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Effect of Climate Change Associated Hazards on Agricultural Workers and Approaches for Assessing Heat Stress and Its Mitigation Strategies - Review of Some Research Significances

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ABSTRACT

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The effect of climate change is one of the most significant intimidations to mankind after the Covid-19. Due to the nature of agricultural work, i.e., outdoor work environment, climate change has a more severe effect on agricultural workers. Hence the agricultural workers are more exposed and vulnerable to climate change-related hazards and hot environments. Therefore, the study on the impact of climate change associated hazards on the hours' agricultural workers' needs. An extensive literature review has been conducted for systematic segregation and representation of available information towards drawing inferences on climate change associated hazards on agricultural workers, effect of heat stress, and mitigation strategies. We have collected the literature by systematically reviewed available literature from various sources like Scopus, Google Scholar, Embase, CrossRef, Science Direct, and PubMed database and hardcopy of journals. The current review discusses climate change-related hazards like extreme weather events, extreme heat, air pollution, high level of O₃, psychological stress, ultraviolet exposure, vector-borne diseases, and other biological hazards affect tremendously outdoor agricultural workers' health, which leads to low income in the agricultural sector. It also suggests possible future research directions to develop better strategies for preventing the effect of climate change on agricultural workers.

Introduction

Climate change is one of the foremost concerns globally as its effect on human health and livelihood (Detz, 2020). It also strongly influences the ecology, environment, and economics of a country and raises many risks for outdoor workers in occupational hazards (Adam-Poupart *et al.*, 2013; Roelofs and Wegman, 2014; Levy and Patz, 2015;

Applebaum *et al.*, 2016; Schulte *et al.*, 2016; Leavy *et al.*, 2019). In the present situation, climate change is one of the most significant threats to mankind after the Covid-19 (Hunter and Hewson, 2020). Agriculture is a highly important sector where excessive numbers of workers are needed, as lots of human efforts are required to accomplish the agricultural work (FICCI, 2015; Pal and Chattopadhyay, 2020). In the case of agricultural workers,

climate change is a more severe issue than any others, as most of the farming work is generally being done in an outdoor work environment (StaalWästerlund, 2018).

Agricultural farmworkers who are mostly work in an outdoor environment often come across the risk of climate change-related hazards and hot situations (Kiefer *et al.*, 2016). Climate, change-related hazards like extreme weather events, extreme heat, air pollution, high level of O₃, psychological Stress, ultraviolet exposure, vector-borne diseases, Lyme disease, and other biological hazards, are affecting tremendously outdoor agricultural workers' health and productivity (Moda *et al.*, 2019; Kiefer *et al.*, 2014; Shortridge *et al.*, 2018; Padhy *et al.*, 2015; De *et al.*, 2005; Rim *et al.*, 2014; Poupart *et al.*, 2014; Nicholas H. Ogden, 2017; Lucas *et al.*, 2014; Sett *et al.*, 2013; Schulte *et al.*, 2009; Mathee *et al.*, 2010; Sorensen *et al.*, 2018; Cogato *et al.*, 2019). Besides, the heat waves due to climate change affect the precipitation, which causes a negative impact on the agricultural sector (Kumar *et al.*, 2014). Agricultural workers may be particularly vulnerable to climate change threats because they are bound to work in hot environments that induced heat disorders (ILO, 2019; Kovats *et al.*, 2008). Due to occupational heat exposure in a tropical developing country, farmers easily come across heat stress, heat illness, and occupational injury, which may eventually cause death (Xiang *et al.*, 2014; Kjellstrom *et al.*, 2014; Kovats *et al.*, 2018; Hancock *et al.*, 2002). On the other hand, the heat-related disorder in farmers plays a significant role in the accident, fall, and heart attacks (Steve Sutter, 1994). To fulfill the livelihood and overcome the economic problem, many agricultural workers are unable to escape climate change threats (Olsson *et al.*, 2014). Further, climate change influences the farmer's life indirectly by affecting the economic sectors in extremes

precipitation and higher temperature (Kim, 2009; Cogato *et al.*, 2019; Burney *et al.*, 2014). Besides, Sea level rise and flooding due to climate change directly affect coastline fishing communities and farmers (Barange *et al.*, 2018).

From the view of earlier research, we found that climate change influences the ozone layer, which leads to an increase in U.V. radiation intensity in the earth's atmosphere. More prolonged exposure of outdoor farmworkers to more intense and frequent U.V. radiation may increase skin cancer risk, impaired immunity, and eye effect (Moda *et al.*, 2019; Kiefer *et al.*, 2014; Schulte *et al.*, 2009; Flouris *et al.*, 2018). Besides, the rising temperature due to climate change enhances air pollution, which is related to chronic health consequences, like an allergic reaction, respiratory diseases, low productivity, etc. (Moda *et al.*, 2019; Ahmed *et al.*, 2015; Neidell *et al.*, 2017). Apart from, agriculture is already a hated profession where climate change will enhance labor migration from the agricultural trade (Barnett and Webber, 2009). Moreover, outdoor farmworkers are losing their productivity due to climate change and higher workload intensity (Bugajska *et al.*, 2005; Kjellstrom *et al.*, 2016). To mitigate all the effects of climate change on farmers needs proper protection and adaptation strategies.

Because of the lack of appropriate, relevant data, it has been difficult to assess how vulnerable and at-risk the impacts of climate change on agricultural workers. To address these issues, it may be useful to develop a framework for identifying how climate change could affect agricultural workers' health. This article appraises comprehensive reviews of different studies with the objectives to evaluate the consequences of various researches on the effect of climate change-related hazards on agricultural workers, approaches for assessing the impact

of heat stress on agricultural workers' health, and highlighted some of the protection approaches of farming workers to mitigate the effect of climate change.

Materials and Methods

After systematically reviewing the previous published priorities, we filter some selected data and utilize those selected data to achieve our objectives. We take a deep insight from our review to elaborate on the effect of climate change on agricultural workers' health, identify different popular heat stress methods for assessing the impact of heat stress on agricultural workers' health, and recommend adaptation strategies to prevent the effects.

The systematic review of the previous published priorities is executed with the standard Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement (Moher *et al.*, 2009). We have reviewed one hundred forty-two published documents, including full-length papers, books, and websites from 1996 to 2020, to recognize relevant noble reviewed articles. After the revisions of different research priorities with the help of Scopus, Google Scholar, Embase, CrossRef, Science Direct and PubMed database and appropriate international and national agencies websites, a comprehensive perception on the issue was considered in the review that supports to elaborate the impact of climate change on farmworkers, method heat stress assessment and its adaptation measures. Out of 841 identified publications (Figure 1), we were citing 142 selected publications and properly evaluated sixty-nine full-length scientific papers. Further, we used Keywords such as 'climate change,' 'global warming' 'climate change effect' 'climate change hazards,' 'climate change events,' 'heat stress,' 'agricultural workers health in extreme

events,' 'agricultural outdoor workers health,' 'work-related health and safety,' 'agricultural workers productivity' etc. during the searching of relevant previous publication.

Systematic analysis of selected studies

For the Systematic analysis of selected studies, we categorized the reviewed data into six divisions: author name, Objective Study, Study inhabitants, Learning theme, Study Involvement, etc. Table 1 shows a complete summary of a systematic review of 69 full-length scientific publications. Apart from, we review the climate change effect related scientific study of India, Saudi Arabia, Ghana, Germany, Bangladesh, South Africa, China, USA, Pakistan, Australia, Italy, Costa Rica, Ethiopia, etc. countries and finally concentrated on south Asia's developing countries to achieve our objectives.

Results and Discussion

We have systematically reviewed one hundred forty-two publications, including full-length papers, books, and websites from 1996 to 2020, where 16 % publications from 1994 to 2009 and 84 % publications from 2010 to 2020. Out of one hundred forty-two citing publications, we properly evaluate sixty-nine full-length scientific papers where 69 % of analysed documents are associated with climate change effect on typical indoor/outdoor workers and public health and adaptation strategies. Around 20% of analyzed papers are focus on climate change impact on the outdoor men /women agricultural workers, approaches for assessing the effects of heat stress, and prevention strategies. The rest of the analyzed papers are associated with workers related to construction, mining, brick industries, steel industries, etc., on the same topic. Apart from, we review the climate change effect related scientific study of India, Saudi Arabia, Ghana,

Germany, Bangladesh, South Africa, China, USA, Pakistan, Australia, Italy, Costa Rica, Ethiopia, etc. countries and finally concentrated on south Asia's developing countries to achieve our objectives. Further, from the selected suitable papers, we have mainly focused on climate change effect, occupational hazards due to climate change events, agricultural workers health, approaches for assessing the heat stress, productivity, and adaptation.

In the present study review 142 published documents to abstract data for the following objectives that include to evaluate the effect of climate change-related events on agricultural workers. To highlight the approaches for assessing the heat stress on agricultural workers. And also to highlight some of the protection approaches for agricultural workers to mitigate the effect of climate change.

The principle review topic of the analysis papers is to identify the effect of climate change on agricultural workers' health. To address this issue due to limited evidence related to the agricultural sector, we also review some similar topics on common public health effects, assessing the impact of heat stress and decrease productivity due to climate change. In this review paper, we also reviewed the adaptation strategies for the common public and workers. Finally, we highlighted the essential prevention strategies to mitigate the effect of climate change on agricultural workers.

Effect of climate change related hazards on agricultural workers

Increased temperature, changes in precipitation, increased air pollution, more extensive flooding, enhanced drought, heatwaves, the extent of vector-borne disease, and other climate change-related hazards are

significantly influencing the life of agricultural workers, which affect the productivity of workers (Krishnamurthy *et al.*, 2016; Sadiq *et al.*, 2019). The reduction in productivity will further lead to low income (Nilsson *et al.*, 2010; Lundgren *et al.*, 2012; Xiang *et al.*, 2016; Day *et al.*, 2018; Flouris *et al.*, 2018; Kjellstrom *et al.*, 2009). This will affect workers' livelihood and, as a result, migration of labor from the agricultural sector to sector (Staal/Westerlund, 2018; Sadiq *et al.*, 2019; Ahmed *et al.*, 2019; Day *et al.*, 2018; Moda *et al.*, 2019; Michael Safi, 2017). Swaminathan *et al.*, (2016) exposed that Climate change may have subsidized the suicides of around 60,000 Indian agricultural workers and farmers over the past three decades, which is one of the burning evidence of the influence of climatic variation on agricultural workers in a developing country. Further, the adverse effects of climatic variation on job associated safety and health have already been extensively deliberate on the general population rather than agricultural workers. Following the considerable effects of Climate Change, related hazards on agricultural workers are described below.

Extreme heat

Global Climatic variation influences the working and living surroundings and generates health threats for the millions of population (IPPC, 2007; Costello, 2009; Kjellstrom *et al.*, 2009). The first concern of Climatic variation is global warming, which directly hurts the biological, physical, and human system by causing many negative impacts (Sustainability Committee, 2018). The average global temperature is increasing, and it is predicted that temperature may increase from 2.5 to 10 °F at the end next century (IPPC, 2007, Bilbeisi *et al.*, 2017). At extreme levels, heat events become a significant problem for vulnerable agricultural populations as harsh hot environments

increase the risk of work-related heat illness (Flocks *et al.*, 2013). According to the WHO report, from 2000 to 2016, around 125 million people are exposed to heatwaves, and more than 166000 people died from 1998 to 2017 worldwide from extreme heat exposure..If average ambient temperatures increase, more farmworkers will be exposed to heat-induced disorders, as most agricultural workers are bound to work in hot outdoor environments (Moda *et al.*, 2019; ILO, 2019). Applebaum *et al.*, (2016) noted that heat-associated mortality and mobility risks are most apparent in the agricultural sector. Pogačar *et al.*, (2017) are also exposed in their study that agricultural workers come under the highest impact of heat stress in outdoor working conditions.

Apart from pregnant farmworkers, when they are exposed to a hot environment, they usually face additional health risks (Flocks *et al.*, 2013). Stephen L. McQueen (2012) reported that the heat-related mortality rate in agricultural workers is almost twenty times of other industries. Christopher Walljasper (2019) stated that around 20% of heat-related deaths narrated by OSHA are in the agricultural, forestry, and fishing sectors.

Further, the "Body temperature" term generally use to ill define. The human body is divided into two sections, which are well recognized as the "shell" and the "core." The "shell" consists of skin, limbs, hypodermal tissues, etc. and the "core" includes by skull, abdomen, thorax, etc. (Cooper, 1996). Because numerous jobs in the agricultural sector are physically demanding, the body of farmers usually produces significant surplus heat. The human body able to perform work when it transforms food into energy, which also makes heat.In the human body, about 75% of the life in food converted into heat. More power is required to perform more massive work, and hence more heat is

produced.

A lesser portion of the heat is used to maintain the inner body temperature at 37 °C. Still, the most significant part of the heat is dissolute into the surroundings by radiation, convection, conduction, and evaporation in the form of sweat. (Staal Wästerlund,2018; Matthew Stevens, 2016;David J. Sailor, 2011). From a thermal comfort point of view, there is a primary need to maintain core body temperature (CBT) close to 37°C (98.6°F). The subtraction of heat produce by metabolic rate and the mechanical work must be balanced with heat lost by our body in the environment to maintain the CBT as close to 37 °C. A combined group of situations such as a hot environment, high humidity, physical exercise, dehydration, and clothing can disturb the equilibrium. However, factors responsible for heat stress in the human body are characterized into six categories, out of which two personal and four environmental. The personal factors are activity, clothing, etc. and environmental factors are relative air velocity, mean radiant temperature, air temperature, air relative humidity, etc. (Acharya *et al.*, 2018; Gubernot *et al.*, 2013; Morioka *et al.*, 2006; Park *et al.*, 2017, Halawa, *et al.*, 2012). Due to this imbalance, the temperature of our core body becomes more than 37 °C, resulting in heat stress (Kjellstrom and Crowe, 2011; Crowe *et al.*, 2009; Adrian *et al.*, 2008; Meg Jenkins, 2019; Fantozzi and Lamberti, 2019). Furthermore, heat stress causes physiological strain, fatigue, and tiredness among workers in many work-related settings where agricultural work plays a prominent role. Heat stress may lead to mild heat disorder to death (Heat stoke) (Tustin *et al.*, 2018; Hanna *et al.*, 2015). Besides symptoms arise by extreme heat and autonomic dissipation mechanisms of our body are generally characterized as heat cramp, heat rash, heat syncope, heat exhaustion, heatstroke, etc. (Jackson and

Rosenberg, 2010; Kjellstrom *et al.*, 2014; Kilbourne *et al.*, 1997; Wilson *et al.*, 2012; Kovats *et al.*, 2007). Apart from the mention of heat illness, some others direct and indirect effect of extreme heat are chronic kidney disease, enhance work injury, accident risk, increase chronic mental disorder, reduction in physical activity capacity, reduce productivity can be observed in agricultural workers, which are illustrated in Figure 2 (Varghese *et al.*, 2018; Kiefer *et al.*, 2016; Xiang *et al.*, 2014; Messeri *et al.*, 2019; Huang *et al.*, 2011; Hancock *et al.*, 2003; Sheng *et al.*, 2018). Moreover, high ambient temperature because of climate change may also increase work-related exposure to hazardous chemicals and harms agricultural workers (Balbus *et al.*, 2013; Boxall *et al.*, 2009).

Extreme weather events

Climatic variation, global climate change, and a higher frequency of extreme weather events lead to a considerable increase in agricultural risk and decrease farm income. Extreme weather events influence the life of farmworkers and cause an impact on agrarian policymakers (Gobin *et al.*, 2013). On the other hand, extreme weather event causes a tremendous effect on crop yield, which indirectly affect the farmer's income (Powell *et al.*, 2016; Kumar *et al.*, 2014). Levy and Roelofs (2019) mention in their report that many workers, including agricultural workers, are at high risk of work-related hazards from extreme weather events. Extreme weather events such as cyclone, landslides, floods, thunderstorm, lightning strikes, droughts, heat, and cold waves, and wildfires are causes harmful effect on agricultural workers (Handmer *et al.*, 2012; Conforti *et al.*, 2018; Levy and Roelofs, 2019; Schulte *et al.*, 2016; Applebaum *et al.*, 2016; Bouzid *et al.*, 2013; Schulte *et al.*, 2009; Ylipaa *et al.*, 2019; De *et al.*, 2005).

Thrilling climate events extend a diverse safety and health risks such as hit by flying substances, falls and injuries from slips, vector bone disease, inadequate sleep, and nourishment because of long and continuous work shifts, mental Stress, and physical tiredness (WHO, 2018; Kiefer *et al.*, 2016; Levy and Roelofs, 2019). Mahapatra *et al.*, (2018) reported that around five individuals per million died due to exposure to extreme events, which is approximately 25% of all coincidental death due to natural causes. Prolonged drought and other climate-associate calamities may destroy the economic and social foundation on which agricultural populations are related (Berry *et al.*, 2011). Schulte *et al.*, (2016) noted that extreme weather events force workers to extend work hours and persist at the workplace until substitutes arrive, enhancing mental exhaustion that raises accidental risk. Swaminathan and Rengalakshmi (2016) stated that extreme weather events appear as a prospective hazard to farmer's livelihoods and food security in the circumstance of climate change.

Air pollution

There are many links between climate change and air quality. A hot climatic condition leads to severe air pollution, particularly with ground-level ozone and delicate particulate matter (FPM) (Fiore *et al.*, 2015; EPA, 2020; Ebi and McGregor, 2008).

Climate change also influences air quality by changing rainfall patterns, air composition, atmospheric interaction, anthropogenic and natural sources, which are responsible for air pollution (Fann *et al.*, 2016; Fiore *et al.*, 2015).

Table.1 Systematic analysis of scientific papers for review (Adopted and revised from Moda *et al.*, s2019)

Sl. No.	Author and Year	ObjectiveStudy	Study Inhabitants	Learning Theme	Study Involvement	Outcome Data and Study Measure
1	Schulte <i>et al.</i> , (2016)	Improvement of an outline to the recognition of climatic variation effect on workers and work-related safety and health	Mutual worker	Extreme weather events, work-related safety and health, risk assessment and management	Determination of interactions among work hazards, climate, and other influences, assessment of risk by the hazard of climate change	The practice of lookout effects and foremost pointers to support the investigation of climate associated occupational effects and theoretical outline established to avoiding hostile effects of climate change by risk assessment
2	Applebaum <i>et al.</i> , (2016)	Overview of climate change-related work-related exposures and its recommendation	Common workers	Climate change, Work-related risks, Heat, Polycyclic scented hydrocarbons, Ozone, Pathogenic microbes, Vector-borne diseases, and Violence	Assessment of most vulnerable occupational sectors due to climate change effects and define study required to defend workers from the projected health intimidations from climate alteration	Suggestions for forestalling about most susceptible workers due to climate change and demonstrating situations concentrating on work-related impacts of extreme climate events and its extenuation.
3	Crowe <i>et al.</i> , (2009)	An experimental, qualitative field assessment on occupational heat stress in sugarcane workforces	Sugarcane workers of Costa Rica	Climate alteration, Costa Rica, heat contact, heat stress, and sugarcane workers	Plan to improve the health and safety of sugarcane workers from heat influences	Improve understanding of various factors that help to increase sugarcane workers health and safety
4	Deressa <i>et al.</i> , (2010)	Identify the farmer's awareness of Climate Change and Prevention to mitigate climate change	Farmers of Ethiopia	Climate Change, Farmer, Nile basin of Ethiopia, Perception of Climate Alteration and Adaptation	Identify and mitigation of the effect of climate alteration on agriculturalists	Define how agriculturalists can minimize the harmful effect of climate change
5	Fang <i>et al.</i> , (2013)	Relationship between climate alteration and air chemistry affects atmospheric configuration and human death related to increasing air pollution by industry.	population	Climate change, Methane concentration, Fine particulate matter and ozone, Air pollution, Human mortality	Identify how increasing delicate particle matter, ozone, methane responsible for human mortality	Explain the relation between climacteric variation and air pollution, its impact on air quality and health of the population, and the measure to air pollution control policy by methane mitigation.
6	Sherwood <i>et al.</i> , (2010)	Find the Survivability limit of the general population in heat stress for climate change	General population	Paleoclimate, Climate change, Global Warming, Climate impact, WBGT, Human Physiology	Define human adaptableness limit to mitigate the effect of climate alteration	Identify heat stress, and it used to clarify trends in the human fossil record
7	Varghese <i>et al.</i> , (2018)	Observe the association between heat contract and occupational injuries	Common workers	Climate alteration Increasing Temperature, Heat exposure, heat stress, and Occupational hurts	Heat exposure and Occupational injuries	Deliver suitable proposal for policy and research direction to reduce occupational injuries
8	Jackson <i>et al.</i> , (2010)	Reduction of heat-related illness of agricultural workers by proper prevention measures	Agricultural workers	Agricultural workers, Occupational heat stress, heat-related illness, hyperthermia, acclimatization and Prevention	Heat-related illness and prevention measure	Help to understand the heat-related illness of farmers and promote proper Prevention
9	Acharya <i>et al.</i> , (2018)	Assessing the harshness of heat stress that influence the construction workers and efforts in applying preventive measures.	building workers	Climate alternation, elevated temperature, construction workers, heat stress, heat-related illness, and Prevention measure.	Heath of construction workers in changing climate	Identify the risk factor of heat stress in construction works and its preventive measure

Continuation of Table 1						
Sl. No.	Author and Year	Objective Study	Study Inhabitants	Learning Theme	Study Involvement	Outcome Data and Study Measure
10	Al-Bouwarthan <i>et al.</i> , (2019)	Measure heat stress among construction workers with the help of WBGT and define the work factor associated with heat stress and parameter for managing heat stress.	construction worker	Excessive heat, construction workers, heat exposure, intensity and duration of heat stress, WBGT, and protective measures	Measurement of heat stress of construction workers with the help of the WBGT index and define protective measures	Identify the severity of heat stress and its influence on construction workers and improve work-related heat stress experience strategies in S.A.
11	Moda <i>et al.</i> , (2019)	Evaluation of the primary and secondary consequence of extreme heat and its safety measure for outdoor workers	Outdoor worker	Climate change, high temperature, outdoor workers, direct and indirect impact, prevention measure	Heat stress on outdoor workers and its prevention strategies	Reveal the urgent need for research on health and financial influences of climate change in the developing country and define safety measure of outdoor workers against extreme heat
12	Srinivasan <i>et al.</i> ,(2016)	Describe the Sign of work-related heat stress and its health effects	General work Population of India	Work-related heat stress, India, Core body temperature, health impact, and Prevention measure	Contests and Prevention measure of job-related heat anxiety	Suggest the Prevention measure to mitigating the effects of too much heat on workforces health
13	Kjellstrom <i>et al.</i> , (2009)	Measure the possible consequence of heat for climate variation on workers' health and productivity.	the population of middle and low-income country	Global climatic variation, temperature elevation, heat exposure, WBGT, core body temperature, and work capacity	A consequence of job associated hotness anxiety on workers' physical health and output	Highlight the relationship between working capacity and WBGT and the negative effect of climate change on worker productivity and heat-related social and economic development measures.
14	Xiang <i>et al.</i> , (2016)	To examine workers' observations and communicative replies to extreme heat contract and recognize individuals' warmness observations factors	South Australian typical workers	Occupational heat exposure, heat stress, heat illness, Occupational injuries, observations, risk awareness, and prevention strategies.	Inspect workers' response and perception in extreme heat.	Highlighted the needs to strengthen workers' by proper training in extreme heat, improve prevention strategies, and promotion of educational training
15	Flouris <i>et al.</i> , (2018)	Assessment of heat strain effect on workers productivity and health	Common workers	Work-related heat strain, workers' health, productivity, PRISMA guidelines, statistical models, and heat stress mitigation.	A consequence of heat anxiety on workers' healthiness and output	Exposed heat stress affected workers' health and work productivity, Suggest the need for international action to mitigate climate change.
16	Kiefer <i>et al.</i> , (2016)	Recapitulates and deliberates the effect of climatic variation on American workforces healthiness and wellbeing	American workers	Climate change, work-related heat exposure, work-related hazards, America's worker, heat illness, workers health, and safety	Effect of climate change on workers health	Provides strong evidence of the effect of climate change on workers and prevention strategies
17	Orru <i>et al.</i> , (2017)	Assessment of current indication on the consequence of climaticvariation on air contamination and its health outcome	General Population	Climatic variation, air pollution, particulate matter, ozone, emission, Spreading, and health impact	Air pollution and Climatic variation effect on population wellbeing	Discovers the associations among climate alteration, air contamination, and air contamination associated with health effects and predicts the future air pollution emission.

Continuation of Table 1						
Sl. No.	Author and Year	ObjectiveStudy	Study Inhabitants	Learning Theme	Study Involvement	Outcome Data and Study Measure
18	Xiang <i>et al.</i> , (2014)	Inspect the effect of heat waves on worker's safety and health, injuries and illnesses from heat waves	South Australian workers'	Climate change, heatwave, South Australian workers', work-related health, injuries, adaptation and Prevention	Effect of heatwaves on worker's health and safety	Identify the occupational illness associated with heatwaves and provides a measure for adaptation and Prevention from heatwaves
19	Laaidi <i>et al.</i> , (2011)	Evaluation of research gap associated with work-related heat and research need to overcome assessment heat disorders	Common U.S. worker	Climate change, U.S. worker, heat exposure, occupational heat, heat illness, adaptation, and Prevention	Epidemiology of work-related heat contact and prevention strategies	Identify the research gap on work-related heat exposure and Making policy for Prevention from work-related heat
20	Gubernot <i>et al.</i> , (2013)	Review of high-temperature illness for job-related heat contact and prevention approaches	population of U.S.	The United States, climate change, heat exposure, workplace hazard, risk, heat-related illness and death, adaptation and Prevention strategies	Health hazardfor work-related heat contact and its prevention policy	Highlight the risk factors due to heat exposure and suggest adaptation strategies
21	Kjellstrom <i>et al.</i> , (2013)	To observe the physiological indication due to heat effect, climate strategies for suitable work environments, and evaluate the influence of future climacteric scenarios on workers' productivity.	Regional labor	Global climate change, heat load, indoor and outdoor worker, heat effect on health, climate modeling, and labor productivity	the straight impression of climatic variation on regional workers output	Evaluate the loss of working capacity and measure the need for Prevention from heat exposure
22	Singh <i>et al.</i> , (2018)	Identify different research on heat stress of farmers and preventing measure	Farmers	Farmers, hot weather, heat stress, WBGT, core body temperature, heart rate, B.P., and Prevention measure	Effect of heat stress on farmer and Prevention measure	Evaluation of heat stress by WBGT index and its effect on farmers body and discuss the significant measure to minimize heat stress
23	Nunfam <i>et al.</i> , (2018)	Evaluation of Consciousness and identify Community impressions of job-related heat anxiety, and suitable prevention measure	Common workers	Climate alteration, work-related heat anxiety, healthiness, safety, andprevention	Communal influences of work-related heat anxiety and suitable prevention policy	Describe the awareness of labors in work-related heat stress, the communal effect of heat anxiety, and prevention measure of heat stress
24	Fisk (2018)	Review the probable health concerns in indoor climate due to climate change	Indoor residential people	Indoor residential environment, climatic variation, inside air freshness, and health	Effect of climaticvariation on inside residential setting and human health	Identify health problem in indoor climate due to climate change and provides a protective measure of indoor temperature for human health
25	Rasanen <i>et al.</i> , (2016)	Review of climate change literature to examine how multiple stressors of climate change or non -climate change affect human vulnerability	General Population	Review, climate change, multiple stressors, risk and human vulnerability, adaptation, and analytical framework	Multiple interacting stressors of climate change or non-climate change and adaptation policy	Measure the social context of Susceptibility within literature associated with climate change and suggest future analytical frameworks of dissimilarities between different types of stressors and adaptation policy

Continuation of Table 1						
Sl. No.	Author and Year	ObjectiveStudy	Study Inhabitants	Learning Theme	Study Involvement	Outcome Data and Study Measure
26	Krishnamurthy <i>et al.</i> , (2016)	A consequence of job-related heat anxiety on steel industry workers healthiness and output due to ambient temperature	Work population of the steel industry	The steel industry, ambient temperature, WBGT, dehydration, heat-related illness, productivity loss, and Prevention policy	Assessment of productivity loss due to heat stress in the steel industry and Prevention policy	Productivity loss of workers in steel industries due to occupational heat exposure and suggest suitable protective policies
27	Yazd <i>et al.</i> , (2019)	Review of literature of risk factor associated with farmer's mental health	Farmers	A systematic review, PRISMA guidelines, Farmers' mental health, mental disorder, farming stress, and mitigation policy	Mental stress factor of farmers	Describe farmers mental health risk factory, reduction strategy, and further research
28	Cianconi <i>et al.</i> , (2020)	Review of the consequence of climate on the mental fitness of people	Common population	A systematic review, climate change, mental health, mental disorder, psychological adaptations	Relationship between climate change and mental health	Identify major mental disorder due to climate change and psychological adaptations
29	Balbus <i>et al.</i> , (2012)	Connotation among climate change, chemical blowout, and probable hazard to health	General Population	Worldwide climate change, pollutants, chemical spread, Risk valuation, and Susceptibility	Effect of worldwide climate change to change the degree of human exposure to chemical and probable health effect	Determination of better facts to define human contact to the chemical atmosphere relatedto climaticvariation
30	Sadiq <i>et al.</i> , (2019)	Evolution of climatic variation effect on maize farmer's fitness and output	Maize Farmer	Heat stress, maize farmers health, WBGT, heat stress disorders, and Productivity	Evaluation of heat stress disorder and productivity of maize farmers	Highlight the heat stress disorder and predict productivity loss of maize farmers
31	Sadiq <i>et al.</i> , (2019)	Evaluation of the farming community to identify the change of the vulnerability index of farmers	Farmer	Climate change, weather-related hazards farmers, physiological impact, vulnerability, and adaptation strategies	Effect of climate change on the vulnerability of farmers	Vulnerable factors of farmers from climate change and suggest adaptation strategies
32	Kiefer <i>et al.</i> , (2017)	Assessment of workers healthiness and hazard from the climatic variation	Common worker of America	Impact of climate change, heat exposure, work-related risk, American workers health, illness, occupational safety, and health,	Assessment hazards, surveillance, and risk arising from climate change	Highlight the hazard and risk arose from climate change in American workers and research requirement
33	Morioka <i>et al.</i> , (2006)	Evaluation of hot atmosphere ata building site in hot season and its effects on the health of workers.	Workers at Construction Site	Hot surroundings, Construction site, outdoor work condition, health hazard, Prevention Measures and control	Measurement of serum osmotic pressure and other health-associated effects such as blood chemical data (blood sugar, blood urea nitrogen, etc.)	Precautionary heat anxietymethods,for example, passable aeration, edible water, drinks containing salt, break, health education and training

Continuation of Table 1						
Sl. No.	Author and Year	Objective Study	Study Inhabitants	Learning Theme	Study Involvement	Outcome Data and Study Measure
34	Messeri <i>et al.</i> , (2019)	Evaluation of the consequence of warmness anxiety on agricultural and construction sector workers and describe local and migrant workers' awareness and management.	Native and migrant worker	Climate challenges, the native and migrant worker, construction and agricultural sector, heatwave, WBGT, occupational hazard, and productivity	Observation of heat risk in a workplace among native and migrant workers of the agricultural and construction sector	Identify behavior differences on heat stress awareness and prevention strategies to the mitigation of heat stress
35	Xiang <i>et al.</i> , (2013)	Review of the consequence characteristics of job-related heat exposure on workers fitness and mitigation strategy	Workers from different sector	Extreme heat, climatic variation, job-related heat contact, risk, heart disorder, and prevention strategies	Characteristics of workers health in extreme heat and adaptation policy	Deliberate occupational risk due to work-related heat exposure of different sector workers and suggest future research needs
36	Flocks <i>et al.</i> , (2014)	Measure risk factors, work practices, and awareness of heat-related illness of female farmworkers in hot environments	Female farmworkers	Female farmworkers, extreme heat, heat-related illness, awareness, and pregnancy health	Heat effect on the health of pregnant female workers and their Consciousness	Expose heat-related fitness of female pregnant women and suggest protection and prevention strategies
37	Thomas <i>et al.</i> , (2014)	Greater insight into the consequence of climatic variation on human health	Common population	Anthropogenic climate change, health-related impact, health, mitigation, and happiness	Understanding of the health-related effect of climate change with Greater insight	Suggest mitigation strategies of climate change effect on health and future adaptation policies
38	Lucas <i>et al.</i> , (2014)	Evaluation of current and future risk in work-related heat exposure with ergonomic intervention	Common workers	work-related heat exposure, heat stress, ergonomics, and work-related injury	Controlling of heat strain and Mitigation of heat illness	Compulsory protection need to mitigate the effect of extreme heat exposure and make sure clothing possessions and knowledge of thermoregulation and proper management
39	Sett <i>et al.</i> , (2018)	Assessment of the impact of heat on work-related heat exposure female brick workers and their productivity	Female brick worker of India (West Bengal)	Female brick workers, extreme heat, cardiac strain, WBGT, productivity, and cropping strategy	Heat stress on female brick workers, their productivity, and cropping strategy	Productivity loss with temperature and provides some adaptation strategies such as regular fluid intake, slow working, rearranging of the work-rest cycle, and inspire ergonomic involvements
40	Lundgren <i>et al.</i> , (2012)	Evaluation of heat anxiety influences on workers for climatic variation	Work population of Developing countries	Changing climate, heat stress, developing country, working population, and work-related heat strain	Evaluation of consequence of climatic variation on vulnerable groups of people and workers in developing countries	Heat stress intensifies in workers due to hard physical work, urban heat island effect, person to person variation and suggests prevention measure to mitigate heat stress
41	Akinnagbe <i>et al.</i> , (2014)	Reviews of adaptation strategies in the sector of agriculture against the effect of climate change	Agricultural sector	Climate change, effect, risks, agricultural sector, farmers and adaptation strategies	Climate change effect on the agricultural sector and adaptation strategies	Highlight common agricultural adaptation strategies and suggested steps to strengthening human capital

Continuation of Table 1						
Sl. No.	Author and Year	ObjectiveStudy	Study Inhabitants	Learning Theme	Study Involvement	Outcome Data and Study Measure
42	Gobin <i>et al.</i> , (2014)	Evaluation and management of weather-related hazards in agriculture.	Farmers	Weather, hazards, agriculture, risk, farm income, farm management, risk, and policymakers	Influences weather-related hazards in agriculture	Analysis of weather-related hazards helpful for farm management and policymakers
43	Ford <i>et al.</i> , (2011)	Climate change adaptation review related to the developing country	Ordinary people of developing country	Literature review, developing nation, climate change impact, climate change adaptation	Identification and characterization of climate change adaptation	Highlight adaptation strategies and monitoring improvement in a developing country
44	Heidari <i>et al.</i> , (2015)	Assessment of heat stress of farmers with the help of WBGT index	Farmers	Farmer, heat stress, environmental and biological monitoring WBGT index and correlation coefficient	Heat stress measurement by environmental and biological monitoring system	Measure hot and humid environment using the WBGT index, and it can be associated with an overestimation and encountered our judgment about the environmental condition with a significant error
45	Park <i>et al.</i> , (2017)	Assessment of the effect of heat on heat illness of outdoor workers and evaluate the impact of personal factor to reduce heat stress	Outdoor worker	Extreme heat, heat stress, heat illness, WBGT, environmental factors, personal factors, and acclimation	Influences of environmental and personal factors on heat illness of outdoor workers	Individual risk factors such as environmental factors as well as heat acclimation and high metabolic rate throughout work are the chief causes of heart associated illnesses.
46	McQueen <i>et al.</i> , (2012)	Assessment of heat stress of migrant farmworkers	Farmworker	Heat stress, environmental body temperature, heart rates, bodyweight loss, adaptation, acclimation, and hydration	Evaluation of body warmth pressure parameters and adaptation strategies	Propose the necessity for farmworker safety training regarding hydration and acclimation
47	Nichols <i>et al.</i> , (2009)	A systematic evaluation of the consequence of climatic variation on health and sustainable adaptation strategies	Common population	A systematic review, Climate change, impact, health, and protection approaches	A consequence of climatic variation on public health and its mitigation strategies	Report about climate change impact on health and highlight action taken to mitigate the impact
48	Bouزيد <i>et al.</i> , (2013)	Evaluation of the usefulness of public health involvements to reduce a load of high significance climate-sensitive illnesses.	Common population	Climate change, public health, warmer world, climate-sensitive illnesses, adaptation, and future research	Review of climate-sensitive diseases and usefulness of public health involvements to reduce the illness	Determine the effectiveness of public health involvements to reduce climate-sensitive illnesses and suggest future research
49	Gao <i>et al.</i> , (2017)	A consequence of job-related heat anxiety on workforces due to climate change and prevention strategies	Common working population	Climate change, global warming, heat risk, meteorological data, thermal climate factors, WBGT, and Prevention strategies	Review of several designated heat-related guides, analyse their merit and demerit in relative to climatological data	Measure body, Discomfort Index, Predicted Heat Strain index, heat production, WBGT, etc. and suggest prevention strategies

Continuation of Table 1						
Sl. No.	Author and Year	ObjectiveStudy	Study Inhabitants	Learning Theme	Study Involvement	Outcome Data and Study Measure
50	Kjellstrom <i>et al.</i> , (2017)	Evaluation of health risk due to climate change and prevention policies in the S.E. of Asia	People of South-East Asia	Risk of work-related health and productivity due to climate change in southeast Asia regions	Mitigation of greenhouse gas production and other prevention strategies	Gives effective adaptation strategies to crop up climate change effect and highlight national-level reports on climate change effect
51	Ahmed <i>et al.</i> , (2019)	Effect of climatic variation in the form of environmental stressors on the livelihood of people	People of Bangladesh	Climate change, environmental stressor, Bangladesh, livelihood, insufficient adaptation strategies, and illegal livelihoods	Loss of livelihoods due to climate change and its effect	Describe the raising of Illegal livelihoods due to climate change and steps to stop it
52	Mathee <i>et al.</i> , (2010)	Evaluation of awareness of outdoor workers in the hot working environment and the consequence of job-related heat on' health and output of workers	Outdoor worker	Climate change, hot working environment, the health of the outdoor worker, and work output	Evaluation of perception ability of outdoor workers and protective measure to cope with warm weather	Lower perception ability of outdoor workers in a hot environment and loss in productivity and suggest proper crop up measure
53	Louis <i>et al.</i> , (2008)	Review of global climate change effect on health and its significant implication	Common Populations	Climate Change, greenhouse gas, global health, mitigation and adaptation	Mitigation and adaptation of climate change effect on health	Suggest awareness, strengthening, mitigation, and adaptation policy reduce climate change effect
54	Sorensen <i>et al.</i> , (2018)	A consequence of climate change on women health and the need for appropriate education policy frameworks	Women populations	Climate change, women health, reduction, framework, and adaptation policy	Policies to mitigate gender-associated partiality in the application of climatic variation modification plans	Identify Women health and their economic growth plays an essential role in the policy of climate change and empowering of women to improve mitigation and adaptation policy
55	Lendrum <i>et al.</i> , (2015)	Review of vector-borne diseases due to climate change and plan associated creativities of WHO and its partner	Common populations	Vector-borne disease, climate change, global public health, WHO and its partner, health, policy, and research	Adaptation for vector-borne diseases and suitable initiatives by the WHO and its partner	Expose a future project, adaptation strategies, and suitable initiatives about Vector-borne disease by WHO and its partner
56	Hanna <i>et al.</i> , (2015)	Evaluate the risk of climatic variation, rising heat, etc. and assessment of national work-related health and safety strategy	Common working population	Climatic variation, risky heat events, heat contact, worker health, and adaptation	Assessment of health risks associated with heat contact and mitigation policy	A consequence of thrilling heat on occupational healthiness, and protection and mitigation guidelines
57	Schulte <i>et al.</i> , (2009)	Development of a primary outline for identifying the influences of climatic variation on worker fitness and security	Common population	Global climate change, heat stress, category of occupational hazard and health	The framework of work-related heat hazard due to global climate change	Given information about a different category of climate change-related hazards

Continuation of Table 1						
Sl. No.	Author and Year	Objective Study	Study Inhabitants	Learning Theme	Study Involvement	Outcome Data and Study Measure
58	Nunfam <i>et al.</i> , (2018)	Observation of heat effect due to climatic alteration, job associated heat anxiety, and protection policies among mining workers	Mining workers	Climate change awareness and hazard due to job associated warmness pressure and mitigation approaches	Perspectives about the application of job associated heat anxiety reduction of the mining workforce	The function of workers education and preparedness to mitigate work-related heat stress associated with climate change and suggest alertness and preparation advisory on heat stress to minimizing occupational heat among mining workers
59	Chersich <i>et al.</i> , (2019)	Evaluation of climatic alteration protection policy, assessment of awareness intensities and prevention steps for extreme climate events	Health sector population of South Africa	South Africa, thrilling weather, health, Prevention for climatic alteration, and fitnessplan	Protection policy and prevention steps for risky climate events	Develop Climate change mitigation and adaptation policy, and awareness of extreme heat events,improve and strengthening health sector profession and management
60	Ylipää <i>et al.</i> , (2019)	Evaluation of climate change effects and weaknesses of workers with adaptation and gender disparity.	Agricultural worker	Vietnam, climate change, gender inequality, agricultural workers, sustainability, and adaptation	The requirement of policy to mitigating the influences of climatic variation and gender inequality	Develop a policy for gender equality,gender-based climate change adaptation, and supportable development
61	Pogačar <i>et al.</i> , (2017)	Understanding of climatic variation, job associated heat anxiety effect on farmers and agricultural advisers.	Farmers and agricultural advisers.	Climate change, heatwave, heat stress, agricultural advisers, farmers, health, heat-related illness, productivity, and mitigation	Responses of farmers and agricultural advisers under occupational heat stress	Evaluate the negative effect of occupational heat stress is determined by survey and suggest mitigation strategies
62	Swaminathan <i>et al.</i> , (2016)	A consequence of thrilling weather events for climatic alteration on Indian agriculture and its adaptation strategies	South Australian workers'	Climate change, extreme weather event, crop yield, agricultural productivity, farmers livelihood, and adaptation strategies	Effect of climate change on crop yield and farmers livelihood	How extreme weather event affect crop yield and farmers livelihood and suggest field-level operational strategies and simple few adaptation strategies reduce the effect
63	Day <i>et al.</i> , (2018)	Evaluation of the influence of climacteric variation on workers productivity and maintenance of workers productivity under climate change with proper adaptation	Common workers	climacteric variation, heat anxiety, labor productivity, and mitigation policies	Influence of heat on workers'output and required adequate protection strategies	Productivity loss of workers causes crucial economic impacts on nations and suggest effective adaptation
64	Balanagarajan <i>et al.</i> , (2018)	Effect of negative consequence climacteric variation on employee's health and output	Employee' of different sector	Human health, climate change, global warming, employee productivity, and awareness	climacteric variation effect on employees healthiness and output	Climate change causes a reduction in employees' productivity and how employees' knowledge and awareness and knowledge about the climatic changes help them adapt themselves and become more productive.
65	Moda and Alshahrani (2018)	Assessment of the effect of elevated temperature and extreme heat on the safety and comfort of outdoor workers	Outdoor worker of Jizan	Elevated temperature, extreme heat, outdoor workers, heat exposure, adaptation strategy	Evaluation of awareness of outdoor workers working in hot weather and adaptation strategies for their health	Extreme heat increase occupational injuries and heat illness and reduce the working capacity of outdoor workers

Continuation of Table 1						
Sl. No.	Author and Year	Objective Study	Study Inhabitants	Learning Theme	Study Involvement	Outcome Data and Study Measure
66	Varghese <i>et al.</i> , (2018)	Evaluation of the effect of ambient temperature on the hazard of occupational injury and illness	Common worker	Ambient temperature, heat exposure, occupational injury and illness, health and safety	Effect of heat on workers due to heat exposure and causes of occupational injuries	The requirement of increasing Consciousness of work-related injury and the financial benefits associated with the reduction of v prevention injury and productivity loss and examine the worker's risk of work-related heat exposure and specific injuries
67	Shenga <i>et al.</i> , (2018)	Evaluation of the association of extreme hotness and Job-related injury	Guangzhou working population	Climate change, hot weather, extreme heat exposure, work injury, and occupational health	Evaluate injury associate with work due to hot weather exposure	Define the consequence of Climatic variation effecton employees and adaptation policy
68	Cora Roelofs (2019)	Climatic variation hazard on workers' health and safety	common workers	Climatic variation, hot environment, hot condition, heat risk, heat illness, and risk reduction measure	Climatic variation influences labors and risk reduction strategies	Highlights different Climate change influences on workers and suggest risk-reduction approaches
69	Nicholas H. Ogden (2017)	Review of the probable impression of Climatic variation on vector-borne illnesses	Common population	Climate alteration, the influence of Climatic variation, public health, vector-borne disease	Risk of vector-borne diseases on public health due to climate change	Highlight the evidence of vector-borne conditions on public health due to climate change

Fig.1

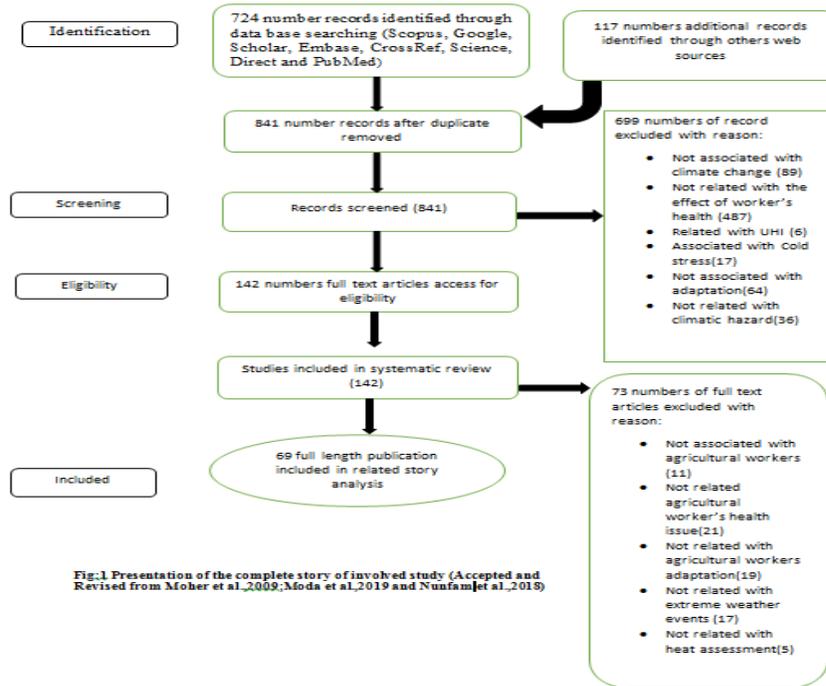
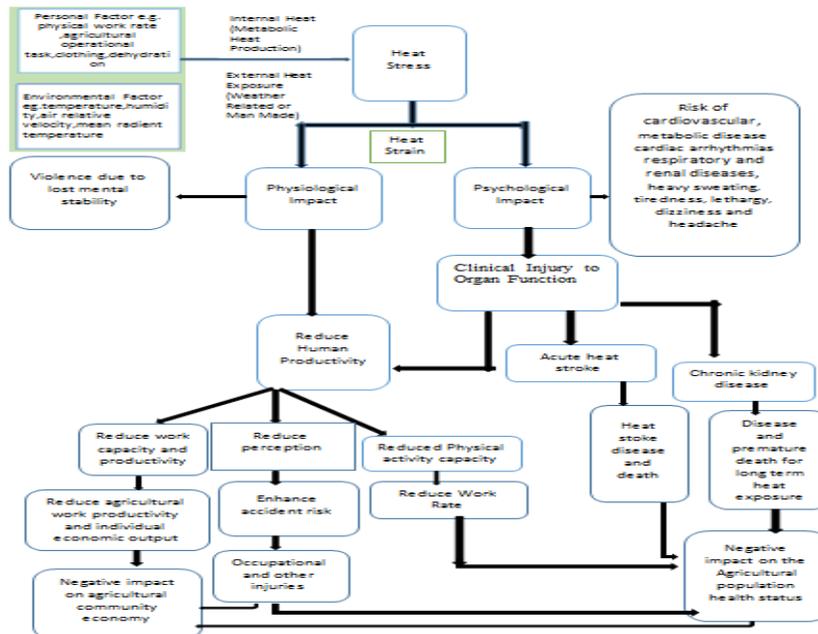


Fig.2 Representation of direct heat effect on agricultural workers with relative factors (Idea taken and improved from Varghese *et al.*, 2018; Raouf, 2012; Makinen and Hassi, 2009; Kjellstrom *et al.*, 2016)



Air pollution considerably affects workers' health; about seven million per year mortality occurs due to air pollution (Orru *et al.*, 2017). Wildfires and droughts both play essential roles in air pollution. The continuously increasing pollen production and lengthier pollen periods are producing more allergic disorders among agricultural workers. Outdoor agricultural workers are commonly impacted by air pollution as they work in an open environment (Levy and Roelofs, 2019). The productivity of outdoor workers is directly related to air quality. With improving air quality, the productivity of workers also improves and vice versa. Earlier research shows that generally increases ground-level ozone and FPM (PM2.5) led to significant decreases in outdoor agricultural workers (Matthew Neidell, 2017). Besides, Arslan and Aybek, (2012) stated that in dry conditions or drought conditions, agricultural practices such as plowing, harrowing, transplanting, harvesting, threshing, etc., producing a significant amount of dust. This particular matter in the form of dust directly affects the respiratory system of outdoor farmworkers.

Kirkhorn *et al.*, (2000) found that considerable numbers of agricultural workers are associated with clinical symptoms with long-term exposure to organic dust due to working in draught and dry weather conditions. Due to dry and hot weather in the agriculture sector, organic dust and toxic gases make it the riskiest occupation. Further, farmworkers are much more influence by air contamination than other workers (Schulte *et al.*, 2016). The common diseases of farmers due to enduring expose to dusty condition are organic dust toxic syndrome, allergic disorders, central nervous system dysfunctions, asthma, lung cancer, mucous membrane inflammation syndrome, cardiovascular illness, hypersensitivity pneumonitis, cutaneous diseases, chronic bronchitis, etc. (Manisalidis *et al.*, 2020; Kirkhorn *et al.*, 2000; Schulte *et al.*, 2016;

Kiefer *et al.*, 2016; William J. Fisk., 2014).

Fang *et al.*, 2013 reported that around 85 % and 95 % of mortalities for air pollution due to O₃ and PM2.5, respectively. They also found that cumulative CH₄ concentrations and climate change are also responsible for around 15 % and 5 %, respectively, of premature mortality. Apart from air pollution causes a direct effect on crop yield, which influences the farmer's economy (S. Ahmed, 2015; Burney *et al.*, 2013).

Vector-borne diseases and additional biological hazards

Apart from the straight impact produced by thrilling heat contact, other indirect health hazards related to climatic variation among agricultural workers are contacts to harmful chemicals and other vector-borne diseases (Moda *et al.*, 2019). Due to the variety of occupations, we found limited literature on specific biological hazards and an agricultural worker's vector bone disease. Climate change plays a considerable role in spreading vector bone diseases .Climate change effects such as temperature, flood, etc., help grow vectors by providing suitable environmental support for a vector growth cycle, waterborne and food-borne pathogens development.

Żukiewicz-Sobczak *et al.*, (2013) explore in their study that for limited health care, unhealthy working conditions, and lack of proper health education, agricultural workers' health status is generally inferior to other workers. Due to the work characteristic of agricultural workers, they commonly come across natural hazards and Vector-borne diseases from different microorganisms and biological agent (bacteria, fungi, viruses, parasites, poisonous plants, venomous insects and reptiles, non-vector-borne pathogens, and toxic plants) (Żukiewicz-Sobczak *et al.*, 2013; Rim *et al.*, 2013).

Further, climate change causes various disease vectors such as mosquitoes, ticks, rodents, fleas, etc., which are spread the vector bone disease such as dengue, West Nile, malaria, chikungunya, Lyme illness, diarrheal, allergic disease. (Levy and Roelofs, 2019; Moore *et al.*, 2017; Kiefer *et al.*, 2016; Schulte *et al.*, 2016; Nicholas H. Ogden, 2017; Lendrum *et al.*, 2015). More pesticides are required to control these disease vectors, which increase the chances of pesticide contract to agricultural workers (Boxall *et al.*, 2010; Gatto, Cabella, and Gherardi, 2016; Levy and Roelofs, 2019). Apart from this, aquatic diarrheal illness is also related to climate inconsistency, which may influence the workers in occupations such as agriculture and fishing (Schulte *et al.*, 2016; Nichols *et al.*, 2009). Ostfeld *et al.*, (2015) and Schulte *et al.*, (2016) reported that workers working in an open environment have up to a five times advanced threat for Lyme illness than typical indoor employees.

Some of the allergic diseases spared by airborne allergens such as plant pollen, mold, fungal spores, etc., are climate-sensitive (Schulte *et al.*, 2016; Kiefer *et al.*, 2016). Besides all the vectorborne diseases, temperatures, and CO₂ also raise the growth of toxic ivy and other poisonous plants, which may influence farmers' health (Kiefer *et al.*, 2016).

Ultraviolet radiation

Climate change plays a vital role indirectly in ultraviolet radiation by influencing the atmospheric percentage of ozone, aerosols, clouds, and ultraviolet-absorbing gases (Bais *et al.*, 2015; Schulte *et al.*, 2016). U.V. radiations are easily absorbed in the human skin and cause adverse health impacts, especially in the eye and skin. Previous research is exposed that compared to longer U.V. waves, the shorter wavelength of U.V.

radiation is more destructive for the human body. Workers who work in outdoor environmental conditions are positively affected by U.V. radiation. Outdoor workers who are mostly working under sun ray without any proper protection are commonly affected by skin aging, skin cancer, declining immunity, and eye damage problems (photokeratitis and cataracts) (WHO, 2003; Jaggernath *et al.*, 2013; Schulte *et al.*, 2016; Kiefer *et al.*, 2014). Apart from affecting the health of farmers, the U.V. radiation also causes a reduction in crop production, variation in weed-crop synergies quality of crops, and fertility, which directly influences the life of agricultural workers (Open Weather, 2018).

Psychological stress

Climate change impacts workers' physical health and plays a considerable effect on workers' mental health (Cianconi *et al.*, 2020; Moda *et al.*, 2019; Padhy *et al.*, 2015). Earlier research exposes that mental health disturbance is more common in farmworkers and farmers than other workers of different sectors (Yazd *et al.*, 2019). By systematic review of the literature, we have identified that financial difficulty, drought, changing pattern of rain, exposure to pesticide, etc. are considerably affecting the mental health of farmers (Yazd *et al.*, 201; Padhy *et al.*, 2015; Rasanen *et al.*, 2016).

Approaches for assessing the effect of climate change on agricultural workers

We have already highlighted the direct and indirect influences of climatic variation on agricultural workers' health. Because of the lack of appropriate, relevant data, it has been difficult to assess how vulnerable and at-risk are due to climatic variation on agricultural workers. We have only reviewed the earlier approaches to evaluate heat stress in

agricultural workers to address these issues. We have already exposed the heat stress effect on farmworkers. More initial research highlighted that skin temperature, blood pressure, core body temperature (CBT), body mass loss, and heart rate are the most consistent process for assessing the hazard of heat stress (Juliana Bunim, 2013). Still, such measurements may restrict work movements, are offensive, and should only be achieved by people with medical training (StaalWästerlund, 2018). Gao *et al.*, (2017), Zamanian *et al.*, 2017 Singh *et al.*, 2018 suggested that the evaluation of climatological facts such as air temperature mean temperature of the surrounding area, air velocity, humidity, and heat radiation are also essential to measure occupational heat stress OSHA, (2017). Heat stress and heat strain computing by Discomfort Index, Universal Thermal Climate Index, Predicted Heat, Wet Bulb Globe Temperature (WBGT), and Strained index (Gao *et al.*, (2017). Out of the mentioned method, WBGT is the most common, predominant index, and popular way to assess workers' heat stress (G. M Budd; 2008) Al-Bouwarthan *et al.*, 2019. WBGT and Humidex are maximum precise approaches to display a healthier association with physiological parameters under heat stress working conditions of agricultural workers OSHA, (2017), Gao *et al.*, (2017) Kjellstrom *et al.*, 2009. Heat stress measure using the WBGT index according to ISO 7243, heat strain was evaluated using by determining the different physiological responses, including mean skin temperatures, oral and aural, rendering to ISO 9886 Heidari *et al.*, (2015). Ken Parsons, 2006; Kirti Kesarwani (2017). Early studies showed that WBGT index values had to range from 24 to 32.6 °C in the hot season irrespective of metabolic rate, work rest, and clothing insulation (Heidari *et al.*, 2015; Kirti Kesarwani, 2017;). Kashyap *et al.*, (2017) found that the mean skin temperature and oral

temperature of workers increase with the increase in WBGT. With the increment of WBGT from 28 to 30°C. Physiological parameters like resting and working heart rate increase with an increase in WBGT. The physical discomfort parameter overall discomfort rate (ODR) increases with an increase from 4.9 to 6.7 during the same working condition in WBGT due to heat stress.

Interventions and strategies for preventing the effect of climate change on agricultural workers

After analyzing the previous research priorities, we expose some prevention and adaptation strategies that may help protect agriculture workers from the adverse consequence of climatic variation. The control of climatic change measures is usually beyond human capability, but following some precaution, Prevention, and adaptation strategies we exposed can mitigate the effect of climate change on human health. Nowadays, job associated heat contact is a burning contest for workers' safety and health. An international agency such as WHO, ILO, WMO, ISO, etc., has been given many climate change adaptation strategies on typical workers' occupational health (Nilsson *et al.*, 2010). As we have already highlighted that in the case of agricultural workers, occupational heat hazard is a principal challenge for their health and safety, so we are only focused on those prevention and adaptation strategies that are suitable for agricultural workers to mitigate the heat stress.

Further, before selecting the strategies, we have kept in mind that the prevention and adaptation measure should be capable enough to protect outdoor workers from minimizing the social difficulties, economy, and productivity losses (ILO, 2019; UNDP, 2016;

Moda *et al.*, 2019). Due to increasing the rates of mortality and mobility by extreme weather hazards, there are healthy needs for rational assessments of vulnerability and threat to improve the knowledge about occupational risk for risk management, agricultural management practices, adaptation and mitigation of climate change effect Schulte *et al.*, (2016) Sherwood *et al.*, 2010 Thomas *et al.*, 2014, Akinnagbe *et al.*, 2014 Ford *et al.*, 2011 Louis *et al.*, 2008, Chersich *et al.*, 2019. Increasing the use of renewable energy or substitute for fossil fuel also plays an essential role in mitigating the climate change effect.

Apart from (Xiang *et al.*, 2016) expose five aspects of workers' awareness about the risk in their study, these are the modification of work habits, anxieties about heat exposure, policy and guideline support, degree of satisfaction preventive and measures arrogances towards more training. Deressa *et al.*, 2010 mentioned that the most important factors that influence the adaptation strategies of climate change for farmworkers are family size, literacy of the head of the family, gender of the family head, livestock status, and manner of crop production (whether mechanized or not, etc).

Recommended some adaptation strategies for agricultural workers such as the provision of proper shade for resting or other suitable means to recover from heat stress, availability of drinking water at the workplace, use of cooling mechanisms, shifting of work, conducting training and awareness program associated with heat safety (Jackson and Rosenberg, 2010, Nunfam *et al.*, 2018 and Crowe *et al.*, 2009 Lam *et al.*, 2013). They also state that assessment of risk due to extreme occupational heat by agricultural workers and proper management practices are also important measures to mitigate the climate change negative impact in the farming sector.

In conclusion the adverse influences of climatic variation on job associated safety and health has been extensively studied on the general population rather than agricultural workers. Even though limited familiar suggestion exists on climate change effect of work-related health and safety among outdoor agricultural workers of a developing country, our systematic review's outcome helps in the assessment of climate change effect on agricultural workers approaches for assessing the impact of heat stress and finding of adaptation strategies. After a systematic review, we are found that climate change-related hazards like extreme weather events, extreme heat, air pollution, high level of O₃, psychological Stress, ultraviolet exposure, vector-borne diseases, and other biological hazards are affecting tremendously outdoor agricultural workers' health and productivity. Besides, due to occupational heat exposure in a tropical developing country, agricultural workers quickly come across heat stress, heat illness, and occupational injury, which may eventually cause death. Further global warming due to climate change plays a vital role in increasing pathogens, insect pests, and weeds, leading to an increase in the use of pesticides, herbicides, and other chemicals that may cause serious health effects on agricultural workers. At last, we highlight some adaptation strategies from our finding of outdoor farmworkers such as the provision of proper shade for resting or other suitable means to recover from heat stress, availability of drinking water at the workplace, use of supportable protective equipment's to mitigate the negative effect of climate change on health, conducting training and awareness program associated with heat safety. Apart from the above consideration, there is an essential need for scientific research work to assess the impact of climate change on agricultural workers' working capacity in a tropical developing country and develop some mechanism to cope with the changing

climatic conditions for sustaining the livelihood of agricultural workers.

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