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.

Keywords: Climate change hazards, Agricultural workers health, productivity, Heat stress assessment, protection, Future research

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; Matthee 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 (Bugajksa 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 publish 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 tropic of the analysis papers is to identify the effect of climate change on agricultural workers' health. To accesses this issue due to limited evidence related to the agricultural sector, we also review some similar tropics 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 (StaalWesterlund, 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, hypothermal 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; Ylipää 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)**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Author and Year</th>
<th>Objective</th>
<th>Study Inhabitants</th>
<th>Learning Theme</th>
<th>Study Involvement</th>
<th>Outcome Data and Study Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Schulte et al., (2016)</td>
<td>Improvement of an outline to the recognition of climatic variation effect on workers and work-related safety and health</td>
<td>Mutual worker</td>
<td>Extreme weather events, work-related safety and health, risk assessment and management</td>
<td>Determination of interactions among work hazards, climate, and other influences, assessment of risk by the hazard of climate change</td>
<td>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</td>
</tr>
<tr>
<td>2</td>
<td>Applebaum et al., (2016)</td>
<td>Overview of climate change-related work-related exposures and its recommendation</td>
<td>Common workers</td>
<td>Climate change, Work-related risks, Heat, Polycyclic scented hydrocarbons, Ozone, Pathogenic microbes, Vector-borne diseases, and Violence</td>
<td>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</td>
<td>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</td>
</tr>
<tr>
<td>3</td>
<td>Crowe et al., (2009)</td>
<td>An experimental, qualitative field assessment on occupational heat stress in sugarcane workforces</td>
<td>Sugarcane workers of Costa Rica</td>
<td>Climate alteration, Costa Rica, heat contact, heat stress, and sugarcane workers</td>
<td>Plan to improve the health and safety of sugarcane workers from heat influences</td>
<td>Improve understanding of various factors that help to increase sugarcane workers health and safety</td>
</tr>
<tr>
<td>4</td>
<td>Deressa et al., (2010)</td>
<td>Identify the farmer’s awareness of Climate Change and Prevention to mitigate climate change</td>
<td>Farmers of Ethiopia</td>
<td>Climate Change, Farmer, Nile basin of Ethiopia, Perception of Climate Alteration and Adaptation</td>
<td>Identify and mitigation of the effect of climate alteration on agriculturists</td>
<td>Define how agriculturalists canminimize the harmful effect of climate change</td>
</tr>
<tr>
<td>5</td>
<td>Fang et al., (2013)</td>
<td>Relationship between climate alteration and air chemistry affects atmospheric configuration and human death related to increasing air pollution by industry.</td>
<td>population</td>
<td>Climate change, Methane concentration, Fine particulate matter and ozone, Air pollution, Human mortality</td>
<td>Identify how increasing delicate particle matter, ozone, methane responsible for human mortality</td>
<td>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</td>
</tr>
<tr>
<td>6</td>
<td>Sherwood et al., (2010)</td>
<td>Find the Survivability limit of the general population in heat stress for climate change</td>
<td>General population</td>
<td>Paleoclimate, Climate change, Global Warming, Climate impact, WBGT, Human Physiology</td>
<td>Define human adaptability limit to mitigate the effect of climate alteration</td>
<td>Identify heat stress, and it used to clarify trends in the human fossil record</td>
</tr>
<tr>
<td>7</td>
<td>Varghese et al., (2018)</td>
<td>Observe the association between heat contract and occupational injuries</td>
<td>Common workers</td>
<td>Climate alteration Increasing Temperature, Heat exposure, heat stress, and Occupational hurts</td>
<td>Heat exposure and Occupational injuries</td>
<td>Deliver suitable proposal for policy and research direction to reduce occupational injuries</td>
</tr>
<tr>
<td>8</td>
<td>Jackson et al., (2010)</td>
<td>Reduction of heat-related Illness of agricultural workers by proper prevention measures</td>
<td>Agricultural workers</td>
<td>Agricultural workers, Occupational heat stress, heat-related Illness, hyperthermia, acclimatization and Prevention</td>
<td>Heat-related illness and prevention measure</td>
<td>Help to understand the heat-related illness of farmers and promote proper Prevention</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Author and Year</th>
<th>Objective Study</th>
<th>Study Inhabitants</th>
<th>Learning Theme</th>
<th>Study Involvement</th>
<th>Outcome Data and Study Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Moda et al., (2019)</td>
<td>Evaluation of the primary and secondary consequence of extreme heat and its safety measure for outdoor workers</td>
<td>Outdoor worker</td>
<td>Climate change, high temperature, outdoor workers, direct and indirect impact, prevention measure</td>
<td>Heat stress on outdoor workers and its prevention strategies</td>
<td>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</td>
</tr>
<tr>
<td>12</td>
<td>Srinivasan et al.,(2016)</td>
<td>Describe the Sign of work-related heat stress and its health effects</td>
<td>General work Population of India</td>
<td>Work-related heat stress, India, Core body temperature, health impact, and Prevention measure</td>
<td>Contests and Prevention measure of job-related heat anxiety</td>
<td>Suggest the Prevention measure to mitigating the effects of too much heat on workforces health</td>
</tr>
<tr>
<td>13</td>
<td>Kjellstrom et al., (2009)</td>
<td>Measure the possible consequence of heat for climate variation on workers' health and productivity, the population of middle and low-income country</td>
<td>the population of middle and low-income country</td>
<td>Global climatic variation, temperature elevation, heat exposure, WBGT, core body temperature, and work capacity</td>
<td>A consequence of job associated hotness anxiety on workers' physical health and output</td>
<td>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.</td>
</tr>
<tr>
<td>14</td>
<td>Xiang et al., (2016)</td>
<td>To examine workers' observations and communicative replies to extreme heat contract and recognize individuals' warmness observations factors</td>
<td>South Australian typical workers</td>
<td>Occupational heat exposure, heat stress, heat illness, Occupational injuries, observations, risk awareness, and prevention strategies</td>
<td>Inspect workers' response and perception in extreme heat.</td>
<td>Highlighted the needs to strengthen workers' by proper training in extreme heat, improve prevention strategies, and promotion of educational training</td>
</tr>
<tr>
<td>15</td>
<td>Flouris et al., (2018)</td>
<td>Assessment of heat strain effect on workers productivity and health</td>
<td>Common workers</td>
<td>Work-related heat strain, workers' health, productivity, PRISMA guidelines, statistical models, and heat stress mitigation</td>
<td>A consequence of heat anxiety on workers' healthiness and output</td>
<td>Exposed heat stress affected workers' health and work productivity, Suggest the need for international action to mitigate climate change.</td>
</tr>
<tr>
<td>16</td>
<td>Kiefer et al., (2016)</td>
<td>Recapitulates and deliberates the effect of climatic variation on American workforces healthiness and wellbeing</td>
<td>American workers</td>
<td>Climate change, work-related heat exposure, work-related hazards, America's worker, heat illness, workers health, and safety</td>
<td>Effect of climate change on workers health</td>
<td>Provides strong evidence of the effect of climate change on workers and prevention strategies</td>
</tr>
<tr>
<td>17</td>
<td>Orru et al.,(2017)</td>
<td>Assessment of current indication on the consequence of climatic variation on air contamination and its health outcome</td>
<td>General Population</td>
<td>Climatic variation, air pollution, particulate matter,ozone,emission, Spreading, and health impact</td>
<td>Air pollution and Climatic variation effect on population wellbeing</td>
<td>Discovers the associations among climate alteration, air contamination, and air contamination associated with health effects and predicts the future air pollution emission.</td>
</tr>
<tr>
<td>Sl. No.</td>
<td>Author and Year</td>
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<td>18</td>
<td>Xiang et al., (2014)</td>
<td>Inspect the effect of heat waves on worker's safety and health, injuries and illnesses from heat waves</td>
<td>South Australian workers’</td>
<td>Climate change, heatwave, South Australian workers’, work-related health, injuries, adaptation and Prevention</td>
<td>Effect of heatwaves on worker's health and safety</td>
<td>Identify the occupational illness associated with heatwaves and provides a measure for adaptation and Prevention from heatwaves</td>
</tr>
<tr>
<td>19</td>
<td>Laaidi et al., (2011)</td>
<td>Evaluation of research gap associated with work-related heat and research need to overcome assessment heat disorders</td>
<td>Common U.S. worker</td>
<td>Climate change, U.S. worker, heat exposure, occupational heat, heat illness, adaptation, and Prevention</td>
<td>Epidemiology of work-related heat contact and prevention strategies</td>
<td>Identify the research gap on work-related heat exposure and Making policy for Prevention from work-related heat</td>
</tr>
<tr>
<td>20</td>
<td>Gubernot et al., (2013)</td>
<td>Review of high-temperature illness for job-related heat contact and prevention approaches</td>
<td>population of U.S.</td>
<td>The United States, climate change, heat exposure, workplace hazard, risk, heat-related illness and death, adaptation and Prevention strategies</td>
<td>Health hazard for work-related heat contact and its prevention policy</td>
<td>Highlight the risk factors due to heat exposure and suggest adaptation strategies</td>
</tr>
<tr>
<td>21</td>
<td>Kjellstrom et al., (2013)</td>
<td>To observe the physiological indication due to heat effect, climate strategies for suitable work environments, and evaluate the influence of future climatic scenarios on workers' productivity.</td>
<td>Regional labor</td>
<td>Global climate change, heat load, indoor and outdoor worker, heat effect on health, climate modeling, and labor productivity</td>
<td>the straight impression of climatic variation on regional workers output</td>
<td>Evaluate the loss of working capacity and measure the need for Prevention from heat exposure</td>
</tr>
<tr>
<td>22</td>
<td>Singh et al., (2018)</td>
<td>Identify different research on heat stress of farmers and preventing measure</td>
<td>Farmers</td>
<td>Farmers, hot weather, heat stress, WBGT, core body temperature, heart rate, B.P., and Prevention measure</td>
<td>Effect of heat stress on farmer and Prevention measure</td>
<td>Evaluation of heat stress by WBGT index and its effect on farmers body and discuss the significant measure to minimize heat stress</td>
</tr>
<tr>
<td>23</td>
<td>Nunasen et al., (2018)</td>
<td>Evaluation of Consciousness and identify Community impressions of job-related heat anxiety, and suitable prevention measure</td>
<td>Common workers</td>
<td>Climate alteration, work-related heat anxiety, healthiness, safety, and prevention</td>
<td>Communal influences of work-related heat anxiety and suitable prevention policy</td>
<td>Describe the awareness of labors in work-related heat stress, the communal effect of heat anxiety, and prevention measure of heat stress</td>
</tr>
<tr>
<td>24</td>
<td>Fisk (2018)</td>
<td>Review the probable health concerns in indoor climate due to climate change</td>
<td>Indoor residential people</td>
<td>Indoor residential environment, climatic variation, inside air freshness, and health</td>
<td>Effect of climatic variation on inside residential setting and human health</td>
<td>Identify health problem in indoor climate due to climate change and provides a protective measure of indoor temperature for human health</td>
</tr>
<tr>
<td>25</td>
<td>Rasanen et al., (2016)</td>
<td>Review of climate change literature to examine how multiple stressors of climate change or non-climate change affect human vulnerability</td>
<td>General Population</td>
<td>Review, climate change, multiple stressors, risk and human vulnerability, adaptation, and analytical framework</td>
<td>Multiple interacting stressors of climate change or non-climate change and adaptation policy</td>
<td>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</td>
</tr>
<tr>
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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 dried 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 foodborne 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; Jagannath 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 access 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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