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MITIGATION AND ADAPTATION APPROACHES TO CLIMATE CHANGE IN URBAN AREAS

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ABSTRACT

It is a well - known fact that there is a cause – effect relationship between climate change and urban areas. Several studies state that urban areas represent unfavourable climate characteristics compared to their surroundings because of their spatial planning and design failures. New urban planning and design approaches adopt innovative techniques to make cities more resilient to the impacts of climate change on one side. On the other side, cities all over the world prepare mitigation and / or adaptation strategies with national or international supports to survive in the future climatic conditions. This review study evaluates the studies in literature conducted on climate adaptation and mitigation applications in cities all around the world in recent years. Some suggestions are presented in the light of the findings.

KEYWORDS:
Climate Change, Urban Climate, Cities, Adaptation, Mitigation, Turkey

INTRODUCTION

Atmosphere, which covers the planet Earth as a gaseous sheet, bids environment for living things with its appropriate characteristics (e.g. solar radiation, temperature, moisture content, and several others). Climate is the average state of certain atmospheric characteristics / variables (like temperature, relative humidity, rainfall, wind speed etc.) over a period of time (classically 30 years as defined by the World Meteorological Organization; WMO [1]). People are responsive to climate due to its effects on almost all their daily activities and needs from food and drinks, physical structures and wearing to leisure and public health [2]. Therefore, the short- or long-term changes and variabilities in climate are expected to affect human activities deeply in the future. During the preindustrial period there was no or little anthropogenic forcing to change climate [3], but since the industrial revolution, human induced production and consumption activities have caused harms and increased the risks on environment and atmosphere due to greenhouse gases. Human population began to increase faster than before and accumulated in urban areas which were originally developed around the industrial plants. Trends in the total and urban population and their ratio are reported in Figure 1.

It is clear from Figure 1 that urban population and its share in world population are on the rise jointly. Even though approximately two – third of the world human population lives in urban areas, they cover only 1 to 3% of total land surfaces of the earth (excluding Antarctica and Greenland) [5]. Urbanization in terms of both population and development has converted natural surfaces into the structured and impervious surfaces with increasing rates of 0.65% and 0.45%, respectively [6]. Anthropogenic activities which are concentrated in cities and need fossil fuel burning like industrial manufacturing, housing and motor – vehicle traffic result in the enlargement of structured surfaces as well as the release of the greenhouse gases into atmosphere [7,8,9,10,11]. Because of the heat production and storage by industrial and housing areas and motor vehicle, urban environment is warmer than its surrounding (Urban Heat Island; UHI effect). Therefore, cities currently face strong and extreme meteorological events more frequently than rural areas [12]. Humans have long known the effects of urban areas on climatic characteristics, e.g. since the Roman Empire period and this effect has been a scientific subject since the study of Luke Howard for London (1820 as stated in [9]).

Various aspects of urban climate are investigated including new subjects and fields like spatial planning and designing and policy making. Within this context, it is important to make cities more resilient and adaptive to the impacts of climate change by comprehending the results of the studies in literature.

The aim of the present study is to investigate the successful spatial planning and design examples for the climate change adaptation and mitigation applications in urban areas for the last 10 years all over the world.

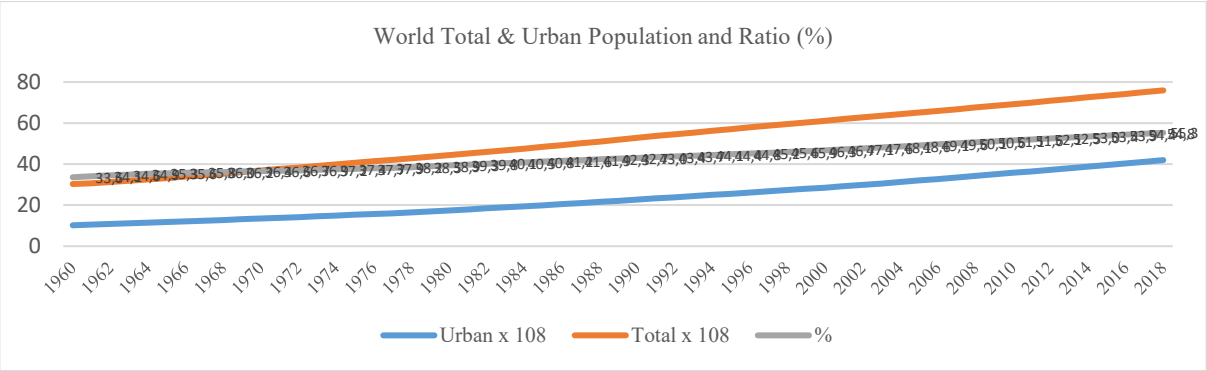


FIGURE 1
World's urban population [4]

MATERIALS AND METHODS

Material of the study is composed of 30 studies reviewed in "Science Direct" and found according to the keywords (Figure 2); "urban climate change mitigation adaptation" and selected among the first 50 articles involving at least the words "urban", "climate" and "mitigation" or "adaptation" from 11.803 results. Content analysis was performed on the studies to determine the study area, aim and scope and results.

RESULTS AND METHODS

Studies reviewed cover the period between 2009 to 2020 and in great majority between 2018 and 2020. Table 1 gives the detailed contents of the studies. These studies are from all terrestrial scales varying from continent to a city park and divers contents from national policies to public opinion detection and best practices presentation to testing strategies. However, their common characteristics are that they all prioritize the climate change mitigation and adaptation to a varying degree.

CONCLUSION AND SUGGESTIONS

For more than 200 years, urban climate change studies have been conducted all over the world. These studies revealed that urbanization causes excessive heating of urban environment. One reason for this is the release of heat from the sources like household heating, industrial production and motor – vehicle traffic into the atmosphere. Another reason is the emission of greenhouse gases (or carbons) and pollutants (e.g. particles) in cities and their surroundings which cause the storage of heat coming from solar radiation in urban atmosphere together with the effect of the altered albedo and impervious urban surfaces (Figure 3).

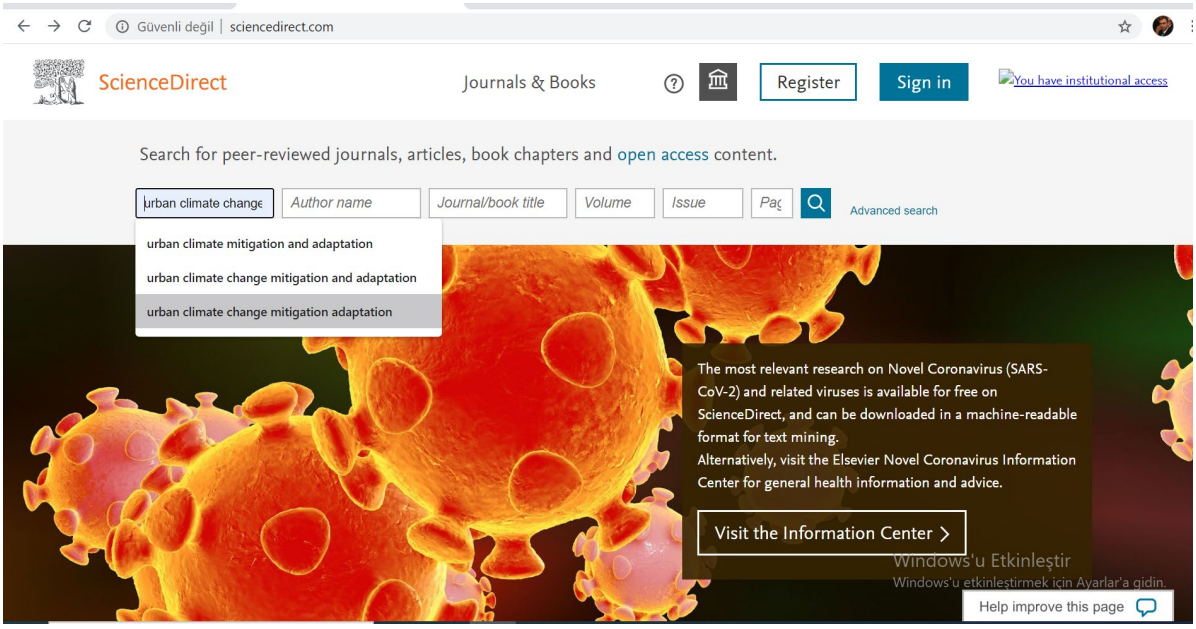


FIGURE 2
Keywords sought

TABLE 1
Content of studies

	Author	Study Area	Aim and Scope	Results and Suggestions
1	[13]	Xiamen City, China	Urban form and the reduction of greenhouse gas (GHG) emissions and climate stresses Role of urban land use in climate change mitigation and adaptation. Selection of mitigation and adaptation strategies preferring potential win-win solutions in land use responses.	Urgency of the integration of climate change mitigation and adaptation in urban land use
2	[14]	European Cities	Integration of mitigation and adaptation is a desired situation for the cities' climate action plans 147 Climate Change Action Plans (CCAPs) out of 885 European cities investigated were found to be successful in doing that using a model.	Even though the plans contain to some degree integration, e.g. consider emission releases and sensitiveness qualitatively, they lack of quantitative assessments on cost – benefits (like public investment for the implementation).
3	[15]	Italy and Spain	European Sustainable Energy and Climate Action Plans for cities are evaluated for the coherency between adaptation and mitigation actions by classifying and comparing best practices as soft, grey and green representing environmental information, buildings and nature-based solutions, respectively).	Large to medium cities adopt soft (52%) and green (28%) adaptation measures in Italy with mitigation actions. Measures are not depended on size of the city. Nature – based solutions are forefront among adaptation and mitigation strategies.
4	[16]	Italian cities	Assessment of 76 + 32 Italian cities' Local Climate Plans (LCPs) based on their contents and actions towards mitigation and adaptation to climate change.	Nearly all urban climate change adaptation plans are in some lacks Majority of (61 out of 76 cities) municipal civil protection plans are associated to extreme weather events. Majority of climate change mitigation plans are convenient with the Covenant of Mayors. Local Climate Action Plans should be prepared voluntarily using international funds at local level since no legal obligation is imposed to local governments.
5	[17]	Bogota, Colombia	Surveying about public preparedness level of the causes and effects of climate change and the present situation of climate change.	Public awareness at all level about climate change is that it is a reality, causes droughts, floods and affects negatively health, water, energy and food sources against which measurements should be taken through adaptation and mitigation strategies.

6	[18]	East and West Africa	Urban and peri-urban agriculture and forestry (UPAF) efforts in developing regions for mitigation and adaptation of climate change in East and West Africa.	In the literature related to study area it was reported that adaptation and mitigation efforts include enhanced food security, productive greening, ecosystem services and innovative policy for urban resilience and transformation.
7	[19]	9 cities	Preparation of a pilot typology with nine case study cities based on a multi – dimensional urbanization climate change typology sensible to the causes of GHG emissions and climate change vulnerabilities.	A standardized evaluation framework may be applied to cities for their evaluation and comparison of GHG emissions and climate change vulnerability at different phases in the urbanization process.
8	[20]	US and Australia	Evaluation of examples from the United States and Australia to determine if the climate change policies include adaptation, mitigation or both and they are in consistency.	Results show that half of the preferred actions in the plans represent conflicts in terms of adaptation and mitigation at the same time.
9	[21]	Latin America	Assessment of the relationship between climate change adaptation and mitigation and three recent slum upgrading programs (urban transformation) in Latin America.	Urban transformation including "slum upgrading" has political and socio-economic faces since it directly affects structured areas and contributes to adaptation and mitigation to climate change if conducted accurately in a combination.
10	[22]	Hungary	Impacts of climate change on planning sustainable and safe cities harboring ordinary housing building typology in terms of real estate sector.	Case study shows roofs may be impacted due to increasing wind load and renovation for the reduction of CO2 emission. City – based points on which planners should be focused are determined for mitigation.
11	[23]	Klagenfurt Austria	Present and future climate scenarios are evaluated to propose realistic climate adaptation measures using a microscale urban climate model (MUKLIMO_3) and the cuboid method to estimate rate and distribution of some parameters.	Efficiency of climate adaptation strategies are tested using climate adaptation scenarios considering albedo changes in covered surfaces and increase in green surfaces. Through the implementation of measures mitigation of hot days is achieved at a significant rate in the scenarios.
12	[24]	Shanghai and Beijing	Contemporary and innovative urban planning and design approaches can be used for climate change adaptation and mitigation integration of which tried to be succeeded using two planning tools: water sensitive urban design and biophilic urbanism.	Innovations used today e.g. solar and wind power, batteries, and electrifying transport should be planned in cities to be effective on adaptation and mitigation.
13	[25]	Melaka, Malesia	Climate governance framework is evaluated to determine the consistency between the policies at local and national levels.	As a good governance example at various scales policies are tested in top-down and bottom-up approach to see their effects on mitigation.

14	[26]	9 case cities from various continents	Effects and application difficulties of digital revolution on climate change adaptation are evaluated (considering Fourth Industrial Revolution (IR 4.0 and 9 case studies in cities from various continents).	Digitalization can support mitigation works through early warning and emergency response systems, enhancing food and water security, improving power infrastructure performance, enabling citizen engagement and participatory adaptation measures and minimizing the impacts of climatic hazards.
15	[27]	Germany	Contribution of municipal advisory committees to climate change mitigation and adaptation with their policy implementation decisions is evaluated through 107 cities and social network analyses of 20 cities to develop a typology of advisory committees.	Participation is an important part of decision-making process for also the development of adaptation and mitigation measures therefore best models should be used to make advisory committees participate actively in the decision-making processes.
16	[28]	India	Transport infrastructure adaptation to climate change which shows its effect as flooding in urban environment is evaluated through a methodological approach to formulate the adaptation strategies.	Study offers three solution sets and compares them to find the first offered set is more effective adaptation measure.
17	[29]	Nepal	Mitigation – adaptation interactions are evaluated qualitatively based on expert survey which addresses four key sectors with relationships between mitigation and adaptation (Agriculture, Forestry and Land use (AFOLU), urban planning, energy and water).	Even though policy documents include synergies of mitigation and adaptation but in practice ownership is not present and there is a need for an institution dedicated to climate change at the national level
18	[30]	New York, US; Bilbao Spain, Europe	Role of Urban Green Spaces in adaptation approaches based on risk control (1) and urban regeneration and sustainability (2) adopted by US and Europe respectively is evaluated over the cases in New York and Bilbao.	Study shows that depending on the extreme events to come, place and contents of Urban Green Spaces are very important to implement adaptation measures.
19	[31]	Fukuoka City in Kyushu, Japan	Local climate change adaptation policies and urban and greenspace planning are evaluated in Fukuoka, Japan.	It is stated that since the case city has deep science-policy background on urban environment, such a situation gives favorable research and policy infrastructure for adaptation, in particular mitigation of heat risk.
20	[32]	Taipei Metropolis, Taiwan	Content of newspaper articles are analyzed to determine the discussion rate of green space and heat matters on city agenda.	It is stated that in urban climate adaptation greening should not be done with sudden decisions and seen as only protector without considering the need for social policy measures.

21	[33]	Different countries	It is aimed in the study to show good practices all over the world for climate change mitigation and adaptation to be examples.	It is suggested that since there is a deficiency in literature containing good practices and problems which may be similar in other cities or countries in climate adaptation and mitigation.
22	[34]	Malaysia	In a review, trend and projection of climate change is evaluated for Malaysia together with greenhouse gases and the impacts of climate change, mitigation and adaptation works and future strategies to manage the impacts of regional climate change.	Results show that yearly temperatures, frequency of extreme weather events and mean sea level are rising while rainfall shows variability while projecting rise of temperature and mean sea level till the end of the 21st century and increased frequency of extreme weather events.
23	[35]	Berlin, Germany,	The study is dealt with the evaluation of the effectiveness of climate change adaptation strategies in Berlin, Germany, on a summer day by using the urban climate model MUKLIMO_3.	Adaptation strategy on albedo (white coating and green roofs) is tested and it is stated that strategies show a higher effect on the daytime and a smaller influence on the nocturnal temperature.
24	[36]	Adelaide, South Australia	A scenario-based modelling built on climate change projections and potential alterations of urban greenery in 2030 and 2090 in Adelaide, South Australia is evaluated based on regional climate change scenarios, potential urban surface cover alternatives and resulted urban microclimate variations in Adelaide.	Results indicate that an ideal urban landscape transformation scenario with 30% tree canopy can effectively decrease the surface temperature by 1 °C in winter and 3 °C in summer by 2090. Urban greenery may be used as a mean of increased urban life resilience to climate change by reducing surface temperature, increasing urban resilience and decreasing the energy demand during summer.
25	[37]	192 UN countries	This study examines the nexus between climate change vulnerability and adaptation readiness in 192 UN countries using mapping and panel data models.	It is stated that Africa is the most vulnerable continent to climate change with high sensitivity, high exposure, and low adaptive capacity. Developed countries, including Norway, Switzerland, Canada, Sweden, United Kingdom, Finland, France, Spain, and Germany, are less vulnerable to climate change due to strong economic, governance and social adaptation readiness. International commitment from developed countries to developing countries is essential to strengthen their resilience, economic readiness and adaptive capacity to climate-related events.
26	[38]	China	At all scales, China's climate change action plans are evaluated to determine if the strategies are suitable based on international agreements.	Results show that the country needs data of cities, impact assessment works including all sides and transformation in market and policy.

27	[39]	Houston, Texas US	Urban Heat Island (UHI) effect is evaluated in different climate zones to see the effectiveness of UHI mitigation strategies such as roof vegetation, trees, and grass coverage ratio.	UHI mitigation in high-rise urban morphology is limited but as grass and tree coverage ratios increase mitigation effect also increase especially in hot climates.
28	[40]	New Zealand	Surveying elected local representatives for their opinions about climate change adaptation and mitigation planning is performed in the study.	Study shows that local awareness increases fed by national measures but at local level climate change is seen as future rather present problem.
29	[41]	Copenhagen, Denmark.	Green climate adaptation, storm-water management and regeneration in a case study is explained as the politics of designing ecological infrastructures.	Ecological turn in design with ecological, social and cultural benefits in conjunction with improvements to storm-water management is evaluated in the case study.
30	[42]	Munich, Germany	Water-Energy-Food Nexus approach is used to determine if more efficient climate change mitigation and adaptation approaches can be achieved through integrated urban planning.	Application of such an approach could meet local demand for food (urban agriculture), freshwater and electricity supply to some degree. Similar pilot projects should be implemented.

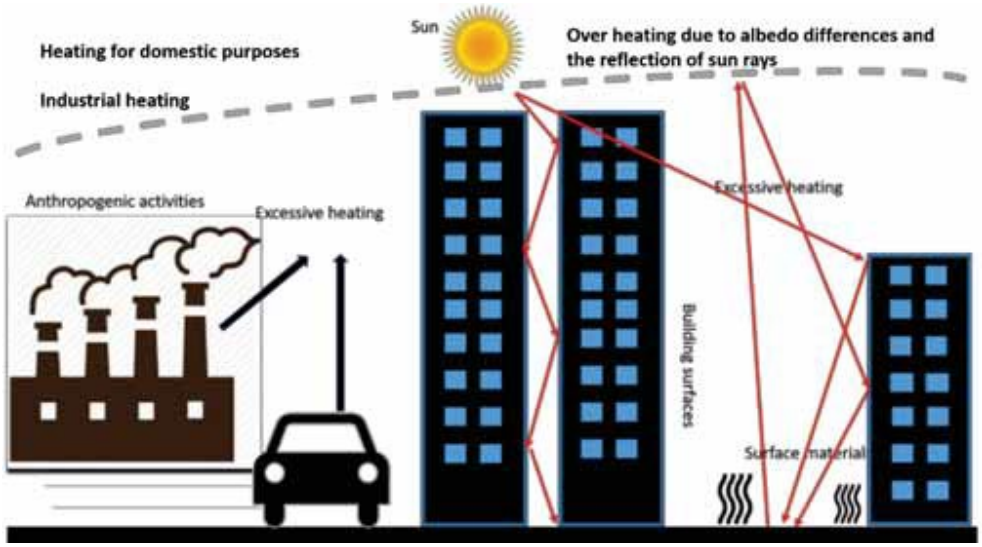


FIGURE 3
Urban heating mechanism [43]

Today it is vitally important to monitor the trend of effective climatic factors on urban climate through measurements, observations or modelling methods in order to prevent socioeconomic losses using appropriate spatial planning and design approaches. These approaches have become highly sensitive to the climatic factors and expected changes (such as eco-city, smart city etc.). In order to apply these approaches in cities in convenience with the adaptation and mitigation efforts, every city should adopt policies and strategical documents then get local supports and ownership.

The present study provides the tips and suggestions gathered from the literature reviewed. An important finding is that climate change is accepted to be a reality in public opinion and action plans for adaptation and mitigation should be prepared and implemented. Therefore, surveying public opinions about climate change, mitigation and adaptation efforts is vitally important to see the public willingness to support action plans.

Urban forms are highlighted to be among the effective factors on urban climate change. Urban characteristics including form, morphology and even

the shape of buildings should be taken into consideration for mitigation and adaptation strategies. It is stated that half of the preferred actions in the climate change plans (strategies) in the US and Australia represent conflicts in terms of adaptation and mitigation at the same time. Therefore, these strategies should be prepared in convenience with each other. All the cities should have adaptation and/or mitigation strategies, so-called Local Climate Action Plans, which are prepared voluntarily using (inter)national funds. Such strategies should involve financial base for the implementation of the actions they include depending on cost – benefit analysis. In the best – practice adaptation and mitigation strategies, nature – based solutions take place more frequently than technical or grey solutions. Future climate change scenarios can be employed to test the efficiency of adaptation and mitigation strategies. Adaptation and mitigation strategies may sometimes be founded on the apparent problems experienced at that time.

Adaptation and mitigation strategies may be tested using suitable scientific methodologies in both preparation and implementation stages. In the preparation and implementation of climate change adaptation and mitigation strategies for settlements, it is important to conduct analyses towards the determination of present situation and to monitor and evaluate the implementation to make impact assessment. After obtaining data in the implementation phase, findings should be used for re-planning and reorganizing strategic framework. Case sensitive urban heat islands should be investigated to mitigate the urban climate and reduce its contribution to global climate change. Innovative and case sensitive local level design examples are adopted all over the world as success stories for climate adaptation and mitigation works.

City–specific points should be determined for planners to focus on in details for mitigation. Top–down and bottom–up planning approaches should be checked for their consistency to see their effectiveness on mitigation. A standardized framework may be employed to evaluate and compare GHG emissions and climate change vulnerability of cities regardless their development stages. Urban transformation including slum upgrading may be a suitable policy to contribute to adaptation and mitigation simultaneously. Best models should be selected to constitute advisory committees to participate actively in the decision-making processes for the cities which have just begun their climate action plans.

The use of new smart technologies can contribute to mitigate climate change but their effects can be increased by using contemporary planning approaches involving them. Consistently developing digitalization technology can support mitigation works through the systems like early warning and emergency response. Application of recycling, reusing and local food producing projects for water, energy and food demands should be achieved to contribute to adaptation and mitigation works. Urban green spaces are very important to implement adaptation measures when their place and structure are organized according to future extreme events. Background of cities in urban planning, green areas and implementation works may assist them to develop resilient settlements to climate change and gain favorable features in terms of adaptation and mitigation to climate change. In urban climate adaptation, local authorities should avoid abrupt decisions without considering long term plan decisions for the land-use changes e.g. brown and green areas. Urban green spaces may serve as a tool to increase resilience to climate change by reducing surface temperature and energy demand. Urban and peri-urban agriculture and forestry (UPAF) efforts may be a solution for enhanced food security, productive greening, ecosystem services and innovative policy for urban resilience and transformation in developing regions for mitigation and adaptation to climate change like East and West Africa.

Trends and projections of climate change are assessed frequently at a very diverse scales to easily take suitable adaptation and mitigation measures. Vulnerability of continents and countries to climate change shows variations depending on their sensitivity, exposure, adaptive capacity, economic, governance and social adaptation capacity to climate change. There may be a need for an institutional structure (e.g. ministry or administrations) to implement the political contexts at national or local level accurately depending on the governance structure of the area. Therefore, developed countries should help developing countries to strengthen their resilience, economic and social adaptive capacity to climate-related events.

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