysis) and to identify hot spot areas using Anselin's local Moran's I and Getis-Ord Gi* methods, respectively. The result from Anselin's local Moran's I analysis revealed that the high-high cluster was located in the districts of the Awi zone. The low-low clusters and outliers were also detected in most districts of East Gojjam and Awi zones **(Figure 14).** The hot spot analysis (Getis-Ord Gi) demonstrated that hot spot areas were located primarily in the northwest and southwest of the study area **(Figure 15).**

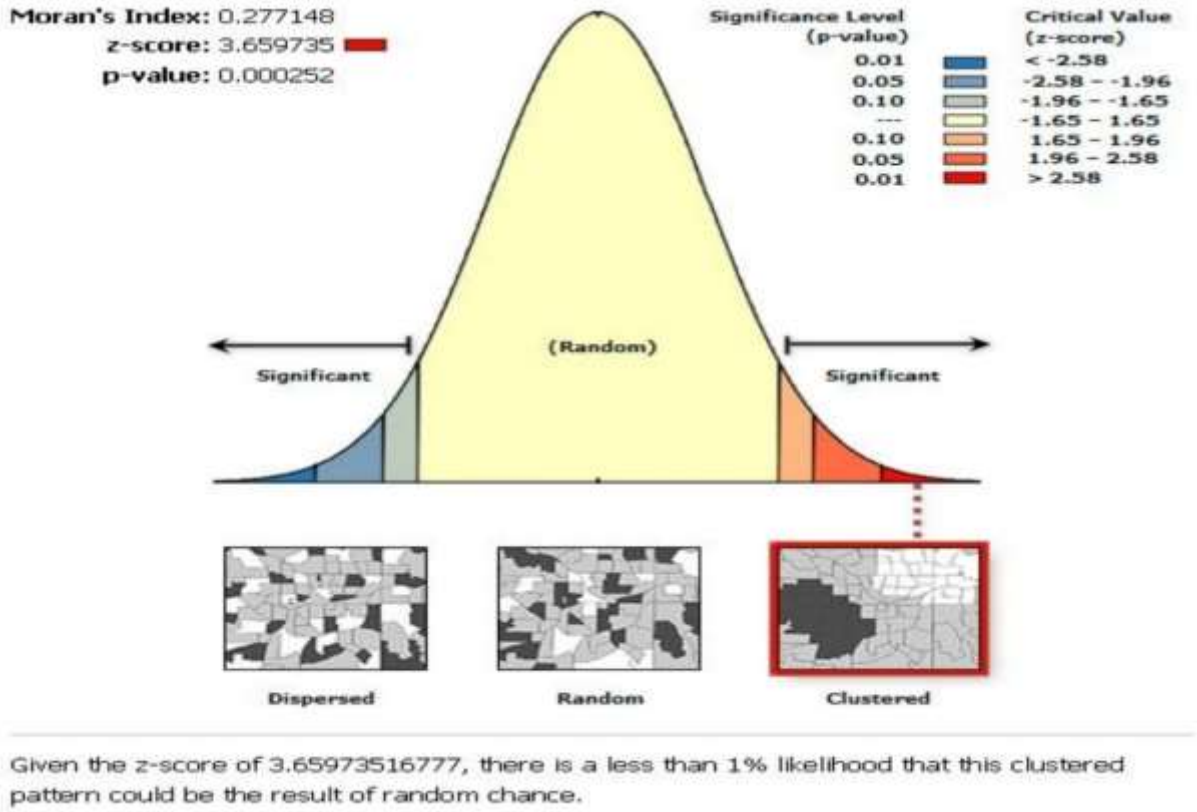


Figure 13: Global spatial autocorrelation (Moran's I) of CRD distribution in the three zones from 2012/13 to 2018/19

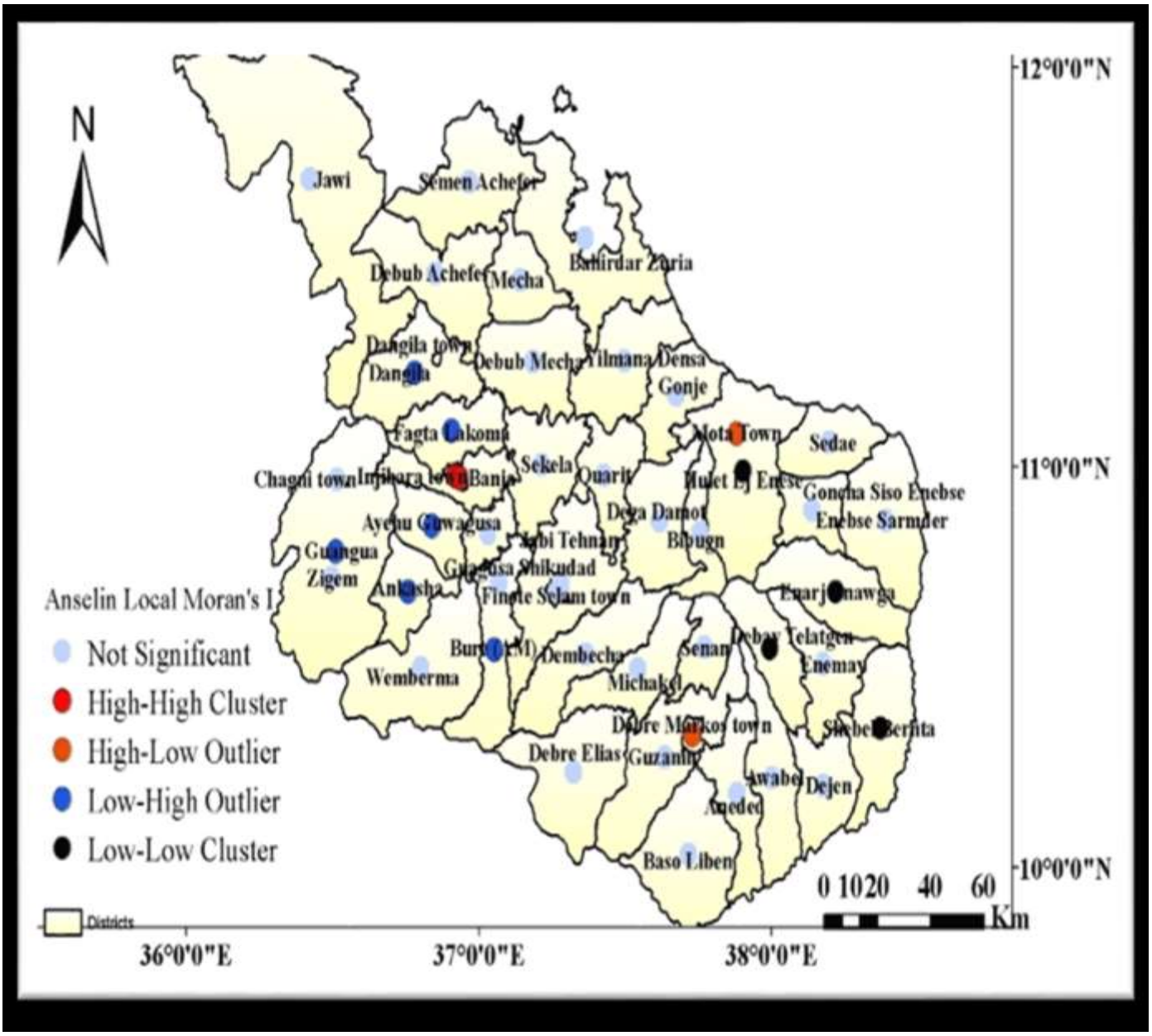


Figure 14: Anselin Local Moran's I analysis on spatial cluster feature and outliers for CRD morbidity rate, 2012/13-2118/19

Figure 15: Spatial clustering of areas with CRD morbidity rate in the three zones, northwest Ethiopia, 2012/13-2018/19

5.2.3. Purely spatial clusters of adult CRD cases

Ten statistically significant purely spatial clusters, one most likely cluster, and nine secondary clusters were detected in the study period **(Table 3).** The most likely cluster, which comprises 11 districts, was located in two zones (8 in the Awi Zone and 3 in the West Gojjam Zone). The cluster window was centered at 10.967700N, 36.925500 E, and the radius of the window was 48.37 km. There were 92597 observed and 33716 expected cases (LLR=47274, p-value < 0.001), with a relative risk (RR) of 4.37 in this cluster window. Secondary clusters are computed, based on the degree of overlap allowed in the cluster circles, and include the option of no geographical overlap criteria for reporting secondary clusters. Among the nine secondary clusters observed, five, one, and three clusters were located in East Gojjam zone, Awi zone, and West Gojjam zone, respectively, during the study period 2012/2013 to 2018/2019. In this spatial distribution, most of the clusters were shown in the northwest and southwest parts of the study area.

Table 3: Most likely and secondary clusters of purely spatial analysis of CRD morbidity in the three zones of Amhara region, Northwest Ethiopia, 2012/13 to 218/19

Cluster type	Cluster year	Cluster center/radius	Number of cluster location/s (Districts)	Observed cases (n)	Expected cases (n)	LLR	RR	P-value
Most likely cluster	2012/13-2018/19	(10.967700 N, 36.925500 E) / 48.37 km	11	92597	33716	47274	4.37	0.001
1st Secondary cluster	2012/13-2018/19	(11.081300 N, 37.877000 E) / 0 km	1	9979	1310	11985	8.35	0.001
2nd Secondary cluster	2012/13-2018/19	(10.327100 N, 37.728700 E) / 0 km	1	10350	1871	9649	6.12	0.001

3rd Secondary cluster	2012/13-2018/19	(10.713000 N, 36.492300 E) / 105.18 km	8	29648	17306	4935	2.14	0.001
4th Secondary cluster	2012/13-2018/19	(11.709200 N, 36.407000 E) / 0 km	1	4597	1733	1707	2.82	0.001
5th Secondary cluster	2012/13-2018/19	(10.543800 N, 37.993300 E) / 49.54 km	12	25656	20104	1371	1.64	0.001
6th Secondary cluster	2012/13-2018/19	(10.221100 N, 38.001200 E) / 83.46 km	3	6891	4558	708	1.79	0.001
7th Secondary cluster	2012/13-2018/19	(11.084800 N, 36.897700 E) / 58.47 km	2	5625	2992	461	1.74	0.001
8th Secondary cluster	2012/13-2018/19	(11.568800 N, 37.356200 E) / 0 km	1	2499	1391	474	2.24	0.001
9th Secondary cluster	2012/13-2018/19	(11.081300 N, 37.877000 E) / 24.90 km	2	2169	1901	32	1.27	0.001

The relative risk compares what is the risk inside the cluster to what is outside the cluster, while the observed /expected compares what is the number of cases inside the cluster to the number that would have been inside the cluster had the null hypothesis been true(236). The risk of getting CRD among people living in eight districts of the Awi zone and three districts of the West Gojjam zone was 4.37 times higher than that of people residing in other districts. Nine significant secondary clusters for the high occurrence of CRD cases were detected in the study area, and most of the districts were from the West Gojjam zone.

5.2.4. Spatial-temporal clusters

Three clusters (one most likely and two secondary clusters) were identified in thirteen cluster locations by space-time cluster analysis. The most likely cluster with 51423 observed and 14825.69 expected cases (LLR=31406.98, RR=4.37, P-value< 0.001) was detected from 2017-2019 from Awi zone (Faggeta Lekoma, Injibara town, Banja, Chagni town, Guagusa Shikudad, Ankasha, Dangila town, and Dangila Zuria) and three districts from West Gojjam zone (Sekla, Bure town, and Finote Selam town).

The high LLR of 31406.98, reflecting a substantial deviation from the expected distribution under the null hypothesis. This indicates that the concentration of cases in this area and time period is not random but represents a true high-risk cluster. Consequently, residence within this cluster is associated with a considerably increased likelihood of developing the disease Secondary clusters were identified in two districts of East Gojjam zone. The first is in Mota town (secondary cluster 1 with 9910 observed and 431.28 expected cases, LLR =21821.89, RR = 24.17, p-value < 0.001) from 2018 to 2019 and Debre Markos town (secondary cluster 2 with 4110 observed and 1364.33 expect cases, LLR= 1806.45, RR = 3.06, p-value < 0.001) detected during 2013 to 2015 cluster year **(Table 4).**

Table 4: Spatiotemporal clusters of CRD morbidity in Awi, East Gojjam, and West Gojjam zones of Amhara region, Northwest Ethiopia, 2012/13 to 218/19

Cluster type	**Cluster year**	**Cluster center/radius**	**Number of cluster location/s (Districts)**	**Observed cases (n)**	**Expected cases (n)**	**LLR**	**RR**	**P- value**
Most likely cluster	2017 to 2019	(10.967700 N, 36.925500 E) / 48.37 km	11	51423	14825.69	31406.98	4.37	0.001

1st Secondary cluster	2018 to 2019	(11.081300 N, 37.877000 E) / 0 km	1	9910	431.28	21821.89	24.17	0.001
2nd Secondary cluster	2013 to 2015	(10.327100 N, 37.728700 E) / 0 km	1	4110	1364.33	1806.45	3.06	0.001

5.2.5. Purely temporal clusters

Purely temporal cluster analysis detected a significantly higher rate of purely temporal CRD clusters. Only one peak period of an identified primary cluster occurred in all districts (with 86410 observed and 55822.41 expected CRD cases, LLR=10866.30, P < 0.001) from 2018 to 2019.

5.3. Effects of exposure to traditional charcoal production on chronic respiratory disease symptoms (Objective III)

5.3.1. Socio-demographic characteristics

The study involved 2,172 participants, with a response rate of 97.1%. Nearly two-thirds (67%) were male, and the median age was 38 (IQR: 30-47) years. Regarding marital status, the majority, 75%, were married, while the rest, 21%, 2.8%, and 1.2% were single, divorced, and widowed, respectively. The majority of participants, 78% (1689), lived in rural areas. More than half of the participants, 55.7 %(1211), reported drinking alcohol, and only four respondents had a history of ever smoking **(Table 5).**

Looking at household characteristics, on average, families had four members (SD± 1.7), and their homes had an average of 2.6 rooms (SD ± 0.8) and an average of 1.7 (SD±0.47) windows. Most houses in 1962(90.3%) had soil floors, and 1723(79.3%) had a separate kitchen. Biomass fuel (wood, plant residue, cow dung) was the primary cooking fuel. Regarding income, the respondents were almost similar across the wealth index categories. More than 78% of respondents were members of the community-based health insurance.

From the total participants, 685 (31.5%) were engaged in TCP (either in combustion, packing, or carrying) activities, and the majority, 86.7%, were males. The median age was 34 years (IQR: 28-43). Among those non-producers, 58% were males, and the median age was 39 (IQR: 30-50) years.

Among the total respondents, 662(30.5%) presented at least one CRD symptom in the past 12 months. Cough was the most frequent symptom (35%) reported, followed by chest tightness (21.6%), phlegm (12.4%), wheeze (10.9%), and shortness of breath (9.4%). Among the participants, 119(5.5%) had confirmed asthma. Nearly 29% from urban residents and 30.1% of rural residents reported at least one type of CRD symptoms in the past 12 months. Among those who lived in homes without having a separate kitchen and a separate animal home, 44.3% & 39.2% experienced CRD symptoms compared to 26.9% & 27.7% from those who lived in homes having a separate kitchen and a separate animal room, respectively. From those engaged in traditional

charcoal production, 385(56.2%) and from those not engaged in it, 277(18.63%) exhibited at least one CRD symptom in the past 12 months.

Table 5: Sociodemographic and environmental-related characteristics of the study participants (N=2172).

Characteristics	**Category**	**Frequency (n)**	**Percentage (%)**
Sex	Male	1458	67
	Female	714	33
	Single	454	21
Marital status	Married	1632	75.1
	Divorced	60	2.7
	Widowed	26	1.2
Religion	Orthodox Christian	2139	98.5
	Muslim	33	1.5
Ethnicity	Amhara	1644	75.7
	Agew	528	24.3
Residence	Urban	483	22.2
	Rural	1689	77.8
	Unable read and	674	31
Educational	write	476	21.9
status	Able to read and	651	30
	write	241	11.1
	Grade 1-8	130	6.0
	Grade 9-12		
	Certificate and		
	above		
Family head	Yes	1577	72.6
	No	595	22.4
CBHI member	Yes	1712	78.8
	No	460	21.2

Characteristics	Category	Frequency (n)	Percentage (%)
	Farming	1418	65.3
Occupation	Government employ	66	3
	Merchant	124	5.7
	Charcoal producers	685	31.5
	Daily laborers	329	15.1
	Students	80	3.7
Water source	Pipe	1241	57.1
	Others	931	42.9
Latrine	Yes	1852	85.3
	No	320	14.7
	Wood	2172	100%
Fuel source	Plant residue	1271	58.5
	Cow dung	1629	75
	Electricity	57	2.6
Floor of the house	Cement	210	9.7
	Soil	1962	90.3
Separated kitchen	Yes	1723	79.3
	No	449	20.7
Having farm land	Yes	1496	68.9
	No	676	31.1
Room for animals (n=1108)	Yes	751	67.8
	No	357	32.2
	Poor	728	33.5
Wealth index	Medium	729	33.6
	Rich	715	32.9

5.3.2. Results from the propensity score matching analysis

In propensity score matching analysis, several key steps are employed. First, the propensity score is estimated. Second, matching is performed. Third, covariate balance is assessed. Fourth, the effect is estimated using ATET and ATE. Finally, sensitivity is assessed to ensure the robustness of the estimated effect.

Propensity score estimation

The logistic regression model is used to estimate the propensity scores by considering variables that could influence the individual to be engaged in the traditional charcoal production. The model describes that almost all variables significantly influence the probability of engaging in traditional charcoal production choices of the respondents **(Table 6).**

Table 6: Logit estimates, likelihood of engaging in charcoal production activities among the participants

Variables	Coef.	St.Err.	t-value	p-value	[95% Conf. Interval]
Age	-0.04	0.01	-7.76	0.001	-0.05, -0.01
Sex	1.86	0.15	12.26	0.001	1.56, 2.16
Marital_status	0.33	0.12	2.68	0.007	0.09, 0.57
Occup_Farm	-1.69	0.14	-12.06	0.001	-1.96, -1.42
Occup_gov	-2.32	0.45	-5.21	0.001	-3.20, -1.50
Occup_Merch	-0.30	0.20	-1.47	0.141	-0.70, 0.10
Occup_daily	-1.13	0.17	-6.74	0.001	-1.45, -0.80
Edun	0.10	0.06	1.63	0.102	-.019, 0.21
Residence	2.41	1.13	2.14	0.033	0.20, 4.62
CBHI	-1.78	1.13	-1.58	0.115	-4.00, 0.44
Famil_charprodun	1.59	0.16	9.75	0.001	1.27, 1.91
Drink_alcol	-0.29	0.12	-2.43	0.015	-0.53, -0.06
Charprodun_invilage	1.37	0.15	9.40	0.001	1.10, 1.65
Constant	-3.37	1.20	-2.82	0.005	-5.72, -1.03

The logistic regression model showed moderate discrimination between the exposed and unexposed groups with an area under the curve of 0.846 (**Figure 16).**

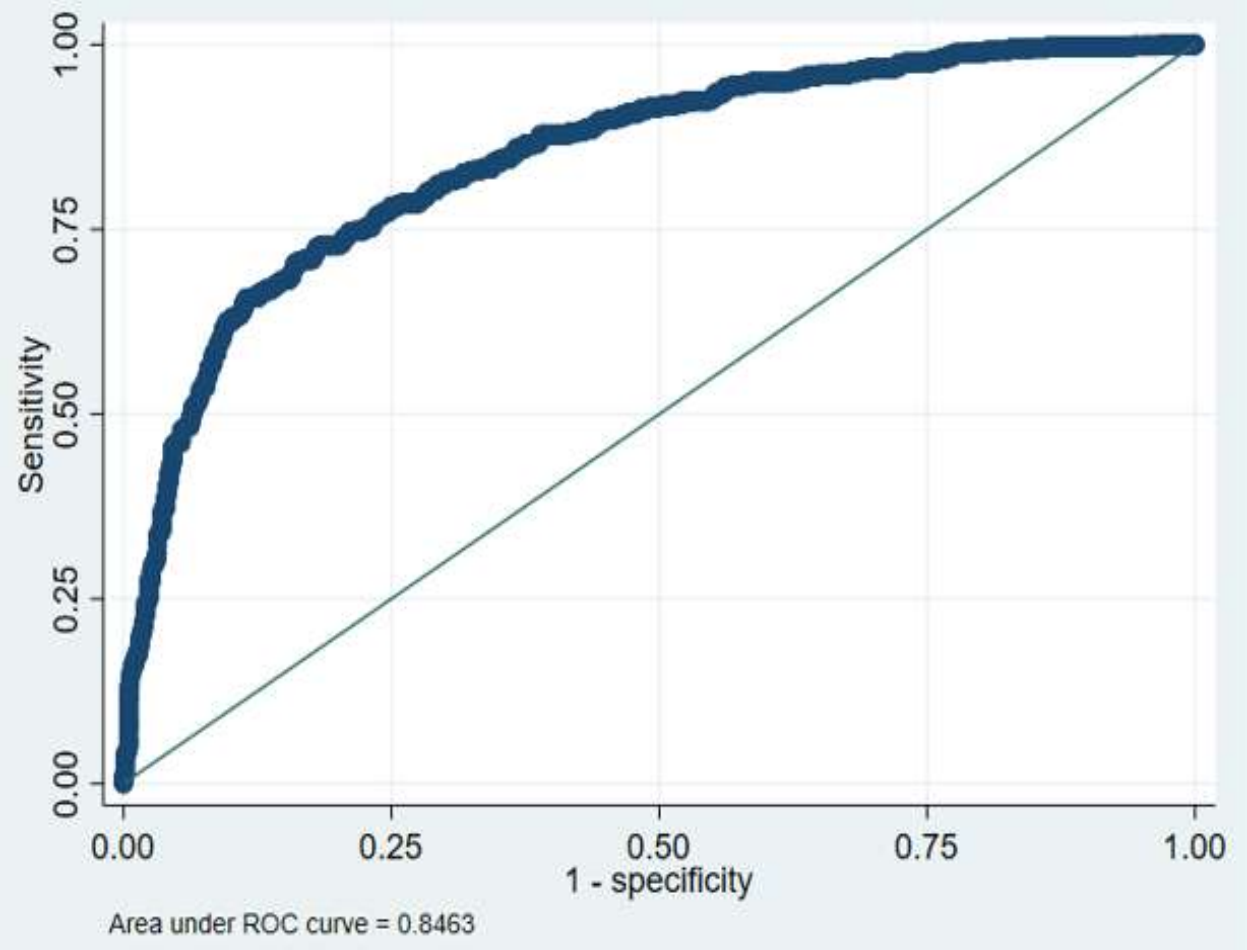


Figure 16: Receiver Operating Characteristic (ROC) Curve depicting the predictive accuracy of the model in differentiating exposed versus unexposed groups

The distribution of propensity scores also demonstrated substantial overlap (common support), ensuring comparability between the exposed to TCP and unexposed groups. From the exposed groups, seven participants had propensity scores that did not overlap with any unexposed individuals. The off-support exposed individuals were excluded from further analysis to maintain validity. However, the un-exposed group's propensity score distribution overlapped with the exposed group **(Figure 17).**

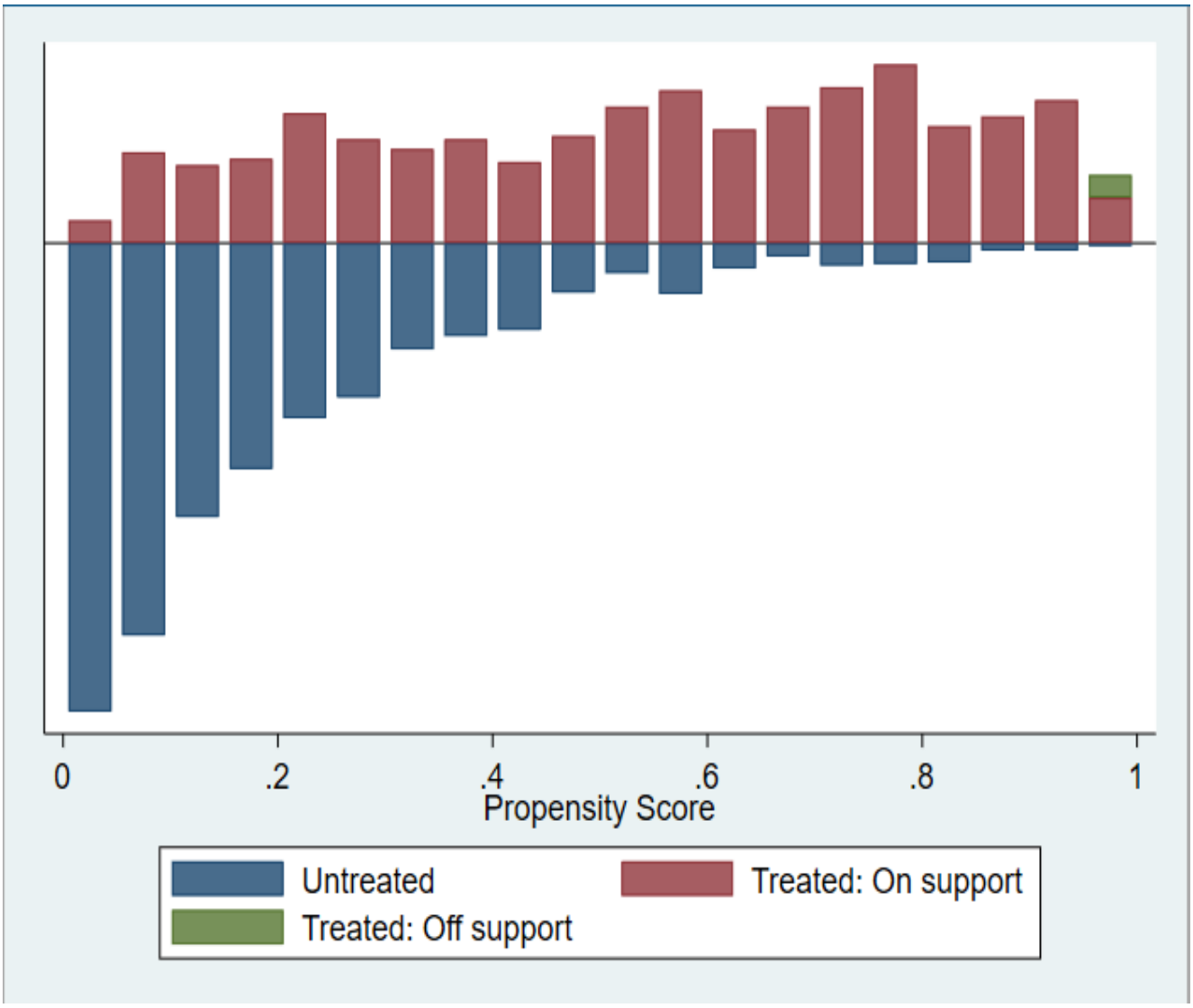


Figure 17: Histogram of propensity score distribution for adults who participated in traditional charcoal production (exposed) and those adults without it (unexposed)

Propensity score matching

After estimating the propensity score with logistic regression, we used a nearest neighbor 1:3 ratio and caliper width of 0.05 standard deviations to ensure comparability between exposed and unexposed groups by balancing the covariates. Before matching, there was a sample size of 2172(1487 un-exposed and 685 exposed), and after matching, seven exposed subjects dropped due to lack of matching with the un-exposed groups (off support), and the final matched sample size is 2165 (678 exposed and 1487 un-exposed).

Assessing balance across all covariates between the exposed and unexposed groups after matching

Before matching, several covariates exhibited high-standardized percentage bias, above 40%. After matching, the standardized bias for all covariates decreases significantly, with most covariates having bias below 10%, which is an acceptable threshold for good balance. The overall bias reduction across covariates was above 90% reduction across covariates**,** indicating that the matching procedure was effective in improving covariate balance **(Table 7).**

Table 7: Comparison of the standardized mean differences, percentage bias, and percentage bias reduction of covariates before and after matching

Variables	Unmatched Matched	Mean		%bias	%reduction bias	t-test		V(T)/ V(C)
		Exposed	Un-exposed			t	p>/t/	
Age	U	35.90	43.16	-42.3		-8.81	0.001	0.65*
	M	36.00	36.24	-1.9	95.5	-0.38	0.701	0.91
Sex	U	0.87	.58	67.5		13.75	0.001	.
	M	0.87	.86	1.60	97.6	0.37	0.713	.
Marital status	U	1.88	1.83	10.5		2.25	0.024	0.87
	M	1.88	1.88	0.00	100.0	0.00	1.00	0.96
Farming	U	0.46	0.74	-61.5		-3.66	0.001	.
	M	0.45	0.45	2.8	95.4	0.49	0.62	.
Government Employee	U	0.01	0.04	-21.1		-4.12	0.001	.
	M	0.01	0.01	0.00	100.00	0.00	1.00.	.
Merchant	U	0.09	0.09	0.1		0.02	0.983	.
	M	0.09	0.11	-5.5	-83.7	-0.97	0.330	.
Daily laborer	U	0.18	0.14	10.7		2.35	0.019	
	M	0.18	0.24	-15.8	-47.9	-2.61	0.009	
Education	U	2.67	2.26	36.1		7.53	0.001	0.66*
	M	2.67	2.84	-15.3	57.6	-2.71	0.007	0.58*
Residence	U	1.85	0.76	21.6		5.17	0.001	0.69*
	M	1.84	0.84	1.7	94.0	0.30	0.767	0.97
CBHI	U	0.85	0.76	21.6		4.55	0.001	.
	M	0.85	0.84	1.7	91.9	0.35	0.729	.
Family engaged in charcoal production	U	0.26	0.07	54.2		13.00	0.001	.
	M	0.26	2.80	-6.0	87.4	-1.02	0.300	.
Alcohol drink	U	0.54	0.57	-5.5		-1.20	0.230	.
	M	0.54	0.59	-9.3	-67.7	-1.72	0.086	.
Char_production in village	U	0.39	0.15	55.1		12.64	0.001	.
	M	0.38	0.40	-4.70	91.4	-0.76	0.447	.

Love plot

The Love plot shown below revealed that standardized bias for each covariate before (red) and after matching (blue). The large deviations from zero indicate a significant imbalance in covariates between the exposed and unexposed groups. The plot demonstrated several covariates exhibited high-standardized bias before matching, with values ranging from about -50% upto around +50%. In this analysis, matching has shown a reduction of bias, bringing most covariates close to the reference line at 0 **(Figure 6).**

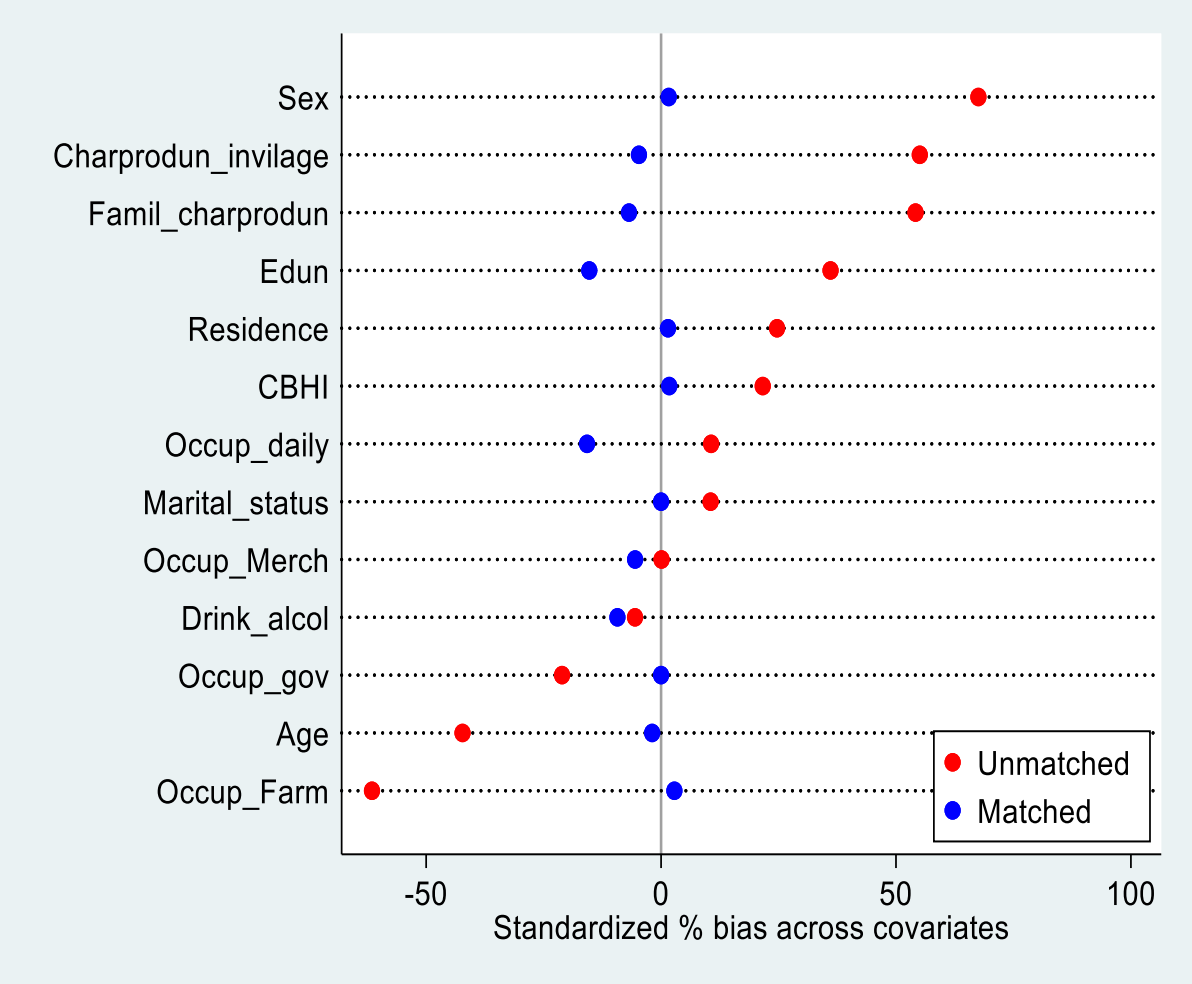


Figure 18: Covariate balance assessment before and after propensity score matching between the exposed and unexposed groups

Table 8: The propensity score matching analysis results for the effect of exposure to traditional charcoal production on CRD among individuals aged 18 years and above in Northwest Ethiopia

Sample	Ps R^2	LR Chi^2	P > Chi^2	Mean Bias	Med Bias	B	R	%Var
Unmatched	0.289	783.64	0.001	31.6	24.7	143.3*	1.00	75
Matched	0.013	24.89	0.024	7.4	5.9	27.2*	0.74	50

- Ps R^2 - Pseudo R-squared
- LR Chi^2- Likelihood-Ratio Chi-Square
- P > Chi^2 - p-value of the likelihood ratio test
- Mean bias - Average of the absolute standardized differences (in %) between exposed and unexposed groups for all covariates
- Median bias - Median of the absolute standardized differences. Less sensitive to outliers than the mean bias
- B - Ratio of the variances of the propensity score in exposed versus unexposed groups
- R - Ratio of the variances of the residuals in exposed versus unexposed groups
- %Var - Percentage of covariates for which the variance ratio of exposed to unexposed groups lies outside the range

From the above balance diagnostics before and after propensity score matching, we observed that a sharp drop in pseudo R-square (from 0.289 before matched to 0.013 after matched), sharp drop of LR Chi^2 from 783.64 before matching to 24.89 after matching, mean bias and median bias reduced to <10% after matching, and this confirms that the matching process effectively balanced the covariates (baseline characteristics) between the exposed and un-exposed groups. This ensures that differences in outcomes between groups exposed and unexposed groups are more likely to be due to the exposure rather than pre-existing differences in covariates.

Estimating the treatment effect (ATET, ATE)

The findings of this study demonstrated that the ATET was 0.418 (95%CI: 0.371, 0.465, p<0.001), indicating that among adults who were engaging in TCP, the probability of presenting at least one CRD symptom was 41.8 percentage points higher compared to it would have been if they had not been engaged in TCP, and show statistically significant. In addition, the results of this study illustrated, on average, if all individuals (exposed and non-exposed) had engaged in TCP, the expected impact would be an increase of 36.7 percentage points (ATE=0.367, 95%CI: 0.291, 0.442, p<0.001) in experiencing the CRD symptoms, and the effect is statistically significant **(Table 9).**

In addition, the population attributable fraction (PAF) estimated from the ATE was found to be 0.38. This suggests that exposure to the traditional charcoal production was expected to account for 38% of the population's CRD symptoms burden.

Table 9: Estimation of ATET and ATE of engaging in the traditional charcoal production on experiencing CRD symptoms among adults 18 years and above in northwest Ethiopia

CRD symptoms	Coefficients	Std. error	z	p>/Z/	95% Conf. Interval
ATET Charprodu_trearvar (Yes Vs No)	.4181462	.0240385	17.39	0.001	.3710316 .4652608
ATE Charprodu_trearvar (Yes Vs No)	.3670555	.0383511	9.57	0.001	.2918886 .4422223

* Charprodu_treatvar – charcoal production as treatment (exposed) variable

ATET- Average Treatment Effect of the Treated

ATE- Average Treatment Effect

Sensitivity analysis

The results from sensitivity analysis using Rosenbaum's Bounds showed that our estimated treatment effects (ATET and ATE) are robust to hidden bias from unmeasured confounders for both gamma r=1 and r=1.2, $p < 0.001$(both upper and lower bounds). Moreover, since the upper and lower bounds of t-hat did not vary (i.e., 0.5), it indicates that the exposure effect was stable across different levels of unmeasured confounding **(Table 10).**

Table 10: Sensitivity analysis assessing the impact of hidden bias from unmeasured confounders using Rosenbaum's Bounds (Gamma 1 1.2)

Gamma	Sig+	Sig-	t-hat+	t-hat-	CI+	CI-
1	0.001	0.001	.5	.5	-2.9e.07	.5
1.2	0.001	0.001	$-2.9^{e-.07}$	.5	$-2.9^{e-.07}$	.5
*gamma- log odds of differential assignments due to unobserved factors						

5.3.3. Results from the multivariable logistic regression analysis

Bivariate logistic regression analysis was employed to identify candidate variables for the final multivariable logistic regression model, and a p-value threshold of 0.25 or less was used for selecting variables to ensure inclusivity. In the final model, eight predictors remained statistically significant with CRD symptoms: sex, age, farming as occupation, number of rooms in home, separated kitchen, separated animal home, engaging in traditional charcoal production, and charcoal production in village.'

This study found that for each additional year of age, the likelihood of experiencing CRD symptoms increased by 1.02 times (AOR: 1.02; 95%CI: 1.01, 1.03 and p-value <0.044). Males had lower odds of experiencing CRD symptoms than females (AOR = 0.73; 95% CI: 0.54–0.99; $p < 0.001$).

The results of this study revealed that people who engaged in TCP had higher odds (AOR: 7. 72; 95% CI: 5.61, 10.65) of presenting CRD symptoms compared to those who did not engage in TCP. People living in villages where TCP takes place had more than double the odds of developing CRD symptoms compared to those in areas without it in their village (AOR = 2.52; 95% CI: 1.83–3.46; $p < 0.001$). Moreover, the findings of the study indicated that those who had engaged in farming as an occupation had higher odds (AOR: 1.65; 95%CI: 1.18, 2.30; p-value <0.004) of presenting CRD symptoms than those not engaged in farming activities.

The data from this study noted that for each additional room in the home, the likelihood of experiencing CRD symptoms decreased by 20% (AOR = 0.80; 95% CI: 0.68, 0.94; $p < 0.005$). Living in a home with a separate kitchen were 33% less likely to exhibit CRD symptoms compared to those living in a home with no separate kitchen (AOR=0.67; 95CI: 0.49, 0.91; p-value <0.02). Furthermore, people whose homes had a separate room for animals were 43% less likely to suffer from CRD symptoms than those where animals shared living rooms with families (AOR = 0.57; 95% CI: 0.42–0.77; $p < 0.001$) **(Table 11).**

Table 11: Bivariable and multivariable logistic regression analysis on predictors of CRD symptoms among adults 18 years and above living in Amhara region, northwest Ethiopia

Variables	Response	CRD symptoms		COR	AOR	p-value	95%CI for the EXP(ß)
		Yes	No				
Sex	Male	415	1043	0.75	.73	0.044	[.5356945 .991099]
	Female	247	467	1	1		1
Age		-	-	1.01	1.02	0.001	[1.00852 1.031855]
Marital status	Single	152	302	1	1		1
	Married	463	1169	0.77	.71	0.157	[.5379881 1.105339]
	Divorced	35	25	2.78	1.57	0.252	[.7265295 3.381545]
	Widowed	12	14	1.70	2.06	0.172	[.7316302 5.752983]
Occup_Farmer	Yes	504	1014	1.56	1.65	0.004	[1.17762 2.309967]
	No	158	496	1	1		1
Occup_daily labor	Yes	78	209	0.83	.78	0.283	[.5023318 1.223197]
	No	584	1301	1	1		1
Educational status	Unable to read or write	200	474	1.61	1.31	0.283	[.6837161 3.677095]
	Able to read and write	140	336	1.59	1.21	0.661	[.5223005 2.783826]
	Grade 1-8	221	430	1.96	.99	0.999	[.4373068 2.284069]
	Grade 9-12	74	167	1.69	1.61	0.295	[.6617985 3.897492]
	Certificate and above	27	103	1	1		1
Home floor	Soil	619	1343	1.79	1.38	0.378	[.6725385 2.845269]
	Cement	43	167	1	1		1

Variables	Response	CRD symptoms		COR	AOR	p-value	95%CI for the EXP(ß)
		Yes	No				
No. HH_rooms	-	-	-	0.62	.80	0.005	[.6802663 .935078]
No. HH_window	-	-	-	0.93	.89	0.497	[.6242928 1.256834]
Kitchen separated	Yes	463	1260	0.46	.67	0.012	[.4875111 .914177]
	No	199	250	1	1		1
A separate room for animals	Yea	325	850	0.59	.57	0.001	[.4216038 .7716055]
	No	140	217	1	1		1
Char_production in village	Yes	260	230	3.60	2.52	0.001	[1.827388 3.464143]
	No	402	1280	1	1		1
Participat_charcoal production	Yes	385	300	5.61	7.72	0.001	[5.597126 10.64602]
	No	277	1210	1	1		
Family Hx Asthma	Yes	28	48	1.35	1.12	0.743	[.5699001 2.200497]
	No	634	1462	1	1		
Wealth_Index		-	-	0.99	.99	0.311	[.9993513 1.000207]

5.4. Mask utilization and its associated factors among traditional charcoal producers (Objective IV)

5.4.1. Sociodemographic and economic characteristics of the respondents

A total of 685 participants were included in the study. The mean age was 34.5 years (SD±9.4). More than half, 364(53.1%) of the respondents were between 30 and 45 years of age. Males accounted for 594(86.7%) of the respondents. More than three-fourths (76.9%) were married, and 579(84.5%) were from rural areas. Regarding education, the majority of respondents, 338(49.3%) had primary education (grade1-8), while 121(17.7%) were unable to read and write, 116(16.9) were able to read and write, 86(12.6%) were grade 9-12, and 24(3.5%) had territory education (certificate and above). Among the total respondents, 341(49.9%) belonged to the poor category based on their wealth index. Almost all (98%) were produced for sale as a source of income **(Table 12).**

Table 12: Sociodemographic and economic characteristics among those engaged in the traditional charcoal production in Amhara region, northwest, Ethiopia

Variables	Category	Frequency (%)
Sex	Female	91(13.3%)
	Male	594(86.7%)
Age	18-29	227(32.1%)
	30-45	364(53.2%)
	46-58	94(13.7%)
Marital status	Single	130(19%)
	Married	527(76.9%)
	Divorced	25(3.6%)
	Widowed	3(0.4%)
Educational status	Unable to read and write	121(17.7%)
	Able to read and write	116(16.9%)
	Primary education (grade1-8)	338(49.3%)
	Grade 9 to 12	86(12.6%)

	Certificate and above	24(3.5%)
Residence	Rural	579(84.5%)
	Urban	106(15.5%)
Family head	Yes	480(70%)
	No	205(30%)
Family size	One to two	186(27.2%)
	Three to four	270(39.4%)
	Five and above	229(33.4%)
Wealth index	Poor	341(49.9%)
	Rich	344(50.1%)

Among the total producers, the majority, 502(73.3%) were participated in combustion activity, while, 298(43.5%) participated in packing, and 247(36.1%) participated in carrying/transporting. Among women involved in the production activities, the majority, 63(69.2%) were engaged in packing, while 41(45.1%) engaged in carrying activities and none of them were engaged in combustion. On average, the work experience of the producers was 4 years (SD±2), and the average working hours per day was 12 hours (SD±3), and nearly 85 % (581) of workers work for more than eight hours in a day during the production times. The average duration (days) taken to complete one cycle of production was 10.7 days (SD±3). Between the production cycles, the average number of days rest until the next round was 15.7 days (SD±8). Of the participants, 580(84.7%) were CBHI members. The majority of producers, 470 (68.6%) undertaken their production activity at a distance of 500 to 1000 meters from the main roads.

5.4.2. Knowledge, attitude, and practice of the respondents toward mask use

Of the total participants, a small proportion of participants, 201(29.3%), recognize that their work exposure put them at risk for various health effects. Nevertheless, 288(42%) perceived they were at risk of respiratory diseases, and 276(40.3%) believed that charcoal producers have to use masks to reduce respiratory health problems **(Table 13).**

Table 13: Knowledge related to mask use among traditional charcoal workers in Amhara region, northwest Ethiopia.

Statements about knowledge	**Frequency (%)**	
	Yes	**No**
Do you know that engaging in charcoal production activity could exposes to respiratory diseases?	288(42%)	397(58%)
Do you know that engaging in charcoal production activity could exposes to other health risks?	201(29.3%)	484(70.7%)
Do you think charcoal producers have to use masks to reduce respiratory diseases?	276(40.3%)	409(59.7%)
Do you know that charcoal producers have to wear a respiratory mask consistently during production times?	364(53%)	321(47%)
Do you think that a mask could prevent smoke and dust enters into the respiratory tract?	313(45.7%)	372(54.3%)
Do you think not only those engaged in combustion are expected to use a mask, but also others who participated in packing into sacks and carrying need to use a mask?	285(41.6%)	400(58.4%)
Do you know that long-term exposure to smoke/dust can cause respiratory diseases?	342(49.9%)	343(50.1%)
Do you know where to get /buy/ the mask?	488(71%)	197(29%)
Do you motivate your colleagues to use masks during working hours?	398(58.1%)	287(41.9%)
Do you think covering with clothes could have a protective effect like masks?	282(41.2%)	403(58.8%)

Among the participants, 241(35.2%) had perceived that being engaged in charcoal production could affect their health, and 469(68.5%) perceived that respiratory health could be the most vulnerable one. Due to their risk exposure, 495(72.3%) had a positive attitude towards persons involved in charcoal production needing to have frequent health visits **(Table 14).**

Table 14: Attitude toward mask use among charcoal producers in Amhara region, northwest Ethiopia.

Questions related to attitude	**Response with Frequency (%)**				
	Strongly disagree	**Disagree**	**I don't know**	**Agree**	**Strongly agree**
Do you think being engaged in charcoal production affects your health?	23(3.4%)	305(44.5%)	116(16.9%)	111(16.2%)	130(19%)
Do you think being engaged in charcoal production affects your respiratory health?	40(5.8%)	57(8.3%)	119(17.4%)	394(57.5%)	75(10.9%)
Do you think people involved in charcoal production need to have frequent health visits?	28(4.1%)	45(6.6%)	117(17.1%)	342(49.9%)	153(22.3%)
Do you believe persons involved in charcoal production need to get advice from professionals	11(1.6%)	15(2.2%)	44(6.4%)	394(57.5)	221(32.3%)
Do you believe masks prevent you from respiratory problems at work?	24(3.5%)	125(18.2%)	103(15%)	367(53.6%)	66(9.6%)
Do you feel that everyone who engages in charcoal	6(0.9%)	11(1.6%)	126(18.4%)	387(56.5%)	155(22.6%)

production has to wear a mask at the production place?					
Do you think workers who are working in areas with dust or chemicals should wear a mask?	10(1.5%)	69(10.1%)	93(13.6%)	376(54.9%)	137(20%)
Do you feel that wearing a mask at work places don't hinder your work?	8(1.2%)	16(2.2%)	139(20.3%)	415(60.6%)	107(15.6%)
Do you feel safe when you wear a mask while you are at the production site?	12(1.8%)	63(9.2%)	153(22.3%)	385(66.2%)	72(10.5%)
I would encourage others at work place to wear their masks.	28(4.1%)	30(4.4%)	71(10.4%)	431(62.9%)	125(18.2%)

Overall, among the participants, 295(43.1%) had good knowledge about masks, and 309(45.1%) had a favorable attitude toward its use. However, only 87(12.7%) producers utilized a respiratory mask during working times.

The reasons for non-use of masks by the producers were due to lack of comfort at work 300 (50.2%), inability to buy191 (32%), and due to lack of accessibility 213(35.6%). Among the respondents, only 27% were obtained training on the health risks and care to be taken from professionals. Of the total producers, 37(5.4%) had confirmed asthma.

5.4.3. Results from the bivariable and multivariable logistic regression analysis to assess factors associated with mask use among traditional charcoal producers

Bivariate logistic regression analysis was employed to identify potential variables for the final multivariable logistic regression model, and a p-value threshold of 0.25 or less was used for selecting variables. In the bivariable analysis, age, involvement in combustion activity, work experience, working hours, living with asthma, knowledge, attitude, comfortability and accessibility of mask were identified as candidate variables. Nonetheless, in multivariable analysis, age, involvement in combustion activity, working hours, knowledge, and attitude toward mask utilization remained statistically significant with respiratory mask utilization **(Table 15).**

This study found that for each additional year, the likelihood of utilizing a mask was decreased slightly by 3 percent (AOR: 0.97; 95%CI: 0.95, 0.99; and p-value <0.045). Participants who had good knowledge were nearly two times more likely to utilize a mask compared to those who had poor knowledge (AOR=1.96; 95%CI: 1.20, 3.17; p<0.006). The odds of utilizing a mask was more than three times higher among participants who had a favorable attitude toward mask use than those who had an unfavorable attitude (AOR=3.33; 95%CI: 2.01, 5.50; P<0.001). Individuals who were working for long-hours daily were 54 percent less likely to utilize a mask (AOR=0.46, 95%CI: 0.24, 0.91; P< 0.024) compared to those workers working for eight and less hours. The odds of using a mask was 3.19 times higher among those workers engaged in combustion activity than those not involved in combustion (AOR=3.19; 95%CI:1.55, 6.54; P<0.002).

Table 15: Bivariable and multivariable logistic regression analysis on predictors of mask utilization among charcoal producers in Amhara region, northwest Ethiopia.

Variables	Responses	Mask		COR(95%CI)	AOR(95%CI)	P-value
		Yes	No			
Age	-	-	-	0.98(0.96, 1.00)	0.97(0.95-0.99)	**0.045**
Involved in combustion	Yes	75	427	2.50(1.33, 4.72)	3.19(1.55, 6.54)	**0.002**
	No	12	171	1	1	
Work experience	One to three years	27	259	1	1	
	Four years and above	60	339	1.70(1.05, 2.75)	1.60(0.96, 2.67)	0.70
Daily working Hrs.	1-8hrs	17	87	1	1	
	9 hrs. and above	70	511	0.70(0.39, 1.25)	0.46(0.24, 0.91)	**0.024**
Live with asthma	No	80	568	1	1	
	Yes	7	30	1.66(0.70, 3.90)	2.19(0.85, 5.78)	0.103
Knowledge on mask	Poor knowledge	37	355	1	1	
	Good knowledge	50	245	1.95(1.24, 3.10)	1.96((1.20, 3.17)	**0.006**
Attitude towards mask	Unfavorable attitud4e	27	349	1	1	
	Favorable attitude	60	249	3.12(1.92, 5.05)	3.33(2.01. 5.50)	**0.001**
The mask is not comfortable.	Yes	30	270	1	1	
	No	57	328	1.56(0.98, 2.50)	1.63(0.98, 2.96)	0.057
The mask is not accessible.	Yes	34	179	1	1	
	No	53	419	0.67(0.42, 1.06)	0.75(0.46, 1.24)	0.26

CHAPTER SIX: DISCUSSIONS

This PhD study aimed to assess and better understand the impact of exposure to traditional charcoal production on CRD symptoms, mask use among charcoal producers, trend, seasonality, and forecasting of CRD and spatiotemporal variations of CRD symptoms in northwest Ethiopia. To achieve this, the study was guided by four specific objectives, each looking at a particular aspect of the issue. A variety of study methods were employed across the entire work to address the study objectives. In this chapter, the key findings are discussed in the context of existing literature. The limitations of the current study and the implications for the implementations of the interventions and future research are also highlighted.

6.1. Trends, seasonal variations and forecasting of CRDs

The study showed a concomitant annual increase in the morbidity rate of asthma and COPD, which subsequently resulted in an increase in CRD across seven years, which is consistent with reports from previous studies (48, 246). The study also revealed that morbidity due to asthma was found to be the highest proportion (90.5%). Similar results have been noted in prior studies conducted elsewhere (106, 213). Likewise, as shown in earlier systematic reviews and meta-analyses, asthma appears to be more common than COPD, possibly because short-term exposure to pollen and other allergens can readily trigger allergic responses and asthma symptoms(247). This may suggest that potentially asthmatic cases were seeking care to reduce their wheezing symptoms. However, a large proportion of deaths attributed to CRD accounted for COPD (54, 248). Chronic obstructive pulmonary disease causes morbidity and mortality in adults in SSA (213). Evidence from earlier research has indicated that exposure to pollutants attributed to particulate matter arising from various sources is the major contributor to deaths from COPD in areas with a low socioeconomic index (83, 99). In contrast, asthma has been reported as a common cause of death in Nigeria (249).

The current study also identified that the morbidity rates due to asthma, COPD, and combined condition (CRD) persistently increased in both sexes across the seven years. In addition, the morbidity rate is almost similar in both sexes, which is similar to the result observed in Tanzania (250). However, in contrast to the present study, the study in India revealed that females

outweighed males (251). The difference might be because the present study used secondary data from DHIS 2 records of three zones, including zonal and district towns, and may have the potential to use clean fuel, in comparison to the previous study conducted in a rural village where biomass fuels meet their daily heating and cooking.

Interestingly, the study revealed that the morbidity rate due to asthma, COPD, and combined CRD varied among the three zones. The yearly average morbidity rate of CRD was highest in the Awi zone compared to WGZ and EGZ. Nevertheless, the relative percent change in asthma morbidity rate was the highest in EGZ. Whereas, the highest relative percent change in morbidity rate attributed to COPD was identified in WGZ. This suggests that there is a significantly increased number of asthma and COPD cases observed in EGZ and WGZ, respectively, in 2019 compared to 2013. The estimated peak-to-trough difference was higher for asthma than for COPD. Studies have also demonstrated that geographic variation in CRD morbidity rates may be linked to an increase in environmental risk and low socioeconomic factors (252, 253), (76, 254). In that context, it will be necessary to understand the factors influencing the higher morbidity rate in Awi zone compared to the West Gojjam and East Gojjam zones in future studies.

The study found that trends in asthma, COPD, and CRD increased steadily across the three zones during the past seven years in adults aged 15 years and older. This is in agreement with trend studies conducted elsewhere (106, 255, 256). This may reflect increased exposure to indoor and outdoor pollution and occupational exposure to risk factors such as charcoal production and agricultural activities, climatic variability, and exposure to motor vehicle gases and other chemicals (14, 257). Despite findings from a former study indicating a downward trend in COPD mortality(258), the trend of morbidity rates increased (259). Earlier research revealed that CRD is mainly attributed to occupational risk factors (57), and 2% of the world's disease burden is attributed to biomass smoke exposure (260).

In the current study, trends were identified in asthma and COPD, with a relative increase of 139% and 138%, respectively. This is consistent with other prior research conducted elsewhere (261) and with the global burden of disease report (54, 69). It has been reported that the COPD burden in LMICs versus HICs is expected to grow, with a projected growth of 32.7% in LMICs and 3.8% in

HICs from 2020 to 2050 (14). In contrast, another study indicated that the trend of mortality due to COPD decreased in both sexes throughout 1980-2017 (262). This may be due to the use of bronchodilators, as well as enhanced knowledge of the disease, its control, and the management of its comorbidities(263)

When looking at trends by sex, both males and females CRD, COPD, and asthma trends increased persistently, despite the relative percent change of male asthma (70%) being higher than female asthma (58%) during 2013-2019. This implied that the number of male asthma cases increased significantly compared to female cases. Similarly, the CRD trend increased in both males and females from 2013 to 2019. Correspondingly, a relative percent change of 67% and 38% was detected in male and female COPD cases, respectively. This is in agreement with a study conducted in Brazil (108). Congruently, a global study showed the trend of male cases of COPD will continue to be higher than female cases through 2050(14). Differences in the percent change of asthma, COPD, and CRD trends between males and females might also be partially attributed to the outdoor exposure to risk factors, which increased rapidly among males compared to females. In contrast, Pelkonen and colleagues in their long-term repeated cross-sectional study in Finland reported that the trend of asthma prevalence was higher in females than males (71), and COPD mortality among females increased across the study period (264). Thus, further study is advised to examine the factors linked to the disparities in illness burden between males and females.

Furthermore, our study has demonstrated that a change point in the morbidity trend of asthma and CRD increased in a steep pattern during 2017, and this needs further investigation. However, among all the years, the lowest percent change was detected from 2018 to 2019. This might be due to the time when the early phase of COVID-19 and people may be less likely to visit hospitals owing to fear of the virus, which could contribute to the drop in CRD during this time.

Despite this, the occurrence of CRD morbidity rate was rising in the three zones of the Amhara region across seven years, and the highest was observed in the Awi zone since 2017, compared to the other two zones. The reason for this is unknown, and the reasons for the notably different morbidity rate variations in the three zones are worth further investigation. Further analysis of climate, including humidity and precipitation data in the different zones in the region, will help

better characterize the region and potentially shed light on the effects of weather on exacerbation rates.

Results of the present study have clearly shown marked seasonal variations in asthma, COPD, and CRD morbidity during the seven years. Of all asthma and CRD morbidity, the highest proportion of cases, 36% and 35% respectively, were noted in "Tsedey" (Spring; September to November - cold season), followed by "Kirmet" (summer; June to August- heavy rainy fall) with proportions of 30% and 29% of asthma and CRD cases respectively. This is in agreement with previous studies, in which the cold season had the highest asthma exacerbations and hospitalizations (92). The reasons for the increase in CRDs during these seasons are not entirely explained in this study. However, evidence from previous studies revealed that the underlying mechanisms for morbidity during these seasons are thought to include some combination of infectious, allergic, environmental, and climatic stimuli (91, 254). The highest proportion of COPD cases (31%) was marked in winter (December to February- dry season), followed by spring with a proportion of 30%. This is in agreement with a previous study in which summer (dry season) had the highest proportion of severe exacerbations of COPD(95).

Moreover, in the current study, we noticed a 1.8-fold increase in asthma, a 2-fold increase in CRD morbidity in Spring and summer, and a 1.7-fold to 2-fold increase in COPD morbidity in winter compared to Spring, which is consistent with another study conducted elsewhere (92). Furthermore, the results of the present study illustrate that major peaks of CRD in each year occurred frequently from September to November and from June to August. This seasonal component had a notable effect, with seasonality indices 41.47% and 19.16% of excess CRD cases in the period between September and November and June to August, respectively, above the base of the moving average, and stayed low in December to February and March to May with seasonality indices 28.8% and 34.76% below the moving average, respectively. The above difference could be attributed to the differences in climatic characteristics between seasons.

Seasonal differences occurred during all seven years, indicating that the results were not the consequence of a single summer and spring. The spring and summer seasons in the present study area are characterized by the presence of cold temperatures, heavy rainfall, and high plant pollen,

whereas the winter season is characterized by dry and hot temperatures. The observed differences between the seasons may highlight the importance of cold weather conditions and allergens attributed to plant pollen. Generating evidence on the seasonality of CRD contributed a significant role in early prevention and control of the disease since it would strengthen the low self-care practice in most of the patients in northwest Ethiopia (102).

The present study demonstrated that in the next ten years, the trend of CRD will increase by 38% from 2020-2030, respectively. This confirms a study that reported CRD tended to increase globally(221). Congruently, a previous study reported that the COPD burden is expected to grow, with a projected growth of 32.7% in LMICs from 2020 to 2050(14).

6.2. Spatial, temporal and spatiotemporal variations of CRDs

To the best of our knowledge, this study is the first study to apply ArcGIS and SaTScan analyses to depict the spatial, temporal, and spatiotemporal variations of CRDs in the Amhara region, northwest Ethiopia. The study revealed that the spatial, temporal, and space-time distribution patterns of CRD morbidity rate in the study districts were non-random. Investigating risk factors of CRD in the surrounding districts is an area of future research. However, the possible spatial variations might be explained by the difference in exposure to risk factors for CRD. The population within these districts has been exposed to massive charcoal production and indoor biomass fuel use. This is in agreement with a spatial analysis that revealed COPD case clustering observed in areas with higher firewood exposure, greater smoking exposure, and in households with closer proximity to local roads(265). Congruently, other studies also showed respiratory health outcomes with charcoal production and utilization(1, 174). NCD deaths accounted for 43% in the Amhara region, and CRDs were among Ethiopia's leading causes of death in 2019(68). Our study revealed that the spatial distribution pattern of CRD cases in districts is not random. CRD morbidity rate persistently increased in three zones across the study period. The purely spatial and spatiotemporal model identified that most of the districts included in the most likely cluster were from Awi zone, and the secondary clusters were located in the districts of East Gojjam zone and West Gojjam zone. Moreover, hot spot clusters were detected in the northwest and southwest of the study area. This might be due to the massive charcoal production activity undertaken (25, 210, 211) in these

areas in addition to the other contributing factors. This is in agreement with a study that showed morbidity rate attributed to CRD was commonly observed in areas with higher firewood exposure(265).

Based on the analysis of records from 2012/13 to 2018/19, the annual morbidity rate of CRD showed an increase of 139%. Increasing numbers of health facilities and improving the diagnostic capacity, which lead to early detection and prevention of CRDs, could be the reason for increasing CRD morbidity rates. In our study area, the number of hospitals increased from five to twenty since 2015/16 onwards due to the initiatives for the establishment of primary hospitals in districts in the country. This increase is in agreement with the results from a global data set 1990-2017 and systematic review(83, 106). Despite the increase in the annual morbidity rate of CRD, it might still be underestimated because the average readiness of health facilities for CRD service was low(266). Similarly, a national study assessing the availability of health facility services for diagnosing and managing NCDs in 2014, 2016, and 2018 found that readiness level was 76%, 45%, and 53%, respectively, for chronic respiratory disease(267). A finding from the spatial analysis showed that inappropriate medication users lived at a distance from their preferred health facilities compared to appropriate users(268). This means the reported morbidity rate likely underestimates the true situation, since they might not visited the health facility, and their illnesses could not be captured in the routine records.

A study on NCDs reported that 60.4% of CRD mortality is attributed to modifiable risk factors, including indoor and outdoor air pollution, the existence of exposure to biomass smoke, and road traffic vehicle exposure(68, 265). Wood charcoal production, which is known to emit PM and harmful gases, appears to be the main factor associated with CRD morbidity and mortality, especially in LMICs(25). This is supported by studies revealing a higher proportion of CRD cases reported in areas exposed to biomass smoke **(**269**,** 270**).**

Our study found that CRD morbidity rates vary from 62 to 7314 per 100,000 population among districts. The reason for this variation is not clear and needs further study. The geographic variations in CRD morbidity have been reported in other countries **(**271-273**)**. Nevertheless, the magnitude of these geographical inequalities also highlights the importance of geographically

manifesting factors in understanding the CRD burden in the study area. In contrast, even if the number of CRD cases is still increasing, CRD mortality declined among Global Alliance Respiratory Disease member countries from 2000-2015(44, 105). This might be due to strong advocacy for the reduction of cigarette smoking interventions, utilization of clean fuel sources, and early detection and treatment. Our study revealed that CRD distribution among males and females was similar. This is in agreement with a study reported in China (44). On the contrary, some studies have shown that CRD morbidity is higher in men than women (101, 128). This might be explained by the fact that the former studies were conducted among factory workers, and males were more involved than females in this occupation. Congruently, the mortality rate of CRD in males was higher than in females(274).

The study revealed that the spatial, temporal, and space-time distribution patterns of CRD morbidity rate in the study districts were non-random. The possible spatial variations might be explained by the difference in exposure to risk factors for CRD. The population within these districts has been exposed to massive charcoal production and indoor biomass fuel use. Investigating risk factors of CRD in the surrounding districts is an area of research. This is in agreement with a spatial analysis that revealed COPD case clustering observed in areas with higher firewood exposure, greater smoking exposure, and in households with closer proximity to local roads (265). Congruently, other studies also showed respiratory health outcomes concerning charcoal production and utilization (1, 174).

6.3. Effects of exposure to traditional charcoal production on CRD symptoms

This research highlights not only the link between exposure to traditional charcoal production activities and CRD symptoms but also uses the PSM technique, a method that simulates randomization, to create a counterfactual scenario for each exposure individual. It assumes that adults who are exposed to TCP and those who are not exposed to TCP are similar on average by matching individuals from both groups based on their characteristics. This approach helps to address the problem of selection bias. By doing so, it shows the average treatment effect on the treated, estimating the real impact of engaging in TCP on the exposed group, while removing what would have happened if they had not been engaged in TCP (the counterfactual outcome).

It is evident from PSM analysis that there is a significant increase in the presentation of CRD symptoms among adults exposed to TCP compared to those without it. The findings of this study showed that the average treatment effect on the treated (ATET) was 0.42, $p < 0.001$, indicating that if these adults were not exposed to TCP, their risk of developing these symptoms could be reduced by 42%. In addition, the results of this study demonstrated, on average, if all individuals (both those who engaged and non-engaged in TCP) had been engaged in the production, the expected impact would be an increase of 37.0 (ATE=0.37, $p<0.001$) percentage points in experiencing the CRD symptoms, and the effect is statistically significant. This effect is lower than the ATET (0.42), which means that the impact of engaging in the traditional charcoal production is much stronger among those who were actually engaged in the production than what is estimated for the unengaged group. This is supported by a systematic review done on health risks associated with the production and usage of charcoal(1). In addition, the population attributable fraction estimated from the ATE was found to be 0.38. This finding indicates that eliminating/reducing exposure to charcoal production emissions could prevent about 38% of respiratory disease symptoms in the community. This is supported by an earlier study that reported that a higher proportion of COPD among non-smokers was attributed to biomass smoke exposure(275). Therefore, creating accessibility to better technology like MRV steel kilnsin the community is crucial, since engaging in charcoal production could not be banned due to multifaceted use as

a source of low cost energy sources, a source of income for family livelihood in the existing scenarios in our context (23, 25, 137).

6.4. Factors associated with CRD symptoms

The study further analysed other risk factors associated with CRD symptoms. Males had significantly lower odds of experiencing CRD symptoms compared to females, with an adjusted odds ratio of 0.73. This is supported by previous studies conducted in low-and middle-income countries where biomass was the primary cooking fuel(62, 276). This is possibly because biomass fuel was the main cooking fuel, and women are disproportionately exposed to biomass smoke because of traditional cooking practices (276). They often spend several hours each day near open fires or in poorly ventilated kitchens, which significantly increases their risk of developing CRDs like COPD, asthma, and lung cancer compared to men, and is even expected to be increased in low-middle-income countries (14, 148). In contrast to our study, a study conducted in Morocco(277) revealed that the odds of COPD among men was nearly two times higher compared to women. This might be due to the fact that in the earlier study, there was a higher proportion of men active smokers compared to women, with 18.3% and 0.2% respectively, even though biomass fuel was the most common source of cooking fuel. However, in our study, we found only four respondents who had ever smoked. Similarly, a study done in India reported that females were at a lower risk of chronic respiratory disease and asthma compared to males(278). The differences in this finding are most likely due to variations in cooking fuel source, where more than 55% of homes utilized clean fuel, compared to 100% wood fuel users in our study. In addition to this, there is variation in assessing the disease, i.e., spirometric assessment was performed in the earlier studies.

The current study demonstrated that as people get older, the risk of presenting CRD symptoms increases. Similarly, several studies have shown an association between age and chronic respiratory disease (51, 61, 279, 280). This might be because, as people get older, ongoing exposure to environmental pollutants like air pollution and work-related hazards gradually harms the lungs and airways, increasing the risk of CRDs. In addition, some respiratory issues may also persist without manifesting symptoms when people are younger, only to become more noticeable with

age (281). The results of this study revealed that engaging in the TCP put individuals at a higher risk of experiencing CRD symptoms compared to those who did not participate in the production. This is in line with previous studies assessing the association between engaging in charcoal production and health effects (1). This is because the smoke and dust released during production expose the produces for variety of respiratory diseases (77, 125, 282). The findings of this study elucidated that living in areas where TCP is taking place significantly increase risk of presenting symptoms of CRD compared to those living in areas without it. This is supported by the earlier studies, which reported that the production areas posed moderate to severe health risks, particularly respiratory problems, both for the producers and the community residing near it (282-284). Our finding is consistent with that of prior studies reporting farming as an occupation was significantly associated with CRD symptoms (127, 285, 286). This might be due to the fact that farmers exposed to various particulates, organic dust containing allergens, microbial and particulate matters, and /substances during their farming activity lead to CRDs and present symptoms.

The findings from this study illustrated that for each additional room, the likelihood of experiencing CRD symptoms decreased 20%. This is in line with a previous study conducted in Vietnam(287). This is because the presence of additional rooms improves the home's ventilation, which in turn plays a significant role in reducing the risk of developing or worsening chronic respiratory diseases(288).

The findings from this study showed that individuals who lived in homes where animals had their own separate room were 43% less likely to develop CRD symptoms than those who lived in homes where animals did not have their own separate rooms. This is consistent with previous studies reported on residential proximity to pollutants source are risk for respiratory diseases (163, 289-291). This may be because the living room helps improve ventilation and air quality by allowing better airflow and reducing exposure to indoor harmful pollutants. Furthermore, individuals living in homes with a separate kitchen were significantly less likely to have CRD symptoms than those without it. Congruently, earlier studies reported that using an indoor kitchen increased the odds of developing COPD among female participants(292, 293).

6.5. Mask utilization among charcoal producers

This study showed that utilization of masks was lower (12.7%) compared to reports of previous studies conducted among brick workers in Nepal (28.9%)(294), small and medium-sized enterprises in Kashan city 27.3% (40), particleboard workers in Ethiopia 27.3%(101), and textile workers in Pakistan (21%)(42). A possible explanation for this might be that in the previous studies, there was regular supervision in the workplace, which could encourage them to use a respiratory mask more than in the present study. Another study also reported that (48.7%) of workers utilized a respiratory mask in work place(184). Similarly, a study performed in the Kombolcha textile factory found that the practice of respirator PPE use was 82.3%(180). The most possible reason for this variation could be that workers were supervised for their occupational safety and health in their respective working sections, and there was provision of PPE use from the factory. However, these are lacking in the current study participants.

In this study, the proportion of charcoal producers with good knowledge of mask (43.1%) was low compared to previous studies conducted among welders in small-scale metal workshops (61.4%) (183), textile workers (77%)(42), and particleboard workers(100%)(295). This could be due to that in the previous studies, there was regular supervision on PPE use and frequent health and safety training, and this could have an effect in motivating them to use. In addition, in the previous study, more than half of the participants (56%) had vocational training. However, there is a lack of occupational health and safety training for charcoal producers.

In this study, the proportion of charcoal producers with a favorable attitude toward mask use (45.1%) is lower than in earlier studies (93%)(42). Similarly, another study conducted in Iraq revealed that a relatively higher proportion of workers (68.2%) exhibited a fair attitude towards PPE usage(296). The possible explanation for this might be due to the provision of frequent training for workers in the previous factory, and this may improve their attitude towards mask use. However, in the present study, due to a lack of mask use training, its use was learned only while already working, consequently affecting compliance.

In this study, the proportion of mask use among workers is low compared to the proportion with good knowledge and a positive attitude. The findings suggest that having good knowledge and a positive attitude toward mask use alone may not be sufficient to ensure actual practice. This may indicate the presence of other barriers, such as a lack of access or perceived inconvenience that hinder proper mask utilization. This pattern is consistent with findings from a study conducted during the early stages of COVID-19 prevention efforts(297). Similarly, another study showed that training employees to improve their knowledge and attitude had no significant impact on PPE use; instead, the perceived efficiency of the PPE use had a statistically significant effect on its utilization(298)

6.6. Factors associated with mask use

The present study revealed that the likelihood of practicing mask use decreases with increasing age. This finding is consistent with an earlier study (193)**.** However, in contrast to our findings, a study conducted among construction workers showed that utilization of PPE was more common among the older age group(184). The possible reason for this outcome may be that the older age group had experienced more occupational injuries than the younger age group, which in turn raised their risk of prevention practices.

The findings of this study showed that participants who had good knowledge had higher odds of mask use. This is in agreement with earlier studies (180, 183). This might be due to that those who had good knowledge perceived more on the health effects of their exposure status. In addition, the majority of the participants attended secondary education and above, and this would increase their level of understanding towards their exposure to the hazardous working environments.

In line with the previous research(183), our results indicate that participants with a favorable attitude toward mask use were more likely to use a mask compared to those with an unfavorable attitude.

The findings of this study revealed that workers involved in the combustion process were more likely to utilized respiratory mask than those engaged in packing and carrying. This is in agreement with a previous study conducted among textile workers, who utilized respiratory mask who are

working in spinning than workers working in other departments(180). This could be due to that some working environments (departments) were more at risk of respiratory problems than others.

6.7. Strengths and limitations of the study

6.7.1. Strengths of the study

To the best of our knowledge, this is the first study to investigate the effect of exposure to TCP on CRD, mask use among charcoal producers, trends, seasonality, forecasting, and spatial & spatiotemporal variation of CRD in northwest Ethiopia, and it provides valuable information on this specific, previously understudied population. In addition, the research is a community-based study and combining both primary and secondary data, which helps to capture a broader and more complete picture of the issue. In addition, it utilized different statistical analysis methods, which adds depth and strengthens the credibility of the results. This makes our work an important step toward filling a knowledge gap and would stimulate support for action to customize efforts to reduce the burden of chronic respiratory diseases, and can help public health planners for the allocation of scarce resources and to devise interventions, and guide future research. Overall, we believe the study brings new insights and provides a solid starting point for further exploration and action.

6.7.2. Limitations

This study, however, is not without limitations. First, the cross-sectional nature of the study limits the ability to establish a temporality in disease occurrence. Second, we relied on people reporting their own experiences with CRD symptoms, without spirometry testing. That means there is a chance some cases were missed, or that people did not remember or report things accurately. Furthermore, we note that one of the shortcomings in the informal sector is the absence of a known number of producers and specific producing areas to select study participants among the producers, which makes it difficult to establish a clear sampling frame and limits the ability to generalize the findings. Moreover, even though the trend models show a good agreement with the reported data, we did not make any claims to take into account CRD cases that couldn't visit health facilities (in the community), which might under-estimate the CRD morbidity rate in the three zones, since this is a retrospective study and used aggregated data in these charcoal-producing areas. In addition to the retrospective nature of the study, it lacks information on potential environmental and lifestyle factors.

In addition, this study used self-reported CRD symptoms, which likely underestimates the true prevalence of the disease. However, it is worth noting that this method is commonly adopted in large population studies to assess the symptoms of CRD, especially in poor resource settings.

6.8. Validity and reliability of the study

To ensure the validity and reliability for the generalizability of the study, several design and methodological approaches were implemented throughout the research process. The key procedures that enabled us to enhance the validity, reliability, and generalizability of this study were also strictly adhered to.

Internal validity

This study considered different designs to ensure both reliability and validity of findings. By using a PSM technique, the study tried to compare the exposed and unexposed groups to minimize the impact of confounding factors through appropriate design and statistical adjustments. An adequate number of participants were included in the study to detect meaningful differences and provide more stable estimates for generalization. Including seven full years of data helped to capture seasonal trends and long-term patterns, which improves the robustness and generalizability of the forecasts, and the ARIMA model was employed, a well-established method in time series analysis, after confirming that all key assumptions like stationarity, autocorrelation, and residual randomness were met. To maintain high data quality, training was given to data collectors to ensure ethical and unbiased data collection, followed by a standardized approach, asking questions consistently and recording answers accurately, and HMIS experts were also involved in data extraction from the DHIS 2 records.

To maintain the quality and internal validity of the study, experts were invited to evaluate whether the study tool was clear, relevant, and of good quality. They checked whether each question matched the study objectives and was easy to understand. Based on their feedback, adjustments were made to improve the wording and content. This helped us strengthen the internal validity of the questionnaire and ensure it truly measured what we intended. Furthermore, throughout the process, we implemented strong quality control measures, including regular field supervision, spot-checks, and daily reviews of the collected data. Supervisors also carried out real-time data checks in the field, helping catch and correct any errors early on. Together, these steps helped create a strong foundation for producing valid results.

External validity

Data were collected under natural conditions rather than controlled environments, improving the applicability of findings to similar settings. A large enough number of participants were included from different areas in a community-based study to detect important differences and provide stable, reliable estimates, and the results represent real situations. By using a multistage sampling method, people from different areas and backgrounds were included, making the sample more representative of the population that the study aimed to study. The consistency of these findings with previous studies in similar contexts also supports their wider relevance. The data came from the DHIS2 national health information system, making it reflective of actual program conditions, covered a wide geographic area, and a large population over seven years. Instead of selecting a sample, we used all recorded cases, which helped avoid selection bias and gave us a fuller picture of the situation on the ground.

6.9. Implications of the study

The findings of this PhD dissertation showed that many traditional charcoal production workers are regularly exposed to harmful pollutants, putting them at higher risk of developing chronic respiratory disease symptoms. Unfortunately, the use of masks among these workers is very low. Beyond that, many have limited knowledge about mask and unfavorable attitudes toward using it. This study also revealed a concerning rise in disease trends over time, along with clear seasonal patterns that indicate the problem is not random. Forecasting results suggest that, if left unaddressed, the burden of disease will likely continue to rise over the next ten years. Additionally, the spatial, temporal, and spatiotemporal analysis showed that the distribution of the CRD is clustered and uneven, meaning some areas and time periods are more heavily affected than others. Overall, this study highlights a crucial but often overlooked issue, and hence it calls for smart, targeted public health and policy responses.

Policy implications

Policy makers should focus on enhancing clean energy sources like hydroelectric power, improving access to new charcoal-producing technologies, and supporting producers in transition

to better equipment through incentives, subsidies, or regulations could greatly reduce pollution levels and protect the health of both workers and residents. In this informal sector, workplaces operate outside formal regulation, so developing simple, practical safety guidelines and supporting informal employers to adopt safer practices can make a big difference. Hence, it is expected policy makers need to do more to protect these workers by focusing on building awareness around the importance of mask as PPE and designing PPE to be accessible, affordable, and easy to use for workers in the informal sector. Furthermore, investing in predictive surveillance systems and integrating spatial data into annual health planning is necessary to target the most affected areas and seasons, allowing for smarter allocation of limited resources.

Public health implications

For public health professionals, this means going beyond clinical care, and this is a chance to take a proactive approach to prevent illness before it starts. Integrating forecasting tools into regular health planning can improve early warning and help communities prepare. Reaching workers where they are, and there is a need to work closely with communities, raise awareness about occupational risks, promote protective measures like PPE, and integrate occupational health into broader public health programs can help reduce the burden of respiratory disease and improve the overall well-being of vulnerable working populations. The identification of high-risk clusters suggests the need to strengthen targeted screening, early diagnosis, and community-based interventions in affected districts.

Research implications

While this study provided important insights into the impact of exposure to the traditional charcoal production on CRD symptoms, and the increasing trends, seasonal variation, spatial distribution, and low use of protective measures related to CRD, it also uncovered several areas that require further investigation using objective measurements (spirometry) with in a longitudinal study. Furthermore, this work highlights baseline evidence to conduct ongoing advocacy at both the community and national levels to reduce the CRD burden, especially at the risk population.

CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

The study showed a significant association between charcoal production exposure and increased CRD symptoms. It also accounted for a higher burden of CRD symptoms in the population. In addition, age, exposure to charcoal production, charcoal production in the village, sex, farming in occupation, number of rooms in home, separate animal rooms, and separated kitchen have shown statistically significant association with CRD symptoms.

The study indicates that the utilization of mask was low, alongside a low level of knowledge and an unfavorable attitude among charcoal producers. Among the studied workers, the most important predictors of respiratory mask use were age, knowledge, attitude, working in combustion, and working hours in the workplace.

The study revealed an increase in the trend of asthma, COPD, and CRD morbidity rates across seven years. The prediction also suggested that CRD will continue to increase in the next ten years in the three zones of the Amhara region, and this may result in a significant societal and healthcare burden. Furthermore, the result of smoothing using the moving average also demonstrated that the seasonal component was attributed to an excess of CRD morbidity above the base of the moving average in the period between September and November, and June to August. Additionally, more cases of COPD were noted during the periods December to February. Asthma accounts for a substantial proportion of CRD morbidity compared to COPD in the study area.

This study has also demonstrated that the spatial, temporal, and spatiotemporal pattern of CRD morbidity among those aged 15 years and above in the study period between 2012/13 and 2018/19 showed spatial variation, i.e., not random. CRD morbidity rate persistently increased in three zones, and the highest rate was observed in the Awi zone across the study period. Nevertheless, hot spot clusters were detected in the northwest and southwest of the study area.

7.2. Recommendations

To Policy Makers

- Collaborating with technology providers and research institutions to adopt innovative technologies to reduce harmful pollutant emissions and make them accessible and affordable to producers
- Enforce occupational safety and environmental standards to reduce the risk of exposure from the emissions in the informal sectors.

To the Ministry of Health and Regional Health Bureau

- The Ministry of Health shall establish occupational health surveillance into national health policy to monitor respiratory diseases related to pollutant exposure
- Working closely with industries and environmental protection offices, and biodiversity environmental forum, to reduce emissions will go a long way.
- Spatial data on respiratory disease burden should be integrated into the annual health planning process to help health planners allocate resources more effectively, ensuring that areas with the highest disease burden receive the support they need to prevent and manage respiratory illnesses.
- Increasing the effort and remedial measures should be placed in the high-risk areas in the future for the allocation of scarce resources.

To Zonal Health Department and District Health Offices

- Monitor PPE availability and utilization in local exposed occupational settings where traditional charcoal production is undertaken.
- Promote public awareness about how to reduce exposure, and the local health teams should also check that workers in charcoal production are using mask properly and consistently.
- Targeted interventions promoting prevention strategies to those exposed to traditional charcoal production, other risk factors attributed to chronic respiratory diseases, to mitigate the burden of CRD

To Health Facilities and Health Professionals

- Integrate occupational safety education into primary health care outreach, and organize regular mobile training and awareness campaigns focused on proper PPE use, especially targeting high-risk informal sector workers such as charcoal producers.
- Maintain accurate and disaggregated data on respiratory disease trends to support localized decision-making and forecasting.
- Educate patients on mask usage and self-care strategies to minimize exposure and symptom exacerbation.

To Patients and the Community

- Community members should be encouraged to protect themselves from pollution by taking simple, practical steps, especially in polluted areas and during high-risk seasons when exposure is highest.

To the researchers

In addition, further research is recommended use Air Quality Index data and spirometer measurements to examine causality for disease onset and to assess the dose–response relationship in lung health in the risk population employing a longitudinal study. Future study should also require qualitative study to examine how community practices, beliefs, and coping strategies influence exposure risks and health outcomes.

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ANNEXES

Annex I: Information Sheet and Consent Form

You are kindly invited to participate in this study. This study aims to assess the effect of exposure to wood charcoal production on respiratory diseases among traditional charcoal producers in Amhara region, Northwest, Ethiopia.

Title of the Research Project: the effects of exposure to wood charcoal production on reparatory health among traditional charcoal producers in Amhara region, northwest Ethiopia

Name of principal investigator: Mulugeta Tesfa Gebeyehu

Name of the organization: Bahir Dar University, College of Medicine and Health Sciences, School of Public Health

Introduction: This information sheet and consent form are prepared to explain the purpose of this research and to get your willingness to participate in the study. The main aim of this research project is to assess the health effects of exposure to traditional charcoal production in northwest Ethiopia.

The research team includes a principal investigator, research supervisors, data collectors, and supervisors of the data collection processes.

Risk and /or discomfort: Participating in this research project will not have any risk or discomfort. The interview will take 25-30 minutes.

Incentives/payments for participating: You will not be provided with any incentives or payments to take part in this interview.

Confidentiality: The information collected from you will be kept confidential. It will be stored in a file with codes, without your name. In addition, it will not be revealed to anyone except the principal investigator. In addition, it will be used only for this particular research to achieve its objectives, but for no other purposes.

Right of refusal or withdrawal: Your time will be highly appreciated, and you have the full right to refuse to participate in this research. You can choose not to answer any or all questions, and this will not affect you and your family from getting any kind of health care service. You also have the full right to withdraw from this study at any time you wish, without losing any of your rights.

Ethical clearance: This research project was reviewed and approved by the institutional review board of Bahir Dar University, College of Medicine and Health Sciences, School of Public Health.

Person to contact: if you need any information related to the research project, you can contact the principal investigator, Mulugeta Tesfa, with a Mobile: 09 11 93 54 72 or email address: mulutesfa.g@gmail.com.

Therefore, are you volunteering to participate in this research? **Yes / No.** If a participant does not volunteer to be a part of this interview, extend your thanks and go to the next interviewee. If a participant agrees to be interviewed, start the interview after acknowledging his/her voluntariness and consent has taken.

Consent form

The interviewer has read the information sheet above and clearly understood the purpose and anticipated benefits of this research. I hereby need to assure with my verbal consent without any coercion or forceful pressure by the research team, have decided to voluntarily participate in the study to contribute my part in the effort being made for the prevention of respiratory diseases.

Start by filling in the general information

- Zone: _____Woreda:_____Kebele:_____Got/village:_____
- Starting time: _____ End time: _____
- Questionnaire Code: _____
- Date of data collection: _____
- Name of data collector_____signature_____

Annex II: English Version Questionnaire

The study comprised questions that enable to assess the effects of exposure to traditional charcoal production on CRD, mask use and data extraction checklists to assess trends, seasonality and Forecating of CRD, and Spatial, Temporal and spatiotemporal variations of CRD in the study area. To address basic information required for this study, the questionnaire is generally summarized to include the main categories such as socioeconomic and demographic factors, personal and behavioral factors, knowledge, attitude, and practice regarding the use of mask, family-related factors, and work and environment-related factors.

PART I: Socio-demographic variables

S.No	Variable	Alternatives	Remarks
101	Age	_____ years	
102	Sex	1. Male 2. Female	
103	Marital status	1. Single 3. Divorced 2. Married 4. Widowed	
104	Religion	1. Orthodox 3. Protestant 2. Muslim 4. Catholic	
105	Ethnicity	1. Amhara 3. Tigre 5. Others 2. Agew 4. Oromo	
106	Primary occupation	1. Crop production 5. Daily laborer 2. Charcoal production 6. Student 3. Merchant 7. Others 4. Civil servant	
107	Level of Education	1. Unable to read and write 5. Certificate 2. Able to read and write 6. Diploma 3. Primary education(1-8) 7. Degree 4. Secondary education(9-12)	

108	Family size	_____	
109	Are you the head of the family	1. Yes 2. No	
110	Residence	1. Urban 2. Rural	
111	District	_____	
112	Zone	_____	

PART II: Respiratory symptoms related questions

S.No	Questions	Responseስ	Remark
201	Have you had episodes of wheeze/whistling sound/ apart from those caused by a common cold during breathing in the past 12 months?	1. Yes 2. No	
202	Do you have asthma	1. Yes 2. No	
203	Is the asthma confirmed with physician	1. Yes 2. No	
204	Do you take a drug for asthma	1. Yes 2. No	
205	Is there a family member who has asthma	1. Yes 2. No	
206	Do you have a cough lasted for two months?	1. Yes 2. No	
207	Have you had a cough that lasts for 3 months in a year	1. Yes 2. No	
208	Does the cough disturb your sleep at night?	1. Yes 2. No	
209	Does the cough affect your social interaction	1. Yes 2. No	
210	Have you had phlegm/sputum production/ occurring on most days of	1. Yes 2. No	

	the week (≥4 days/week) for 3 months in a year		
211	Have you had any episodes of chest tightness in the past 12 months?	1. Yes 2. No	
212	Have you had any episodes of shortness of breathing /breathlessness/ in the past 12 months?	1. Yes 2. No	
213	If yes for question **2013,** when does the episode of breathlessness occur?	1. No breathlessness except with strenuous exercise 2. Breathlessness when hurrying on the level ground or walking up a slight hill for at least three months in a year 3. Walking slower than people of the same age on the level because of breathlessness or need to stop for breath when walking at own pace or level at least three months in a year. 4. Grade 3: Stopping for breath after walking about a certain distance or a few minutes on the level ground at least three months in a year. 5. Too breathless to leave the house or breathless when dressing or undressing	
214	Have you awoken from sleep due to shortness of breath?	1. Yes 2. No	

215	Have you visited the health institution/s for respiratory health?	1. Yes 2. No	
216	Did you have a history of hospital admission due to respiratory problems?	1. Yes 2. No	
217	If yes for question 217, how many times have you admitted to a hospital due to respiratory disease in the past 12 months?	------- times	
218	Did you have sneezing, nasal fluid, and nasal congestion without a common cold?	1. Yes 2. No	

PART III: Questions related to charcoal production

S.No	Questions	Response	Remark
301	Have you participated in charcoal production for at least one year?	3. Yes 2. No	
302	If yes for question 201, in which activity do you participate?	1. charcoal production 2. charcoal packing 3. carrying or transporting	
303	For how long have you engaged in the charcoal production activity?	----------	
304	How many times you engaged in charcoal production in a year?	----------	
305	What do you use to ignite the combustion?	1. Straw 2. Leaves 3. other	
306	For how long do you work in a day during charcoal production?	------- hrs	

307	How many days does it take for one production period?	-----days	
308	How many days will be off-work to start the next production/	------- days	
309	Why do you produce charcoal?	1. For marketing For selling 2. For house consumption	
310	Type of wood used to produce charcoal	1. Equalyptus 2. Accacia ducrie 3. Others	
311	Which one is available around the charcoal production sites?	1. House 2. School 3. Church 4. Market 5. Main road 6. If other, mention	
312	How far is the production site from	1. House …..meters 2. School …. meters 3. Church … meters 4. Market …. meters 5. Main road …meters	
313	What do you feel while you are exposed to smoke or dust during the production activities?	1. Cough 2. Wheeze 3. Chest tightness 4. Shortness of breath 5. Discharge from the nose 6. Itching of the eye/tears 7. Skin itching/infection/none of these have occurred	

314	When did it become common for its occurrence?	1. Summer 2. Spring 3. Winter 4. Autumn	
315	Which health problem occurred while you were producing charcoal?	1. Fainting 2. Headache 3. Dizziness 4. Blurred Vision 5. No health problem occurred	
316	Is there a family member produce charcoal?	1. Yes 2. No	
317	Did women participate in charcoal production?	1. Yes 2. No	
318	If yes for question 223, in which activities did pregnant women participated duting charcoal production?	1. Charcoal combustion 2. Packing into sacks 3. Carrying to the store or road	
319	Did pregnant women participate in charcoal production?	1. Yes 2. No	
320	Did children < 15yrs old participate in charcoal production?	1. Yes 2. No	
321	If **<u>yes</u>** for ques. **220**, in which activity of charcoal production did children participate?	1. Charcoal combustion 2. Packing into sacks 3. Carrying to the store or the road	

PART IV: -Personal, behavioural and family-related questions

S.no	Variables	Alternatives	Remarks
01	Smoking history	1. Current smoker 2. Ex-smoker 3. Not smoked	**I** **f**
02	If a current smoker, on average, how many pieces of cigarette smoke per day?	_____ cigarettes/day	
3	I	_____ year/s	
04	Do you drink alcohol?	1. Yes 2. No	
05	If **yes** for question **304**, how often do you drink alcohol?	1. Every day 2. Most frequently 3. Less frequently	
06	If **yes** for question **304,** when do you take alcohol most of the time?	1. During working hrs 2. During off work hrs 3. Both times	
07	Do you chew chat?	1. Yes 2. No	**I**
08	If **yes** for ques **307**, how often do you chew chat?	1. Every day 2. Most frequently 3. Less frequently	
09	If **yes** for ques **307,** when do you chew chat most of the time?	1. During working hrs. 2. During off work hrs. 3. Both times	
10	Which disease do you have? (**Please circle** all the diseases he/she has)	1. TBC 2. HIV 3. Diabetes 4. HPN 5. Heart problem 6. Eye problem 7. Skin problem	

		8. Mental health 9. Others ----------	

PART V: Household, work and environmental related questions

S.No	Questions	Responses	Skip to
501	What is the main source of drinking water for members of your household?	1. Pipe water 2. Other	
502	What kind of toilet facility do members of your household usually use?	1. Flush or pour flush toilet 2. Pit latrine 3. No latrine facility	
503	What is the main material of the floor of your house?	1. Earth 2. Sand/cement 3. Other	
504	What is the main material of the exterior walls in your household?	1. Wood/Bamboo with mud 2. Other	
505	What is the main material of the roof in your household?	1. Metal / corrugated iron 2. Other	
506	Number of rooms in the house	------ rooms	
507	Number of windows in the house	-------windows	
508	What type of fuel does your household primarily use for cooking/heating?	1. Fuel wood 2. crop residues 3. Dung cake 4. Charcoal 5. Kerosene/liquefied petroleum gas 6. Electricity	

509	Most of the time. Where is your cooking place/kitchen location?	1. Inside the living room 2. In a separate room	
510	Does your household have? (You are supposed to circle all available)	1. Radio? 2. Electricity? 3. Television? 4. A non-mobile telephone? 5. Refrigerator? 6. Table? 7. Chair? 8. A bed with cotton/ sponge/spring matters? **9.** Availability of electric mitad? **10.** A kerosene lamp?	
511	Does any member of this household own	1. A watch? 2. Mobile telephone? 3. Bajaj? 4. Motorcycle? 5. Animal-drawn cart? 6. Bicycle? 7. Does any member of this household have a bank account/ microfinance account	
512	Most of the time., where is your cooking place/kitchen location?	1. Inside the living home 2. Outside the living home	

513	Do you have domestic animals?	1. Yes 2. No	**If no, go to 515**
514	If yes for Ques, which animal do you have in your home? (Circle all available in the home)	1. Milk cows or bulls? 2. Other cattle? 3. Back animals (Horses, donkeys, or mules)? 4. Goats? 5. Sheep? 6. Chickens? 7. Beehives? 8. Does any? Menttion	
515	Where do animals live primarily?	1. In a separate room 2. In the living house	
516	Does the household own any agricultural land?	1. Yes 2. No	
517	If the answer for Ques. source of the household's agricultural land	1. Private 2. Rent 3. Both	
518	Does charcoal production take place in your village?	1. Yes 2. No	
519	If **yes** for ques. **417,** the distance between the household's residence and the nearest production place	_____ meters	
520	Does your family engage in charcoal production?	1. Yes 2. No	
521	If **yes** for ques. **410,** how often is it produced per year in your area/village?	_____ times/year	

522	If yes for ques, do you think the smoke/dust released from the production site affected your health?	1. Yes 2. No	
523	Is your family/ household enrolled in a Community-Based Health Insurance scheme?	1. Yes 2. No	

Questions to be asked for charcoal producers only

PART VI: - Knowledge, Attitude and Practice related questions towards Mask utilization

6.1 Knowledge related questions asked for charcoal producers

S.No.	Questions	Response
601	Engaging in charcoal production activity exposes to respiratory diseases?	1. Yes 2. No
602	Engaging in charcoal production activity exposes to other health risks?	1. Yes 2. No
603	Charcoal producers have to use mask to reduce respiratory diseases?	1. Yes 2. No
604	Do you know that charcoal producers have to wear a respiratory mask consistently during production times	1. Yes 2. No
605	Do you think that mask could prevent dust enters into the respiratory tract?	1. Yes 2. No
605	Do you think that mask could prevent smoke enters into the respiratory tract?	1. Yes 2. No

606	Do you think not only those engaged in combustion are expected to use a mask, but also others who participated in packing into sacks and carrying need to use a mask?	1. Yes 2. No
607	Do you know that long-term exposure to smoke/dust can cause respiratory diseases?	1. Yes 2. No
608	Do you know where to get /buy/ the mask?	1. Yes 2. No
609	Do you motivate your colleagues to use mask during working hours?	1 Yes 2. No
610	Do you think covering with clothes could have a protective effect when there is no mask?	1. Yes 2. No
611	Have you trained on prevention techniques to reduce health risks related to engaging in charcoal production activities?	1. Yes 2. No
612	If yes for ques 507, who gave you the training? (Circle more than one)	1. Health professionals 2. Other technical experts 3. From colleagues

6.2. Attitude related questions asked for charcoal producers

	Questions	**Response with Frequency (%)**				
		Strongly disagree (1)	**Disagree (2)**	**I don't know (3)**	**Agree (4)**	**Strongly agree (5)**
613	Do you think being engaged in charcoal production affects your health?					
614	Do you think being engaged in charcoal production affects your respiratory health?					

615	Do you think people involved in charcoal production need to have frequent health visits?					
616	Do you believe persons involved in charcoal production need to get advice from professionals?					
617	Do you believe mask prevent you from respiratory problem at work					
618	I feel that every one who engaged in charcoal production has to wear mask at production place					
619	Workers who deal with dust or chemicals, should wear mask.					
620	I feel that wearing mask at work places hinder my work.					
621	I feel safer when I wear mask while I am at production siteme tasks					
622	I would encourage others at work place to wear their masks.					

6.3. Questions to assess Mask utilization practices of charcoal producers

S. No	**Questions**	**Responses**	**Skip**
623	Do you use a mask at work?	1. Yes 2. No	If no, go to 628
624	If **Yes** for question 623, how often do you use a mask while you	1. Always 2. Less often	

	are working in your charcoal-producing area?		
625	If less often, question 624, what are the reasons for not use mask at work place during charcoal production? (Circle more than one)	1. Not always necessary 2. Not comfortable 3. Unable to buy it always/cost 4. Unable to get it in the market	
626	Do you replace your mask when it is damaged or scratched?	1. Always 2. Sometimes	
627	Before starting work, do you check that your mask is clean and in good condition?	1. Yes 2. No	
628	If **No** for question 521, what is/are the reason/s for not using mask at all? (Circle more than one)	1. Wearing mask is not necessary 2. Wearing mask at work is not comfortable? 3. It is costy to buy a mask? 4. Is it not accessible in the market?	5.

PART VII. Checklist to extract respiratory disease related data from DHIS2 for the trends, seasonality, forecasting, and spatiotemporal study

S.no	Characteristics	Responses
701	Zone	
702	District	
703	Year	
704	Quarter (for each study year)	
705	Month (for each quarter)	
707	Sex by disease type	
708	Age category by diseases type	
710	Number of cases with chronic bronchitis	
711	Number of cases with Emphysema	
712	Number of cases with asthma	
712	Number of cases with chronic obstructive pulmonary disease (COPD)	
714	Number of hospital admissions due to respiratory-related diseases	
716	Total number of patients registered in a year (age >=15 years old) in each district	
717	X coordinate	
718	Y coordinate	
719	Zonal population/ in each year/	
720	District population /in each year/	

:: **End** ::

Annex III. Amharic Version Questionnaire

ከሰል ከማክሰል ተግባር ጋር በተያያዘ የሚከሰቱ የመተንፈሻ አካል የጤና ችግሮችና እየተደረጉ ስላሉ የመከላከያ ዘዴዎች በተመለከተ: ለሚደረግ የዳሰሳ ጥናት የተዘጋጀ መጠይቅ።

<u>መግቢያ:</u>

በቅድሚያ ወደ መጠይቁ እንኳን ደህና መጡ።

ስሜ _____ይባላለል። ከሰል ከማክሰል ጋር በተያያዘ የሚከሰቱ የመተንፈሻ አካል የጤና ችግርሮችና እየተደረጉ ስላሉ የመከላከያ ዘዴዎች በማጥናት በባህር ዳር ዩኒቨርሲቲ በህክምናና ጤና ሳይንስ ኮሌጅ በህብረተሰብ ጤና ት/ቤት በህብተሰብ ጤና የሶስተኛ ድግሪዉን ለመስራት እዚህ ዞን/ወረዳ ለመጣዉ አጥኝ መረጃ እየሰበሰብን እንገኛለን። ስለሆነም ይህንን የተመለከቱ ጥያቄዎችን ለእርስዎ አቀርባለሁ። በዚህ ጥናት በመሳተፍዎ የሚደርስብዎት ጉዳት የሌለ ሲሆን በቀጥታ የሚያገኙት ጥቅም አይኖርም። በመጠይቁ ላይ ስምም ሆነ ሌላ የእርስዎን ማንነት የሚገለልፅ ማነኛዉም ነገር አይጠቀስም። ጥያቄዎችን በተመለከተ የሚሰጡት ምላሽ ሚስጥራዊነቱ የተጠበቀ ሲሆን ሙሉ ጠቀሜታዉ ለምርምር ስራዉ ነዉ። በመጠይቁ ወቅት መመለስ የማይፈልጉትን ማነኛዉም አይነት ጥያቄ መተዉ ወይም በማነኛዉመ ሰአት ማቋረጥ ይችላሉ። ፡ ሆኖም ግን የሚሰጡት መረጃ ወደፊት ከሰል ከማክሰል ጋር በተያያዘ የሚከሰቱ የመተንፈሻ አካል የጤና ችግርሮችና እየተደረጉ ስላሉ የመከላከያ ዘዴዎች ትኩረት ሰጥቶ ችግሩን መከላከል እንዲቻል ለሚደረግ ቀጣይ ተግባር ጠቀሜታዉ የጎላ ስለሆነ በቅድሚያ ለሚያደርጉት ትብብርና ለሚሰጡት ትክክለኛ ምላሽ ምስጋናችን ከልብ የመነጨ ነዉ። መጠይቁ ክ25-30 ደቂቃ ይፈጃል።

ስለዚህ በዚህ ጥናት መሳተፍ ፈቃደኛ ነዎት? አዎ ☐ አይደለሁም ☐

መልስ አዎ ከሆነ አመስግነዉ ወደ ሚቀጠለዉ ገፅ ይለፉ። አይደለሁም ከሆነ አመስግነዉ መጠይቁን አይጀምሩ።

<u>የስምምነት መስጫ ቅፅ</u>

እኔ በዚህ ጥናት ለመሳተፍ የተስማማሁት ስለጥናቱ አላማ ተነቦልኝና ተረድቸ አስፈላጊ መሆኑን በማመን በጥናቱ ለመሳተፍ ያለመንም ተፅዕኖ በራሴ ፈቃድ ተሳታፊ መሆኔን አረጋግጣለሁ።

ፈቃደኝነቱን ያረጋገጠዉ መረጃ ሰብሳቢ

ስም _____

ፊረማ _____

የመጠየይቁ መለያ ቁጠር _____

መጠይቁ የተደገበት ቀን _____

የጥናቱ ተቆጣጣሪ ስም/ፊርማ _____

ክፍል 1፡- የጥናቱ ተሳታፊዎችን የማህበራዊና ዲሞግራፊ ጉዳዮችን ለመዳሰስ የቀረቡ ጥያቄዎች

ተ.ቁ.	ጥያቄ	አማራጭ መልሶች	ምርመራ
101	እድሜ	--------- ዓመት	
102	ፆታ	1. ወንድ 2. ሴት	
103	የጋብቻ ሁኔታ	1. ያላገባ/ች 3. የፈታ/ች 2. ያገባ/ች 4. የሞተበት/ባት	
104	እምነት	1. ኦርቶዶክስ ክርስቲያን 3. ፕሮቴስታንት 2. እስልምና 4. ካቶሊክ	
105	ብሄር	1. አማራ 4. ኦሮሞ 2. አገዉ 5. ሌላ (ይጠቀስ) 3. ትግሬ	
106	ዋና የመተዳደሪያ ስራዎ ምንድን ነዉ	1. ግብርና 5. የቀን ስራ 2. ከሰል ማክሰል 6. ተማሪ 3. ንግድ 7. ሌላ (ይጠቀስ) 4. የመንግስት ስራ	
107	የት/ት ደርጃ	1. ማንበብና መፃፍ አይችሉም 5. ሰርትፊኬት 2. ማንበብና መፃፍ ይችላሉ 6. ዲፕሎማ 3. የመጀመሪያ ደረጃ ት/ት 7. የመጀመያ ድግሪ 4. የሁለተኛ ደረጃ ት/ት	
108	የቤተሰብ አባላት ብዛት	------- አባላት	
109	እርስዎ የቤተሰቡ ሃላፊ ነዎት	1. አዎ 2. አይደለሁም	
110	የመኖሪያ ቦታ	1. ከተማ 2. ገጠር	
111	ወረዳ	_____	
113	ዞን	_____	

ክፍል 2፡- የመተንፈሻ አካል የጤና ችግር ምልክቶቻቸዉን ለመዳሰስስ የቀረቡ ጥያቄዎች

ተ.ቁ.	ጥያቄ	አማራጭ መልሶች	ምርመራ
201	በሚተነፍሱበት ጊዜ የተለየ /ሲጥ ሲጥ/ የሚል የሚሰማ ድምፅ ጉንፋን ሳይኖር ተክሰትብዎት ነበር?	1. አዎ 2. የለም	
202	አስም አለብዎት?	1. አዎ 2. የለም	መልሱ የለም ከሆነ ወደ 205 ይሂዱ
203	ከላይ ለተራ ቁ፡፡ 202 ምልስዎ አዎ ክሆነ አስም አእንዳለብዎት በሃኪም የተረጋገጠ ንዉ?	1. አዎ 2. የለም	
204	አስም መድሃኒት እየወሰዱ ነዉ?	1. አዎ 2. የለም	
305	በቤተሰብዎ የአስም በሽታ ያለበት አለ?	1. አዎ 2. የለም	
206	ለ2 ወራት የቆየ ሳል አለብዎት?	1. አዎ 2. የለም	
207	ባለፉት ሁለት ዓመታት ዉስጥ በዓመት ዉስጥ ለ3ወራት ያህል የሚቆይ ሳል ነበረብዎት?	1. አዎ 2. የለም	
208	በሳል ምክንያት እንቅልፍ እየተቋረጠ ተቸግረዉ ያዉቃሉ?	1. አዎ 2. የለም	
309	በሳሉ ምክንያት ማህበራዊ ግንኙነትዎ ተስትጓጉሎ ያዉቃል?	1. አዎ 2. የለም	
210	በየቀኑ/በሳምንት ዉስጥ ክ4 ቀናት በላይ የሚከሰት / በዓመት ለ3ወራት	1. አዎ 2. የለም	

	ያህል የሚቆይ ባለፉት ሁለት ዓመታት ውስጥ አክታ ነበረብዎት?		
211	ባለፉት 12 ወራት ጊዜ ውስጥ በሚተነፍሱበት ጊዜ ደረትዎን ውጥር አድርጎ የመያዝ ስሜት ተከስቶዎበት ያውቃል?	1. አዎ 2. የለም	
212	ባለፉት 12 ወራት ጊዜ ውስጥ በሚተነፍሱበት ጊዜ የአየር ማጠር ስሜት ተከስቶዎበት ያውቃል?	1. አዎ 2. የለም	መልሱ የለም ከሆነ ወደ 215 ይሂዱ
213	ከላይ ለጥያቄ ቁጥር 212 መልስዎ አዎ ከሆነ የአየር ማጠር ስሜት መቸ ነዉ?	1. ከበድ ያለ እንቅስቃሴ / ሥራ ከሌለ በስተቀር የትንፋሽ ማጠር ችግር የለብዎትም 2. ፈጠን ብለዉ ሲሄዱ ወይም ከፍታ ሲወጡ የትንፋሽ ማጠር ችግር ያጋጥመመዎታል 3. ቀጥ ባለ መንገድ በተለመደዉ አካሄድ ከሌላ ሰዉ ጋር ሲጓዙ የትንፋሽ ማጠር ችግር ይከሰታል 4. በእድሜ እንደ እርስዎ ካለ ሰዉ ጋር በሚሄዱበት ጊዜ በትንፋሽ ማጠር ችግር ምክንያት አብረዉ መሄድ ይቸገራሉ 5. ከቤት ወጣ ሲሉ ወይም ልብስ ሲለብሱ ወይም ሲታጠቡ የትንፋሽ ማጠር ሁኔታ ይከሰትብዎታል	
214	ባለፉት 12 ወራት ጊዜ ውስጥ በሚተነፍሱበት ጊዜ በአየር ማጠር	1. አዎ 2. የለም	

	ስሜት ምክንያት የአእንቅልፍ መቆራረጥ ተከስቶዎበት ያዉዋል?		
215	ባለፉት 12 ወራት ጊዜ ዉስጥ በአተነፋፈስ የጤና ችግር ምክንያት ጊዜ ዉስጥ ወደ ጤና ተቋም ሄደዉ ያዉቃሉ?	1. አዎ 2. የለም	
216	ባለፉት 12 ወራት ጊዜ ዉስጥ በአተነፋፈስ የጤና ችግር ምክንያት ሆስፒታል ትኝተዉ ያዉቃሉ?	1. አዎ 2. የለም	
217	ከላይ ለጥያቄ ቁጥር 216 መልስዎ አዎ ከሆነ፤ባለፉት 12 ወራት ጊዜ ዉስጥ ስንት ጊዜ ሆስፒታል ትኝተዉ ነበር?	_____ ጊዜ	
218	ባለፉት 12 ወራት ጊዜ ዉስጥ ጉነፋን ሳይዝዎት አፍንጫዎትን ማፈን፤ በአፍንጫዎት ፈሳሽ አእና ማፈን ተቸግረዉ ያዉቃል?	1. አዎ 2. የለም	

ክፍል 3: በከሰል ምርት ስራ ጋር የተያያዙ ጥያቄዎች

ተቁ	ጥያቄዎች	መልሶች	ምርመራ
301	በከሰል ማምረት ስራ ቢያንስ ለ1 አዓመት ያህል ጊዜ ሰተዉ ያዉቃሉ?	4. አዎ 2. የለም	
302	ከላይ ለተቁ 301 መልስዎ አዎ ከሆነ በየትኛዉ ተግባር ይሳተፋሉ? (ክሳአንድ በላይ መልስ ያክቡ)	4. ከሰል በማክሰል 5. ከሰሉን ወደ ኩንታል ማስገባት 6. በማጓጓዝ	
303	በከሰል ማምረት ስራ ለሰንት አመት ሰሩ?	----------ዓመት	

304	በከሰል ማምረት ስራ በዓመት ስንት ጊዜ ያመርታሉ/ይሳተፋሉ?	----------ጊዜ	
305	ከሰል በማክሰል ተግባር ለማቀጣጠል ምን ይጠቀማሉ?	4. ጭድ 5. ቅጠል 6. ሌላ	
306	በከሰል ማምረት ስራ ጊዜ በቀን ስንት ሰዓት ይሠራሉ?	------- ሰዓት	
307	በከሰል ማምረት ስራ አንድ ዙር ለማከናወን ስንት ቀናትን ይወስዳል?	-----ቀናት	
308	በከሰል ማምረት ስራ አንድ ዙር ተጠቃሎ ካለቀ በኋላ የሚቀጥለዉን ዙር አስከሚያከናዉኑ ለስንት ቀናት ይቆያል?	------- ቀናት	
309	በዋናነት ከሰል የሚያመርቱት ለምን ተግባር ነዉ?	3. ለሽያጭ /ገቢ ማስገኛ/ 4. ለቤት ፍጆታ	
310	ለከሰል ማምረት ስራ የሚጠቀሙት የአእንጨት አይነት የቱ ነዉ? (ክሳአንድ በላይ መልስ ያክቡ)	4. ባህር ዛፍ 5. ችግኝ/Accacia/ 6. ሌላ	
311	ከሰል በሚያከሰሉበት አካባቢ የሚገኘዉ የቱ ነዉ? (ክሳአንድ በላይ መልስ ያክቡ)	7. መኖሪያ ቤት 8. ት/ቤት 9. ቤተ ክርስቲያን/መስጊድ/ሌላ 10. ገበያ 11. መንገድ 12. ሌላ ትቋም /ይጠቀስ/	
312	ከሰል በሚያከሰሉበት ቦታ _____ በምን ያህል ይርቃል?	6. መኖሪያ ቤት ___ ሜትር 7. ት/ቤት ___ ሜትር 8. ቤተ ክርስቲያን/መስጊድ/ሌላ ___ ሜትር 9. ገበያ ___ ሜትር	

		10. መንገድ ___ ሜትር	
313	በሰል ምርት ስራ እያሉ ለጭሱና ብናኙ ሲጋለጡ የሚሰማዎት ምንድን ነዉ? (ከአንድ በላይ መልስ ያክቡ)	8. ሳል 9. በሚትነፍሱበት ጊዜ ሲጥ ሲጥ የሚል ድምጽ 10. ደረትን ዉጥር አድርጎ መያዝ 11. የትንፋሽ ማጠር 12. ከአፍንጫ ፈሳሽ መፍሰስ 13. አይን ማንባትና ማሳከክ 14. ቆዳን ማሳከክና ቁስለት 15. ምንም ችግር አጋጥሞኝ አያዉቅም	
314	በተ.ቁ. 314 ችግር አእንዳለ ከጠቀሱ አብዛኛዉን ጊዜ በየትኛዉ ወቅት ይከሰታል?	5. ክረምት 6. በልግ 7. በጋ 8. መህር	
315	በሰል ምርት ስራ እያሉ የትኛዉ የጤና ችግር ተከስቶብዎት ያአዉቃል? (ከአንድ በላይ መልስ ያክቡ)	6. ራስን መሳት 7. ራስ ህመም 8. መፍዘዝ ስሜት 9. የአይን ብዥ ብዥ ማለት 10. ምንም ችግር አጋጥሞኝ አያዉቅም	
316	ከቤተሰብዎ ዉስጥ በሰል ማምረት ስራ የተሰማራ አለ?	3. አዎ 4. የለም	
317	በሰል ማምረት ስራ ዉስጥ ሴቶች ይሳተፋሉ?	1. አዎ 2. የለም	
318	ከላይ ለተ።ቁ። 317 መልስዎ አዎ ከሆነ ሴቶች በአብዛኛዉ በየትኛዉ የሰል ምርት	3. በማክሰሉ ተግባር 4. ወደ ኩንታል ማስገባት	

	ስራ ላይ ይሳተፋሉ? (ከአንድ በላይ መልስ ያክቡ)	5. ከቦታ ቦታ በማንገዝ	
319	በከሰል ማምረት ስራዉስጥ ነፍሰ ጡር የሆኑ ሴቶች ይሳተፋሉ?	6. አዎ 7. የለም	
320	በከሰል ማምረት ስራ ዉስጥ አእድሜያቸዉ ከ15 አመት በታች የሆኑ ህጻናት ይሳተፋሉ?\	3. አዎ 4. የለም	
321	ከላይ ለተ.ቁ.320 መልስዎ አዎ ከሆነ በየትኛዉ የሰል ምርት ስራ ላይ ይሳተፋሉ? (ከአንድ በላይ መልስ ያክቡ)	1. በማክሰሉ ተግባር 2. ወደ ኩንታል ማስገባት 3. ከቦታ ቦታ በማንገዝ	

ክፍል 4፡-ግለሰባዊ፤ ሥነ-ባሕርይ እና ቤተሰባዊ ጉዳዮችን ለመዳሰስ የቀረቡ ጥያቄዎች

ተ.ቁ	ጥያቄ	አማራጭ መልሶች	ምርመራ
01	ሲጋራ ማጨስን በተመለከት	1. አሁን ያጨሳሉ 2. ቀደም ሲል ያጨሱ ነበር 3. ምንም አጭሰ አያዉቁም	**የማያጨሱ ከሆነ ወደ 406 ይሂዱ**
02	አሁን እያጨሱ ከሆነ፤ በቀን ምን ያህል ሲጋራ ያጨሳሉ?	___ ሲጋራ /በቁጥር/ በቀን	
03	አሁን እያጨሱ ከሆነ፤ ማጨስ ከጀመሩ ምን ያህል ጊዜ ሆነዎት?	_____ አመት	
04	አልኮል ይጠጣሉ?	1. አዎ 2. የለም	**የለም ከሆነ ወደ 411 ይሂዱ**
05	ከላይ **ለጥያቄ ቁጥር 304፣ መልስዎ አዎ ከሆነ**፤ አልኮል በምን ያህል ጊዜ ይጠጣሉ?	1. በየቀኑ 2. አብዛኛዉን ጊዜ 3. አልፎ አልፎ	

06	ከላይ **ለጥያቄ ቁጥር 304፣ መልስዎ አዎ ከሆነ፤** አልኮል ብዙዉን የሚጠጡት በምን ሰዓት ነዉ?	1. በስራ ሰዓት 2. በእረፍት ሰዓት 3. በሁለቱም ጊዜ	
0	ጫት ይቅማሉ?	1. አዎ 2. የለም	**መልሱ <u>የለም</u> ከሆነ ወደ 410 ይሂዱ**
	ከላይ **ለጥያቄ ቁ. 311 መልስዎ አዎ ከሆነ፤** በምን ያህል ጊዜ ይቅማሉ?	1. በየቀኑ 2. አብዛኛዉን ጊዜ 3. አልፎ አልፎ	
	ከላይ **ለጥያቄ ቁጥር 313 መልስዎ አዎ ከሆነ፤** ጫት የሚቅሙት ብዙዉን ጊዜ በምን ሰዓት ነዉ?	1. በስራ ሰዓት 2. በእረፍት ሰዓት 3. በሁለቱም ጊዜ	
41	ከተዘረዘሩት ዉስጥ የትኞቹ የጤና ችግሮች አለብዎት ተብለዉ ያዉቃሉ (ያሉባቸዉን ሁሉ ያክቡ)?	1. ቲቢ(የሳንባ ነቀርሳ) 2. ኤች አይ ቪ 3. የስኳር በሽታ 4. የደም ግፊት 5. የልብ ችግር 6. የዓይን ችግር 7. የቆዳ ችግር 8. የሥነ- አእምሮ ችግር 9. ሌሎች ካሉ ይጥቀሱ	

ክፍል 5፡- የቤት፤ የስራና አካባቢያዊ ጉዳዮችን ለመዳሰስ የቀረቡ ጥያቄዎች

ተ.ቁ.	ጥያቄ	አማራጭ መልሶች	ምርመራ
501	በቤትዎ ለመጠጥና ምግብ ለማብሰል ዉሃ ከየት ያገኛሉ?	1. ከቧንቧ ዉሃ 2. ሌላ	
502	በቤትዎ ዉስጥ የትኛዉ ዓይነት መጸዳጃ ቤት አለ?	1. በዉሃ የሚሰራ 2. የጉድጓድ መጸዳጃ ቤት 3. የለም	
503	የመኖሪያ ቤታቸዉ ወለል የተሰራዉ ከምን ነዉ?	1. ከጭቃ/አፈር/ 2. ከስሚንቶ 3. ሌላ	
504	የመኖሪያ ቤታቸዉ ገድግዳ የተሰራዉ ከምን ነዉ?	1. አእንጨትና የትመረገ 2. ሌላጣራ	
505	የመኖሪያ ቤታቸዉ ጣራ የተሰራዉ ከምን ነዉ?	3. ቆርቆሮ 4. ሳር	
506	ቤቱ ያለዉ የክፍል ብዛት	--------	
507	ቤቱ ያለዉ የመስኮት ብዛት	_____	
508	በቤት ዉስጥ ምግብ ለማብሰል በአብዛኛዉ ጥቅም ላይ የሚዉለዉ የቱ ነዉ?	1. እንጨት 2. የሰብል ተረፈ ምርት 3. ኩበት 4. ከሰል 5. ቡታጋዝ 6. የኤሌክትሪክ ሃይል	
509	በአብዛኛዉ ለማብሰያ የሚጠቀሙት ቦታ የት ነዉ?	1. በመኖሪያ ቤት ዉስጥ 2. ከመኖሪያ ቤት ዉጭ	
510	በቤትዎ ዉስጥ የሚገኘዉ የቱ ነዉ? (ከአንድ በላይ ያክቡ)	1. ሬድዮ 2. ኤሌክትሪክ 3. ቴሌቪዝን 4. የቤት ስልክ	

		5. ፍሪጅ 6. ወንበር 7. አልጋ ከፍራሽ ጋር 8. ያኤሌክትሪክ ምጣድ 9. ኬሮሲን ምምድጃ	
511	ከቤተሰብዎ ዉስጥ ከተዘረዘሩት ዉስጥ የትኛዉ አላችዉ? (ከአንድ በላይ ያክቡ)	1. የአእጅ ሰዓት 2. ሞባይል ስልክ 3. ባጃጅ 4. ሞተር ሳይክል 5. ጋሪ 6. ሳይክል 7. ባንክ አካዉንት	
512	የቤት እንስሳ አለዎት?	1. አዎ 2. የለም	**መልሱ <u>የለም</u> ከሆነ ወደ ይሂዱ**
513	ከላይ በጥያቄ ቁ.412 ለቀረበው ጥያቄ መልስዎ አዎ ከሆነ፤የትኞቹ አሉ?	1. ላም 2. በሬ 3. የጋማ እንስሳት 4. ፍየል 5. በግ 6. ዶሮ 7. ንብ 8. ሌላ (ይጠቀስ)	
514	በዋናነት የቤት እንስሳት የሚኖሩት የት ነዉ?	1. መኖሪያ ቤት ዉስጥ 2. ከመኖሪያ ቤት	
515	የእርሻ መሬት አላችሁ?	1. አዎ 2. የለም	

516	ከላይ ለቀረበዉ ጥያቄ ቁ.415 መልስዎ አዎ ከሆነ፤መሬቱ የተገኘበት	1. የግል 2. በኪራይ 3. በሁለቱም	
517	እርስዎ በሚኖሩበት ሰፈር አካባቢ ከሰል ይከሰላል?	1. አዎ 2. የለም	**መልሱ <u>የለም</u> ከሆነ ወደ 522 ይሂዱ**
518	ከላይ ለቀረበዉ ጥያቄ ቁ.417 **መልስዎ አዎ ከሆነ፤** ከሰሉ የሚመረትበት ቦታ ከመኖሪያ ቤትዎ በምን ያህል ይርቃል?	--------ሜትር	
519	ከቤተሰብዎ ውስጥ በከሰል ምርት ስራ የሚሳትፍ አለ?	1. አዎ 2. የለም	
520	እርስዎ በሚኖሩበት ሰፈር/አካባቢ የሚከናወነዉ የከሰል ማክሰል ስራ በዓመት ዉስጥ ስንት ጊዜ ይከናወናል?	_____ ጊዜ በዓመት	
521	እርስዎ በሚኖሩበት ሰፈር/አካባቢ የሚከናወነዉ የከሰል ማክሰል ስራ የጤና ችግር አስከትሏል ብለዉ ያስባሉ?	1. አዎ 2. የለም	
522	የማህበረሰብ አቀፍ የጤና መድህን አባል ነዎት?	1. አዎ 2. የለም	

ከሰል በማክሰል ተግባር ላይ ለተሰማሩ የጥናቱ ተሳታፊዎች ብቻ የሚቀርብ ጥያቄ

ክፍል 6፡- ከሰል በሚከሰልበት ጊዜ ሊከሰቱ የሚችሉ በስራ ላይ ጉዳትንና የጤና ጠንቆችን ለመከላከል የሚያገለግሉ ቁሳቁሶችን ስለመጠቀም ያላቸዉን እዉቀት፤ አመለካከትና የመጠቀም ልምዳቸዉን ለመዳሰስ የቀረቡ ጥያቄዎች

6.1. በስራ ላይ ጉዳትን የጤና ጠንቆችን ለመከላከል የሚያገለግሉ ቁሳቁሶችን ስለመጠቀም ያላቸዉን እዉቀት ለመዳሰስ የቀረቡ ጥያቄዎች

S.No.	Questions	Response
601	የስራ ባህሪዎ ለተለያዩ የጤና ችግሮች የሚያጋልጥ ነዉ ብንለዉ ያስባሉ	2. አዎ 2. የለም
602	በከሰል ማክሰል ስራ ላይ መሳተፍ በይበልጥ ለመተንፈሻ አካል ለጤና መታዎክ ሊያጋልጥ ይችላል?	1 አዎ 2. የለም
603	በከሰል ማክሰል ስራ ጊዜ የመተንፈሻ አካላት የጤና ችግሮችን ለመከላከል ማስክ መልበስ ያስፈልጋል?	1. አዎ 2. የለም
604	በከሰል ማክሰል ስራ ላይ የሚሳተፉ በመተንፈሻ አካላት የጤና ችግሮችን ለመከላከል በስራ ሰዓት ማስክ ያለማቋረጥ መልበስ ይኖርበታል?	1. አዎ 2. የለም
605	ማስክ መልበስ በከሰል ማክሰል ስራ ላይ አእያሉ ብናኝ ወደ መተንፈሻ አካል አእንዳይገባ ያደርጋል?	1. አዎ 2. የለም
606	ማስክ መልበስ በከሰል ማክሰል ስራ ላይ አእያሉ ጭስ ወደ መተንፈሻ አካል አእንዳይገባ ያደርጋል?	1. አዎ 2. የለም
607	ከሰሉን የሚያከስሉ ሰዎች ብቻ ሳይሆኑ ክሰሉን ወደ ኩንታል የሚከትቱና የሚያንጉዙ ስዎችም ማስክ መልበስ አለባቸዉ ብለዉ ያስባሉ?	1. አዎ 2. የለም
608	ለጭስና ብናኝ ለረዥም ጊዜ መጋለጥ ለመተንፈሻ አካላት የጤና ችግር ሊያጋልጥ ይችላል?	1. አዎ 2. የለም
609	የስራ ባልደረቦቻዎት ማስክ አእንዲጠቀም ያበረታታሉ?	1. አዎ 2. የለም

610	ማስክ በማይኖርበት ጊዜ አፍና አፍንጫን በልብስ መሸፈን ሊከላከል ይችላል ?	1. አዎ 2. የለም
611	በከሰል ማክሰል ስራ ላይ ሊከሰቱ ይሚችሉ የጤና ችግሮችን ለመከላከል የስራ ላይ ጉዳት መከላከያ ቁሳቁሶችን ስለመጠቀም ስልጠና አገኝተዉ ያዉቃሉ?	1. አዎ 2. የለም
612	ከላይ ልተራ ቁ። 511 መልስዎ አዎ ከሆን ስልጠናዉ በማን ነበር የተሰተዉ? (ከአንድ በላይ ያክቡ)	1. የጤና ባለሙያ 2. ሌሎች ባልሙያዎች 3. ከስራ ባልደረባ

6.2. በስራ ላይ ጉዳትንና የጤና ጠንቆችን ለመከላከል የሚያገለግሉ ቁሳቁሶችን ስለመጠቀም ያላቸዉን አመለካከት ለመዳሰስ የቀረቡ ጥያቄዎች

ተ.ቁ	ጥያቄዎች	ምላሾች (%)				
		በጣም አልስማማም(1)	አልስማማም(2)	አላዉቅም (3)	እስማማለሁ (4)	በጣም አእስማማለሁ (5)
613	በከሰል ማምረት ተግባር መሳተፍዎ የጤና መታወክ ሊያስከትል ይችላል ብለዉ ያስባሉ?					
614	በከሰል ማምረት ተግባር መሳተፍዎ በመተንፈሻ አካል ጤና ችግር በይበልጥ ተጋላጭ ሊያደርግ ይችላል ያስባሉ?					
615	በከሰል ማምረት ተግባር በምሳተፍዎ የጤና ምርመራ ማድረግ አለብኝ ብለዉ ያስባሉ?					
616	በከሰል ማምረት ተግባር በምሳተፍዎ ከባለሙያ የስራ ላይ ደህንነት የምክር አገለግሎት ያስፈልጋል ብለዉ ያስባሉ?					

617	በከሰል ማምረት ተግባር ወቅት ማስክ ማድረግ ተንፈሻ አካል የጤና ችግር መከላከል ይቻላል ብለዉ ያስባሉ?					
618	በከሰል ማምረት ተግባር የሚሳተፍ ሰዉ ሁሉ በስራ ቦታ ሁሉም ማስክ ማድረግ አለበት ብለዉ ያስባሉ?					
619	ብናኝ፤ ኬሚካል እና ሌሎች በካይ ነገሮች ባሉበት የስራ ቦታ ማስከ መደረግ አለበት ብለዉ ያምናሉ?					
620	ማስክ በማድረግዎ ምክኛት ስራየ አይስተጓጎልም ብለዉ ያምናሉ?					
621	በስራ ቦታዎ ማስከ በማድረግዎ የእራስዎትን ደህንነት አእየጠበቁ አእንደሆን ይሰማዎታል?					
622	በስራ ቦታዎ ሌሎች የስራ ባልደረባዎ በስራ ሰዓት ማስክ አእንዲያደርጉ ያበረታታሉ?					

6.3. <u>በከሰል ማክሰል ስራ ጊዜ ራስን ከጉዳት ለመከላከል የመከላከያ ቁሳቁሶችን ስለመጠቀም ያለ ልምድን ለመዳሰስ የቀረቡ ጥያቄዎች</u>

ተ ቁ	ጥያቄ	መልስ	መርመራ
623	በከሰል ማምረት ስራ ወቅት ማስክ ያደጋሉ?	1. አዎ 2. የለም	መልስ የለም ከሆነ ወደ ጥቁ 628
624	ከላይ ለተ ቁ 623 መልስዎ አዎ ከሆነ መች ይጠቀማሉ?	1. ሁልጊዜ 2. አልፎ አልፎ	

625	ከላይ ለተ ቁ 624 መልስዎ አአልፎ አልፎ ከሆነ ምክንያቱ ምን ሊሆን ይችላል? (ከአንድ በላይ ያክቡ)	1. ሁልጊዜ ስለማያስፈልግ 2. ምቹ ስላልሆነ? 3. ሁልጊዜ ማስክ መግዛት ወጭ ስላለዉ? 4. ማስክ ለመግዛት በአካባቢ ስለማይገኝ?	
626	የሚጠቀሙበት ማስክ ሲቅደድ / ሲበላሽ የቀይራሉ?	1 አዎ 2 የለም	
627	ስራ ከመጀመርዎ በፊት ማስክዎ ንጹህና ያልተቀደደ መሆኑነ ያረጋግጣሉ?	1 አዎ 2 የለም	
628	ከላይ ለተ ቁ 623 መልስዎ **የለም** ከሆነ በከሰል ማምረት ተግባር ወቅት ማስክ ሙሉ በሙሉ የማይጠቀሙት በምን ምክንያት ሊሆን የችላል? (ከአንድ በላይ ያክቡ)	1. ማስክ በስራ ላይ አስፈላጊ ስላልሆነ? 2. ማስክ መጠቀም ምቹ ስላልሆነ? 3. ማስክ በየጊዜው ለመግዛት አቅም ስለሌለ? 4. ማስክ ገዝቶ ለመጠቀም ገበያ ላይ ስለማይገኝ?	

ክፍል 7፡ ከጤና መረጃ መዝገብ የሚሞላ

ተ.ቁ	ጥያቄ	Responses
701	ዞን	
702	ወረዳ	
703	ዓመት (ዓ/ም)	
704	ሩብ ዓመት (ለየአመቱ)	
705	ወር	
706	ጾታ	
707	እድሜ	
708	አስማ	
709	ሲ.አ.ፒ.ዲ.(COPD)	
710	እድሜያቸዉ 15 ዓመትና በላይ የሆናቸዉ	
711	X coordinate	
712	Y coordinate	
713	የዞን ህዝብ ብዛት/በዓየመቱ/	
714	የወረዳ ህዝብ ብዛት/በዓየመቱ/	

:::::::::::: መጠይቁን ጨርሰናል፤ስለ ትብብርዎ ከልብ እናመሰግናለን!! ::::::::::::

Annex IV: Published and under review papers

Paper I:

frontiers | Frontiers in Epidemiology

TYPE Original Research
PUBLISHED 15 January 2025
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Trends, seasonal variations and forecasting of chronic respiratory disease morbidity in charcoal producing areas, northwest Ethiopia: time series analysis

Mulugeta Tesfa[1]*, Achenef Motbainor[2] and Muluken Azage Yenesew[2]

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Objective: This study analyzed the trend, seasonal variations and forecasting of chronic respiratory disease morbidity in charcoal producing areas, northwest Ethiopia, aiming to provide evidences in planning, designing strategies, and decision-makings for preparedness and resource allocation to prevent CRD and reduce public health burden in the future.

Materials and methods: The trend, seasonal variation, and forecasting for CRD were estimated using data collected from the three zones of Amhara region annual reports of DHIS2 records. Smoothing decomposition analysis was employed to demonstrate the trend and seasonal component of CRD. The ARIMA (2, 1, 2) (0, 0, 0) model was used to forecast CRD morbidity. The model's fitness was checked based on Bayesian information criteria. The stationarity of the data was assessed with a line chart and statistically with the Ljung-Box Q-test. SPSS version 27 was utilized for statistical analysis.

Results: The annual morbidity rate of CRD has shown an increasing trend in both sexes over a seven-year period among people aged 15 years and older. Seasonal variation in CRD morbidity was observed. The smoothing decomposition analysis depicted that the seasonal component was attributed to 44.47% and 19.16% of excess CRD cases in the period between September to November, and June to August, respectively. A substantial difference among the three zones of the Amhara region in CRD morbidity rate was noted, with the highest observed in the Awi zone. Forecasting with the ARIMA model revealed that CRD-related morbidity will continue to increase from 2020 to 2030.

Conclusion: The study revealed that the CRD morbidity rate has shown an increasing trend from 2013 to 2019. Seasonal variation in the CRD morbidity rate was observed, with the highest peak from September to November. The morbidity attributed to CRD will continue to increase for the next ten years (2020–2030). Therefore, this study could potentially play a groundbreaking role. Further study is warranted to understand the risk factors and facility readiness through a further understanding of seasonality and future trends.

KEYWORDS

chronic respiratory disease, trend, seasonal variation, forecasting, ARIMA, Ethiopia

Paper II

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OPEN

Spatial, temporal, and spatiotemporal variations of chronic respiratory disease in charcoal-producing areas, northwest Ethiopia

Mulugeta Tesfa Gebeyehu[1,2*], Achenef Motbainor Begasew[3], Mintesnot Teni[4] & Muluken Azage Yenesew[3]

Understanding spatial, temporal, and spatiotemporal variations of chronic respiratory disease (CRD) is significant for the early prevention of the disease and efficient allocation of scarce healthcare resources. However, this is not well known in the Ethiopian context, particularly in charcoal-producing areas. Thus, this study aimed to assess the spatial, temporal, and spatiotemporal variations of CRD in northwest Ethiopia from 2012/13 to 2018/19. This study was conducted in three zones (Awi, East Gojjam, and West Gojjam), Amhara Region, Ethiopia. These zones are known for charcoal production. Data on CRD among those aged 15 years and above were obtained from 44 districts for seven years from the three zonal health departments' annual records. Scan statistics with a discrete Poisson model was used to identify statistically significant clusters using SaTScan version 10.1. Global Moran's I and Getis-Ord Gi statistics were employed to assess the spatial heterogeneity and hot spot areas of CRD respectively. To display maps of cluster locations, ArcGIS version 10.8 was used. The annual morbidity rate of CRD was remarkably varied from 305 to 731per 100,000 population in 2012/13 and 2018/19 respectively. The highest annual morbidity rate, 6008/100,000 population, was observed in the Awi zone. The global spatial autocorrelation (Moran's I = 0.2773, Z-score = 3.6587, and P-value < 0.001) shows a strong clustered distribution. The most likely purely spatial and spatiotemporal clusters were detected in eleven districts, and eight of these were in the Awi zone. The cluster center/radius was 10.967700 N, 36.925500 E/ 48.37 km, and RR = 4.37, p-value < 0.001. People living in the highest risk areas had a 4.37 times greater chance of developing CRD than those in the lowest risk areas. The Getis-Ord Gi hot spot analysis detected that hot spot clusters were primarily located in the northwest and southwest parts of the study area. The spatial, temporal, and spatiotemporal variations of CRD were non-random and clustered in high-charcoal production areas. The identified high-risk clusters are the priority areas for target intervention. Further research is recommended to identify risk factors for higher clusters of CRD morbidity in these areas.

Keywords: CRD, Hot spots, Spatiotemporal, Charcoal production, SaTScan, Amhara, Ethiopia

Abbreviations

CRD	Chronic respiratory disease
COPD	Chronic obstructive pulmonary disease
CI	Confidence interval
LLR	Log likelihood ratio
RR	Relative risk

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Paper III

SPRINGER NATURE
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The effect of exposure to charcoal production on chronic respiratory disease among adults in Amhara ...
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Paper IV: Submitted to BMJ Global Health

BMJ Global Health - Manuscript ID bmjgh-2026-023782

BMJ Global Health

to me, motbainor2, mulukenag ▾

Your manuscript entitled "Utilization of Mask and Associated Factors Among Traditional Charcoal Producers in Amhara Region, Northwest Ethiopia" has been successfully submitted online and is presently being given full consideration for publication in BMJ Global Health.

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