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Article

The heat preparedness gap: Bridging urban heat risk and municipal heat governance

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ABSTRACT

Extreme heat is emerging as one of the most critical climate-related challenges facing cities, yet whether municipal planning systems are adequately prepared for local heat risks remains poorly understood. Existing studies predominantly assess either urban heat risk or climate adaptation planning, while the relationship between heat risk and municipal preparedness has received limited attention. To address this gap, this study introduces the Heat Preparedness Gap (HPG), defined as the mismatch between urban heat risk and the preparedness capacity of municipal planning systems. An integrated assessment framework was applied to 21 metropolitan municipalities with publicly available strategic climate plans in Türkiye. A Heat Preparedness Index (HPI) was developed through the evaluation of six preparedness domains, while a multidimensional Heat Risk Index (HRI) was constructed by integrating indicators of heat exposure, sensitivity, and adaptive capacity. The relationship between HPI and HRI was subsequently evaluated through the HPG and a Heat Risk–Preparedness Matrix. The analysis identified four distinct preparedness profiles, demonstrating that municipalities facing comparable levels of heat risk often exhibit markedly different preparedness capacities. The findings further reveal that preparedness is not closely aligned with climatic exposure alone and varies substantially across different planning and governance contexts. Although heat-related issues are increasingly incorporated into municipal planning, operational heat management—including Heat Action Plans, heat-health early warning systems, and targeted protection for vulnerable populations—remains consistently underdeveloped. The proposed framework provides a transferable approach for benchmarking municipal preparedness, identifying adaptation priorities, and strengthening operational heat governance.

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INTRODUCTION

Cities are increasingly recognised as critical arenas for climate change, concentrating populations, infrastructure, economic activities, and environmental vulnerabilities within highly modified landscapes. Among the many climate-related hazards affecting urban areas, extreme heat has emerged as one of the rapidly intensifying threats, driven by rising global temperatures and accelerating urbanisation (Cheval et al., 2024; Khanh et al., 2023; Y. Ren et al., 2023). These processes are increasing the frequency, duration, and intensity of heatwaves, tropical nights, and

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prolonged thermal stress across almost all climatic regions (IPCC, 2022). Their impacts are further amplified by the Urban Heat Island (UHI) effect, whereby dense urban morphology, extensive impervious surfaces, limited vegetation, and anthropogenic heat emissions elevate urban temperatures beyond those of surrounding rural areas (Erdem Okumus & Terzi, 2021; Oke et al., 2017; Santamouris, 2020).

Extreme heat is now recognised as one of the deadliest climate-related hazards, contributing to excess mortality, cardiovascular and respiratory diseases, declining labour productivity, increasing energy demand, and widening social inequalities (Hondula et al., 2015; Mora et al., 2017; Romanello et al., 2024). Unlike floods, storms, or wildfires, heat often develops gradually and leaves little visible physical damage, leading it to be characterised as a "silent killer" (Hughes et al., 2016; United Nations, 2024). Its impacts are also unevenly distributed, with heightened vulnerability among older and younger populations, individuals with chronic illnesses, outdoor workers, and socially and economically disadvantaged groups (Ebi et al., 2021; Erdem Okumus, 2025; WHO, 2026). Consequently, extreme heat is not only a climatic hazard but also a multidimensional urban governance challenge encompassing public health, social equity, infrastructure resilience, emergency management, and spatial planning.

Urban planning plays a central role in shaping both the causes and consequences of urban heat through land-use patterns, urban morphology, building density, transport systems, and green and blue infrastructure (Erdem Okumus & Akay, 2025; Erdem Okumus & Terzi, 2021, 2023; Oke et al., 2017; Yu et al., 2024). At the same time, municipalities are expected to coordinate public health responses, emergency management, social assistance, and risk communication during extreme heat events. Urban heat resilience therefore depends not only on the physical characteristics of cities but also on the local governments' capacity to anticipate, prepare for, and respond to heat-related risks.

Urban heat research has expanded rapidly, with a focus on assessing risk through climatic exposure, demographic sensitivity, socioeconomic vulnerability, and adaptive capacity (Chakraborty et al., 2019; Harlan et al., 2006; Xiang et al., 2022; Xu et al., 2024; Yang et al., 2025). Building upon the IPCC risk framework (IPCC, 2014, 2022), numerous composite indicator approaches have been developed to identify vulnerable populations and support evidence-based adaptation planning (Erdem Okumus, 2025; Li et al., 2022; Qian & Liu, 2025). However, most heat risk assessments remain fundamentally diagnostic, identifying where risks are concentrated rather than whether municipalities possess the institutional capacity to manage them.

In parallel, a growing body of research has examined climate adaptation planning, urban resilience, and local climate governance (Gori Nocentini, 2024; Holtan et al., 2026; Zhang et al., 2024). Municipalities worldwide have increasingly adopted climate adaptation strategies and local planning instruments (Aylett, 2015; Rogers et al., 2023), whose evaluations typically focus on plan quality, policy integration, implementation capacity, or governance arrangements (Berke & Godschalk, 2009; Grafakos et al., 2020; Rose & Göçmen, 2025; Yu et al., 2024). Yet these studies rarely assess whether municipal preparedness is commensurate with local heat risk.

This disconnect also reflects a distinction between heat mitigation and heat management (Keith et al., 2023; Rose & Göçmen, 2025). Heat mitigation seeks to reduce long-term exposure through interventions such as urban greening, blue infrastructure, cool materials, and climate-sensitive urban form (Cui et al., 2024; S. Ren et al., 2025; Srivastava et al., 2026). Heat management, by contrast, protects populations during extreme heat events through operational measures including Heat Action Plans (HAPs), heat-health early warning systems, cooling centres, public communication, and targeted support for vulnerable groups (Singh et al., 2024; WHO, 2026). While complementary, municipal planning has generally prioritised long-term mitigation over operational preparedness.

Accordingly, urban heat governance extends beyond physical cooling strategies to encompass institutional coordination, public health preparedness, emergency management, and implementation capacity (Keith et al., 2023; Yazar & York, 2021). Despite advances in both research traditions, heat risk studies rarely evaluate governance capacity, while planning evaluations seldom examine whether such capacity is proportionate to local climatic risk. Municipalities facing similar heat risks may exhibit markedly different preparedness levels, while those with comparable planning capacities may confront substantially different risks. A fundamental planning question therefore remains: Are cities prepared for the level of heat risk they face? Addressing this question requires moving beyond separate assessments of heat risk and planning quality towards evaluating their alignment.

Although the proposed framework is broadly applicable, Türkiye provides a particularly suitable empirical setting. Located within the Mediterranean Basin—one of the world's most prominent climate change hotspots—the country is projected to experience rising temperatures, more frequent heatwaves, and increasing tropical nights (IPCC, 2022). Its metropolitan municipalities (MMs) span diverse climatic regions while operating within a shared national governance context. Municipalities have increasingly prepared Sustainable Energy and Climate Action Plans (SECAPs), Provincial Climate Change Action Plans (IDEPs), and Provincial Disaster Risk Reduction Plans (IRAPs). More recently, the Regulation on Local Climate Change Action Plans (YİDEPs) and Provincial Climate Change Coordination Boards established YİDEPs as a formal instrument integrating climate risk assessment,

adaptation, responsible institutions, implementation, and monitoring into provincial climate planning (Regulation on Local Climate Change Action Plans (YİDEP) and Provincial Climate Change Coordination Boards, 2026). This combination of climatic diversity and a shared national governance context enables comparison across different heat risk contexts. However, despite growing research on urban heat in Türkiye (Akay & Erdem Okumus, 2026; Birinci et al., 2026; Erdem Okumus & Terzi, 2022), little is known about whether municipalities facing greater heat risk are better prepared to manage it.

To address this gap, this study introduces the Heat Preparedness Gap (HPG) framework for evaluating the alignment between municipal preparedness and urban heat risk. A Heat Preparedness Index (HPI) comprising six preparedness domains is compared with a multidimensional Heat Risk Index (HRI) to identify preparedness gaps and classify municipalities into distinct Heat Risk–Preparedness profiles. Accordingly, the study addresses three research questions: (1) To what extent are MMs prepared to address extreme heat through existing planning and policy frameworks? (2) How does municipal preparedness compare with urban heat risk across metropolitan contexts? (3) Which preparedness dimensions are most consistently underdeveloped across municipalities? By linking municipal preparedness with urban heat risk, this study moves beyond conventional heat risk mapping and plan quality assessment to evaluate whether preparedness is commensurate with local heat risk. It provides a transferable approach for benchmarking municipal preparedness, identifying governance gaps, and supporting evidence-based heat adaptation planning.

MATERIALS AND METHODS

This study develops an integrated framework to evaluate whether municipal preparedness is proportionate to urban heat risk across MMs. The framework combines two complementary assessment components: (i) an HPI, derived from a structured plan evaluation framework encompassing six preparedness domains, and (ii) a multidimensional HRI, integrating indicators of heat exposure, population sensitivity, and adaptive capacity. The relationship between these indices was subsequently assessed through the HPG, which measures the alignment between municipal preparedness and estimated heat risk. The methodological workflow comprises five sequential stages: municipality selection and data collection; construction of the HRI; assessment of municipal preparedness using the HPI framework; calculation of the HPG; and classification of municipalities using the Heat Risk–Preparedness Matrix to identify preparedness profiles and adaptation priorities.

Study Area

The study included the 21 municipalities for which at least one strategic climate planning document—SECAP or IDEP—was publicly available at the time of data collection (Figure 1). All selected municipalities were also covered by IRAPs (AFAD, n.d.), while Istanbul was the only municipality possessing all three planning instruments (SECAP, IDEP, and IRAP). Municipalities without either a SECAP or an IDEP were excluded because municipal heat preparedness could not be evaluated in the absence of strategic planning documents. Plan type itself was not used as an indicator of preparedness; all eligible documents were instead evaluated using the same heat-specific HPI assessment framework. Consequently, the assessment focuses on planning-active municipalities rather than all MMs in Türkiye. The selected municipalities represent approximately 71% of Türkiye's population and encompass diverse climatic, geographical, and urbanisation conditions, providing a suitable basis for evaluating the proposed framework across contrasting heat risk and planning contexts (Table 1).

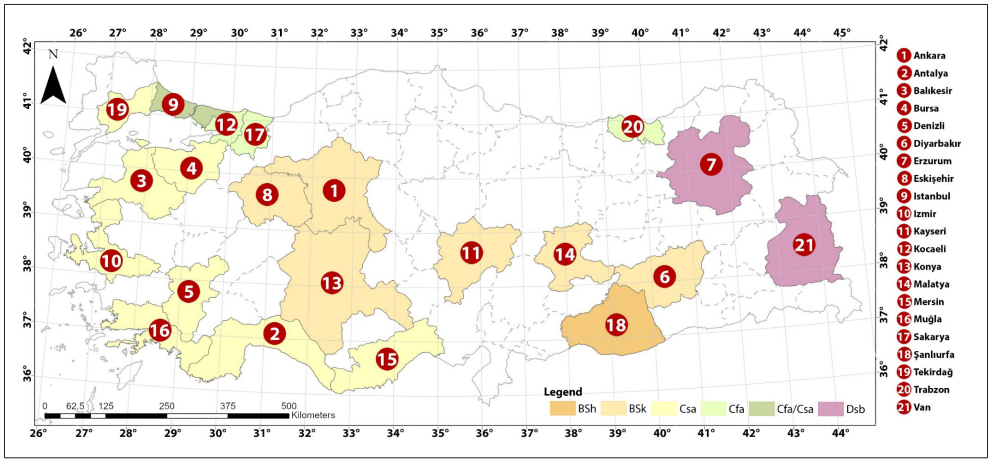

Figure 1. Locations and dominant Köppen–Geiger climate types of the 21 MMs included in the study.

Heat Risk Assessment

Urban heat risk (HR) was conceptualised as the interaction of climatic conditions, exposed populations, and their capacity to cope with impacts (IPCC, 2014, 2022). For comparative assessment, hazard and exposure were operationalised as a unified Heat Exposure (HE) dimension incorporating elevated temperatures, heatwave occurrence, tropical nights, and cumulative thermal stress. Accordingly, the HRI was constructed from three complementary dimensions: HE, Heat Sensitivity (HS), and Adaptive Capacity (AC) (Table 2).

The HR framework assumes that heat risk reflects the combined effect of climatic exposure and population sensitivity, moderated by the capacity to adapt to heat-related impacts. Accordingly, the overall HRI was calculated by integrating the three component indices—Heat Exposure Index (HEI), Heat Sensitivity Index (HSI), and Adaptive Capacity Index (ACI)—using an equal-weighting approach (Equation 1). Because higher AC reduces heat-related risk, the inverse form of the ACI (1 − ACI) was incorporated into the index construction. Consequently, higher HRI values indicate greater heat-related risk, whereas lower values represent comparatively lower levels of risk. The HRI should be interpreted as a comparative measure of heat risk at the metropolitan scale rather than as a measure of intra-urban thermal heterogeneity.

$$HRI = \frac{HEI + HSI + (1 - ACI)}{3} \qquad \text{Equation 1}$$

Equal weighting was adopted because the selected indicators represent complementary dimensions of HE, HS, and AC, and were therefore assumed to contribute equally to the composite index. This approach provides a transparent and reproducible framework for comparative assessment while avoiding subjective weighting decisions.

Table 1. Description of case MMs

Cities	Total Area (km^2)[1]	Built-up Area (km^2-%)[2]	Population (2025)[3]	Climate Type[4]	Planning Documents[5]	Plan Source
Ankara	25602.57	1627.79 (~6.36%)	5,910,320	BSk	IDEP	(AMM, 2022a)
Antalya	20162.43	2279.62 (~11.31%)	2,777,677	Csa	SECAP	(AMM, 2022b)
Balıkesir	14376.22	759.89 (~5.29%)	1,284,517	Csa	SECAP	(BMM, 2025)
Bursa	10791.94	866.08 (~8.03%)	3,263,011	Csa	SECAP	(BMM, 2017)
Denizli	12119.21	667.25 (~5.51%)	1,060,975	Csa	IDEP	(DMM, 2019)
Diyarbakır	15146.15	691.94 (~4.57%)	1,852,356	BSk	SECAP	(DMM, 2025)
Erzurum	24981.95	401.98 (~1.61%)	736,877	Dsb	SECAP	(EMM, 2023a)
Eskişehir	13941.05	378.73 (~2.72%)	927,956	BSk	SECAP	(EMM, 2023b)
Istanbul	5452.18	1536.57 (~28.18%)	15,754,053	Cfa/Csa	SECAP	(IMM, 2024)
Izmir	11831.76	1419.98 (~12.00%)	4,504,185	Csa	SECAP	(IMM, 2020)
Kayseri	16945.56	718.19 (~4.24%)	1,458,991	BSk	IDEP	(KMM, 2022a)
Kocaeli	3395.91	649.66 (~19.13%)	2,161,171	Cfa	IDEP	(KMM, 2022b)
Konya	40785.85	1472.17 (~3.61%)	2,343,409	BSk	SECAP	(KMM, 2024)
Malatya	12240.64	454.75 (~3.72%)	755,854	BSk	IDEP	(MMM, 2017)
Mersin	16004.1	1059.96 (~6.62%)	1,956,428	Csa	SECAP	(MMM, 2023)
Muğla	12614.96	975.97 (~7.74%)	1,099,547	Csa	SECAP	(MMM, 2025)
Sakarya	4822.27	620.58 (~12.87%)	1,123,693	Cfa	SECAP	(SMM, 2020)
Şanlıurfa	19230.48	980.74 (~5.10%)	2,265,800	BSh	IDEP	(SMM, 2022)
Tekirdağ	6213.02	411.67 (~6.63%)	1,208,441	Csa	SECAP	(TMM, 2023)
Trabzon	4627.16	419.97 (~9.08%)	823,323	Cfa	SECAP	(TMM, 2019)
Van	20897.87	554.21 (~2.65%)	1,112,013	Dsb	SECAP	(VMM, 2022)

[1] Total area was calculated directly from the metropolitan boundary.

[2] Built-up area was derived from the ESRI Land Cover 2025 dataset (ESRI, n.d.).

[3] Population data were obtained from the Turkish Statistical Institute (TÜİK) Address-Based Population Registration System (Turkish Statistical Institute [TÜİK], n.d.).

[4] Dominant climate types were assigned according to the Köppen–Geiger climate classification (BSk: Cold semi-arid; Csa: Mediterranean; Dsb: Continental; Cfa: Humid subtropical; BSh: Hot semi-arid).

[5] Provincial Disaster Risk Reduction Plans (IRAPs) for all provinces were additionally examined (AFAD, n.d.).

Table 2. Indicators used to construct the HRI

Dimension	Indicator	Definition	Data Source	Unit	Year
Heat Exposure (HE)[1]	HE1. Mean summer temperature	June–August mean 2m air temperature	ERA5-Land Daily mean	°C	2020-2025
	HE2. Heatwave days	Number of days within ≥3 consecutive days above local 95th percentile Tmax	ERA5-Land Daily maximum	days/year	
	HE3. Tropical nights	Number of nights with Tmin >20°C	ERA5-Land Daily minimum	nights/year	
	HE4. Very hot days	Number of days with Tmax > 35°C	ERA5-Land Daily maximum	days/year	
	HE5. Maximum summer temperature	June–August max 2m air temperature	ERA5-Land Daily maximum	°C	
	HE6. Cooling degree days (CDD)	Annual sum of Tmean above 22°C	ERA5-Land Daily mean	CDD/year	
Heat Sensitivity (HS)[1]	HS1. Population density	Resident population density	TUIK	persons/km²	2025
	HS2. Elderly dependency ratio	Population aged 65 years and over relative to the working-age population			
	HS3. Child dependency ratio	Population aged 0–14 years relative to the working-age population			
	HS4. Unemployment rate	Unemployed population as a percentage of the labour force			
	HS5. Foreign population ratio	Foreign nationals as a percentage of the total population			
	HS6. Low educational attainment	Population aged 6 years and over with less than upper secondary education (below high school level) as a percentage of the population aged 6 years and over			2024
	HS7. Socioeconomic disadvantage index (SEDI)[2]	Composite index	Endeksa socioeconomic segmentation (SES) data	Index (1–5)	2025
	HS8. Single-person household ratio	Single-person households as a percentage of all households	TUIK	%	
	HS9. Lone-parent household ratio	Lone-parent households with children as a percentage of all households			
	HS10. Crude suicide rate	Number of suicides		per 100,000 population	2024
	HS11. Crude death rate	Number of deaths			
	HS12. Infant mortality rate	Number of infant deaths		per 1,000 live births	
Adaptive Capacity (AC)[1]	AC1. Normalized Difference Vegetation Index	Mean annual NDVI	Sentinel-2 Level-2A	Index (-1 to 1)	2025
	AC2. Modified Normalized Difference Water Index	Mean annual MNDWI			

Table 2. Continued

Dimension	Indicator	Definition	Data Source	Unit	Year
Adaptive Capacity (AC)[1]	AC3. High education attainment	Population aged 6 years and over with a bachelor's degree or higher as a percentage of the population aged 6 years and over	TUIK	%	2024
	AC4. Healthcare capacity	Number of physicians		per 1,000 population	
	AC5. Hospital bed capacity	Number of hospital beds			
	AC6. Municipal financial capacity (MFC)	Mean per capita municipal revenue and expenditure.	Official metropolitan municipal budget documents	TL/person	2025

[1] Higher HE and HS values increase HRI, whereas higher AC values decrease HRI. [2] SEDI was calculated from the proportional distribution of Endeksa (Endeksa, n.d.) socioeconomic segments (A+, A, B, C and D) using ordinal weights ranging from 1 (A+) to 5 (D) (SEDI=1(A+)+2A+3B+4C+5D). Higher values indicate greater socioeconomic disadvantage.

Heat Exposure Assessment

HE was characterised using six complementary indicators representing different dimensions of climatic heat stress (Table 2). The indicator set captures background summer thermal conditions (HE1), the frequency and persistence of extreme heat events (HE2, HE4), night-time thermal stress (HE3), peak summer heat (HE5), and cumulative thermal stress and cooling demand (HE6) (Table A1), providing a comprehensive representation of chronic and acute heat (IPCC, 2014, 2022).

All indicators were derived from the ERA5-Land dataset, which provides spatially continuous estimates of near-surface meteorological conditions at approximately 9 km spatial resolution and is widely used in climate assessments because of its spatial consistency and long-term coverage (Muñoz-Sabater et al., 2021). Indicators were calculated for the 2020–2025 period to characterise recent heat exposure while reducing the influence of year-to-year variability. This period was selected to align the exposure assessment with the contemporary planning context represented by the municipal plans evaluated in the HPI, rather than to characterise long-term climatological normals. For event-based indicators (HE2–HE4 and HE6), annual values were calculated by averaging the six-year totals over the 2020–2025 period, whereas HE1 and HE5 were derived directly from the multi-year temperature observations. All indicators were min–max normalised to a 0–1 scale and averaged with equal weights to derive the HEI.

Heat Sensitivity Assessment

HS was represented using twelve demographic, socioeconomic, household, and health-related indicators (Table 2). The indicators were selected to capture complementary pathways through which population characteristics may increase susceptibility to heat-related impacts (Ebi et al., 2021; Erdem Okumus, 2025; Harlan et al., 2006; Wolf & McGregor, 2013). Population density (HS1) represents the concentration of potentially exposed populations, while elderly and child dependency (HS2–HS3) capture age-related physiological and functional susceptibility to heat (Li et al., 2022). Unemployment, foreign population, low educational attainment, and socioeconomic disadvantage (HS4–HS7) represent socioeconomic conditions that may constrain access to information, healthcare, adequate housing, cooling, and other protective resources (Niu et al., 2021). In particular, foreign populations may face additional linguistic, institutional, and socioeconomic barriers that can limit access to heat risk information and protective resources (Li et al., 2022). Household structure (HS8–HS9) captures potential limitations in social support, financial resources, and household-level coping capacity; for example, people living alone may be less likely to receive timely assistance during extreme heat events (Reid et al., 2009). These demographic and socioeconomic characteristics are widely recognised as important components of population-level heat vulnerability.

Health-related indicators (HS10–HS12) were included to represent broader underlying population health vulnerability (Niu et al., 2021). Crude suicide, crude death, and infant mortality rates were used as population-level proxies for adverse health and social conditions that may reflect underlying population vulnerability, rather than as direct measures of heat-related health outcomes. This distinction is important because these indicators characterise pre-existing sensitivity within the metropolitan population and are not interpreted as outcomes attributable to heat exposure. All indicators were min–max normalised to a 0–1 scale and equally weighted to derive the HSI. Higher HSI values indicate greater sensitivity to heat-related impacts and a higher contribution to overall heat-related risk.

Adaptive Capacity Assessment

AC was characterised using six indicators representing four complementary dimensions: environmental resources, human capital, healthcare capacity, and institutional capacity

(Table 2). Environmental AC was represented by NDVI and MNDWI, reflecting the cooling potential of urban vegetation and surface water. Human AC was represented by higher educational attainment as a proxy for adaptive awareness and access to information. Healthcare capacity was represented by physician and hospital bed availability, while institutional capacity was represented by municipal financial capacity (MFC). MFC was calculated as the arithmetic mean of per capita approved annual municipal revenue and expenditure budgets for 2025. Higher MFC values indicate greater financial capacity to plan, implement, and sustain heat adaptation measures. All indicators were min–max normalised to a 0–1 scale. ACI was calculated as the arithmetic mean of the six standardised indicators, assuming equal weighting.

Heat Preparedness Assessment

Municipal heat preparedness (HP) was evaluated using a structured plan evaluation framework developed to assess how existing planning documents address extreme heat. The framework builds on established plan quality approaches that evaluate the progression from problem identification and evidence generation to policy formulation, implementation, and monitoring (Berke & Godschalk, 2009; Grafakos et al., 2020). These principles were adapted to the specific context of urban heat governance, where preparedness encompasses both long-term heat mitigation and short-term heat management responses (Keith et al., 2023; Rose & Göçmen, 2025). Accordingly, the framework comprises six complementary preparedness domains: (HP1) Problem Definition and Risk Awareness, (HP2) Evidence Base and Vulnerability Assessment, (HP3) Heat Mitigation Policies, (HP4) Heat Management Policies, (HP5) Implementation Capacity, and (HP6) Monitoring, Evaluation and Updating (Table 3). Together, these domains capture the progression from recognising and assessing heat-related risks to developing policy responses and establishing the institutional mechanisms required for implementation, monitoring, and updating. All planning documents were assessed using the same protocol and scoring rubric.

Criterion-based scoring was applied to HP1, HP2, HP5, and HP6, whereas HP3 and HP4 were evaluated according to policy maturity, ranging from policy absence or general recognition to increasingly detailed and operationally specified measures. Within the proposed HPI framework, greater weight is allocated to the two policy domains, consistent with heat-preparedness plan evaluation approaches that place particular emphasis on the breadth and strength of heat mitigation and management measures (Rose & Göçmen, 2025). Heat Mitigation Policies (HP3) and Heat Management Policies (HP4) together account for 50% of the total score,

Table 3. HP assessment protocol and scoring rubric

Domain	Assessment Criteria	Score[3]
HP1. Problem Definition and Risk Awareness	Climate change is explicitly identified as a challenge for the city	2
	Extreme heat and/or heatwaves are explicitly identified as an urban planning and public health issue	2
	UHI effects, LST, and/or thermal comfort are addressed	2
	The health impacts of extreme heat are identified	2
	Vulnerable population groups are explicitly identified	2
	Maximum domain score (A)	10 points
HP2. Evidence Base and Vulnerability Assessment	Local temperature and/or meteorological data are used	3
	LST, UHI, heat mapping, or hotspot analysis is included	3
	Population and socioeconomic vulnerability assessments are included	3
	Data on green spaces, impervious surfaces, and/or urban development are used	2
	Spatial prioritisation at neighbourhood or district level is undertaken	2
	Climate projections or future scenarios are incorporated	2
	Maximum domain score (B)	15 points
HP3. Heat Mitigation Policies[1]	Policy absent	0
	General statement only	1
	Policy described in detail and/or accompanied by measurable targets	2
	Policy described in detail, with measurable targets and designated responsible institutions and/or implementation timelines	3
	Maximum domain score (C)	20 points

Table 3. Continued

Domain	Assessment Criteria	Score[3]
HP4. Heat Management Policies[2]	Policy absent	0
	General statement only	1
	Policy proposed, but implementation details are limited	2
	Implementation details, target groups, responsible institutions and/or protocols are specified	3
	Maximum domain score (D)	30 points
HP5. Implementation Capacity	Responsible departments and/or institutions are identified	3
	Inter-institutional coordination mechanisms are defined	3
	Budget and/or funding sources are specified	3
	Short-, medium-, and long-term implementation timelines are provided	3
	Mechanisms for prioritising vulnerable groups are included	3
	Maximum domain score (E)	15 points
HP6. Monitoring, Evaluation and Updating	Measurable indicators are provided	2
	Monitoring responsibilities are assigned	2
	Reporting frequency is specified	2
	A plan revision/update schedule is included	2
	Performance indicators related to heat and/or health outcomes are provided	2
	Maximum domain score (F)	10 points
TOTAL (HP score)=HP1+HP2+HP3+HP4+HP5+HP6		100 points
Heat Preparedness Index (HPI)=HP score/100		1

[1] Heat mitigation policies included urban greening, blue-green infrastructure, cool materials, building energy efficiency, sustainable mobility, climate-sensitive urban design, and heat-responsive urban regeneration. [2] Heat management policies included heat-health early warning systems, cooling centres, protection of vulnerable populations, health response protocols, public risk communication, occupational heat measures, public cooling infrastructure, energy assistance, and inter-agency emergency coordination during heatwave events. [3] For HP1, HP2, HP5, and HP6, criterion scores were summed directly to obtain the domain score. For HP3 and HP4, each policy was evaluated separately using the corresponding 0–3 policy-maturity scale. The resulting raw scores were standardised to the maximum score assigned to each domain (20 points for HP3 and 30 points for HP4) using the ratio of the observed raw score to the maximum possible raw score.

reflecting their role in translating identified heat risks into long-term preventive measures and operational responses during extreme heat events. The remaining domains capture supporting components of preparedness, including risk recognition, evidence generation, implementation capacity, and monitoring. To minimise interpretive subjectivity, the assessment was conducted using a predefined scoring rubric and consistent decision rules across all municipalities, with scores assigned only to explicitly documented evidence. The HPI reflected the level of heat preparedness embedded within planning documents rather than the implementation or effectiveness of municipal heat policies.

Heat Preparedness Gap Analysis

To evaluate the alignment between municipal preparedness and estimated heat-related risk, HPG analysis was conducted by comparing the HPI and the HRI. As both indices were normalised to a common 0–1 scale, the HPG was calculated as their difference (Equation 2). Positive HPG values indicate higher preparedness relative to estimated heat-related risk, whereas negative values indicate comparatively lower preparedness relative to risk. The HPG should therefore be interpreted as a relative index-based measure of risk–preparedness alignment rather than as an absolute measure of whether preparedness is sufficient to offset heat risk.

$$\mathrm{HPG} = HPI - HRI \qquad \text{Equation 2}$$

To further assess the relationship, municipalities were positioned within a Risk–Preparedness Matrix (Table 4) according to their HRI and HPI values. Median HRI and HPI values were used as thresholds to classify municipalities into four strategic profiles: Critical Priority (high risk–low preparedness), Adaptation Leaders (high risk–high preparedness), Emerging Concern (low risk–low preparedness), and Preparedness Leaders (low risk–high preparedness). This classification enabled balanced comparisons among municipalities while also supporting domain-level analyses to identify priority areas for improving municipal heat preparedness.

Table 4. Heat Risk–Preparedness Matrix and strategic municipal profiles

Heat Risk	Heat Preparedness: Low	Heat Preparedness: High
High	Critical Priority	Adaptation Leaders
Low	Emerging Concern	Preparedness Leaders

RESULTS

Heat Risk Profiles

The results revealed substantial spatial variation in urban heat risk across the 21 MMs (Table A2, Table A3, Table 5, Figure A1, Figure A2). The HEI exhibited the greatest variability, ranging from 0.01 in Trabzon to 0.94 in Şanlıurfa. The highest exposure levels were recorded in Şanlıurfa (0.94), Diyarbakır (0.74), İzmir (0.57), Muğla (0.54), and Denizli (0.51), whereas Trabzon (0.01), Erzurum (0.18), Sakarya (0.19), and Van (0.23) recorded the lowest values.

Compared with HEI, the HSI showed relatively limited variation (0.28 to 0.47). The highest HSI values were observed in Şanlıurfa (0.47), Malatya (0.45), İzmir (0.43), and Mersin (0.43), whereas Ankara, Erzurum, Kocaeli, and Sakarya recorded the lowest values. The ACI ranged from 0.12 in Şanlıurfa to 0.68 in Ankara. The highest ACI values were recorded in Ankara (0.68), Istanbul (0.63), İzmir (0.56), Erzurum (0.56), and Trabzon (0.54), while Şanlıurfa (0.12), Diyarbakır (0.24), and Tekirdağ (0.27) exhibited the lowest adaptive capacity. The integrated HRI ranged from 0.28 to 0.76. Şanlıurfa recorded the highest overall heat risk (0.76), followed by Diyarbakır (0.63), Denizli (0.51), Mersin (0.49), İzmir (0.48), Muğla (0.48), and Tekirdağ (0.48). Trabzon (0.28) and Erzurum (0.30) exhibited the lowest HRI values.

Heat Preparedness of Municipalities

HP levels varied considerably across municipalities, with HPI values ranging from 0.57 to 0.89 (mean=0.70), indicating an overall moderate level of preparedness (Table 6, Figure A1). Only two municipalities—Istanbul (0.89) and Mersin (0.86)—achieved Very High preparedness category, while Malatya, Eskişehir, and Konya were classified as High. Eleven municipalities exhibited Moderate preparedness, whereas Ankara, Balıkesir, Denizli, Erzurum, and Trabzon were classified as Low.

A comparison of the six preparedness domains revealed notable differences in municipal performance. The highest

Table 5. Comparative HPG profiles

Cities	HEI	HSI	ACI	HRI	HPI	HPG
Ankara	0.34	0.28	0.68	0.31	0.57	0.26
Antalya	0.44	0.33	0.47	0.43	0.69	0.26
Balıkesir	0.35	0.38	0.40	0.44	0.64	0.20
Bursa	0.29	0.31	0.39	0.41	0.70	0.29
Denizli	0.51	0.38	0.38	0.51	0.58	0.07
Diyarbakır	0.74	0.39	0.24	0.63	0.73	0.10
Erzurum	0.18	0.28	0.56	0.30	0.60	0.30
Eskişehir	0.30	0.39	0.50	0.40	0.77	0.37
Istanbul	0.39	0.41	0.63	0.39	0.89	0.50
Izmir	0.57	0.43	0.56	0.48	0.72	0.24
Kayseri	0.25	0.35	0.39	0.40	0.68	0.28
Kocaeli	0.26	0.28	0.50	0.34	0.73	0.39
Konya	0.34	0.36	0.45	0.42	0.76	0.34
Malatya	0.36	0.45	0.51	0.43	0.80	0.37
Mersin	0.41	0.43	0.37	0.49	0.86	0.37
Muğla	0.54	0.31	0.42	0.48	0.69	0.21
Sakarya	0.19	0.28	0.30	0.39	0.66	0.27
Şanlıurfa	0.94	0.47	0.12	0.76	0.69	-0.07
Tekirdağ	0.43	0.30	0.27	0.48	0.69	0.21
Trabzon	0.01	0.36	0.54	0.28	0.64	0.36
Van	0.23	0.37	0.33	0.42	0.71	0.29

Table 6. Comparative HP scores of municipalities

	City	HP1	HP2	HP3	HP4	HP5	HP6	HPI	Preparedness Level*
1	Ankara	7	11	14	6	12	7	0.57	Low
2	Antalya	8	12	15	13	13	8	0.69	Moderate
3	Balıkesir	7	11	14	12	13	7	0.64	Low
4	Bursa	8	12	15	13	14	8	0.70	Moderate
5	Denizli	7	10	13	8	13	7	0.58	Low
6	Diyarbakır	8	13	15	15	14	8	0.73	Moderate
7	Erzurum	6	11	13	10	13	7	0.60	Low
8	Eskişehir	8	14	17	15	14	9	0.77	High
9	Istanbul	10	15	18	21	15	10	0.89	Very High
10	Izmir	8	13	16	13	14	8	0.72	Moderate
11	Kayseri	7	12	14	13	14	8	0.68	Moderate
12	Kocaeli	7	13	16	14	15	8	0.73	Moderate
13	Konya	8	13	16	15	15	9	0.76	High
14	Malatya	9	14	17	17	14	9	0.80	High
15	Mersin	10	15	18	19	15	9	0.86	Very High
16	Muğla	8	12	15	13	13	8	0.69	Moderate
17	Sakarya	7	11	14	12	14	8	0.66	Moderate
18	Şanlıurfa	9	13	14	11	14	8	0.69	Moderate
19	Tekirdağ	7	12	15	13	14	8	0.69	Moderate
20	Trabzon	8	13	15	10	12	6	0.64	Low
21	Van	7	13	15	14	14	8	0.71	Moderate
Average scores		8	13	15	13	14	8	0.70	

* Preparedness levels were defined for descriptive interpretation using rounded thresholds aligned with the natural breaks observed in the HPI distribution: Very High (HPI ≥ 0.85), High (0.75 ≤ HPI < 0.85), Moderate (0.65 ≤ HPI < 0.75), and Low (HPI < 0.65).

average scores were recorded for Evidence Base and Vulnerability Assessment (HP2; mean=13/15), Heat Mitigation Policies (HP3; mean=15/20), and Implementation Capacity (HP5; 14/15). In contrast, Heat Management Policies (HP4) received the lowest average score (13/30), indicating comparatively limited attention to operational heat response measures within municipal plans. Substantial inter-city variation was also observed. Istanbul and Mersin demonstrated consistently high performance across all domains, whereas municipalities classified as having Low preparedness generally achieved lower scores in the Heat Management Policies domain, resulting in lower overall HPI values.

Heat Risk–Preparedness Gap

The HPG ranged from −0.07 to 0.50 (Table 5, Figure A1). Positive values indicate comparatively higher preparedness relative to estimated heat risk, whereas negative values indicate a preparedness deficit relative to risk. Istanbul exhibited the largest positive gap (0.50), followed by Kocaeli (0.39), Eskişehir (0.37), Malatya (0.37) and Mersin (0.37). Şanlıurfa was the only municipality with a negative HPG (−0.07). Heat Risk–Preparedness Matrix (Figure 2) classified municipalities into four strategic profiles. Four municipalities (Bursa, Eskişehir, Istanbul, and Kocaeli) were classified as Preparedness Leaders, while Diyarbakır, İzmir, Konya, Malatya, Mersin, and Van were identified as Adaptation Leaders. The Emerging Concern profile included Ankara, Erzurum, Kayseri, Sakarya, and Trabzon, whereas Antalya, Balıkesir, Denizli, Muğla, Şanlıurfa, and Tekirdağ were classified as Critical Priority municipalities.

DISCUSSION

Distinct Heat Preparedness Pathways

MMs in Türkiye do not follow a single pathway of heat preparedness. Although 20 of the 21 municipalities had positive HPG values, indicating relatively higher preparedness scores in relation to the comparative risk index, the degree of risk–preparedness alignment varied considerably across cities. Municipalities experiencing comparable levels of heat risk often exhibited markedly different preparedness

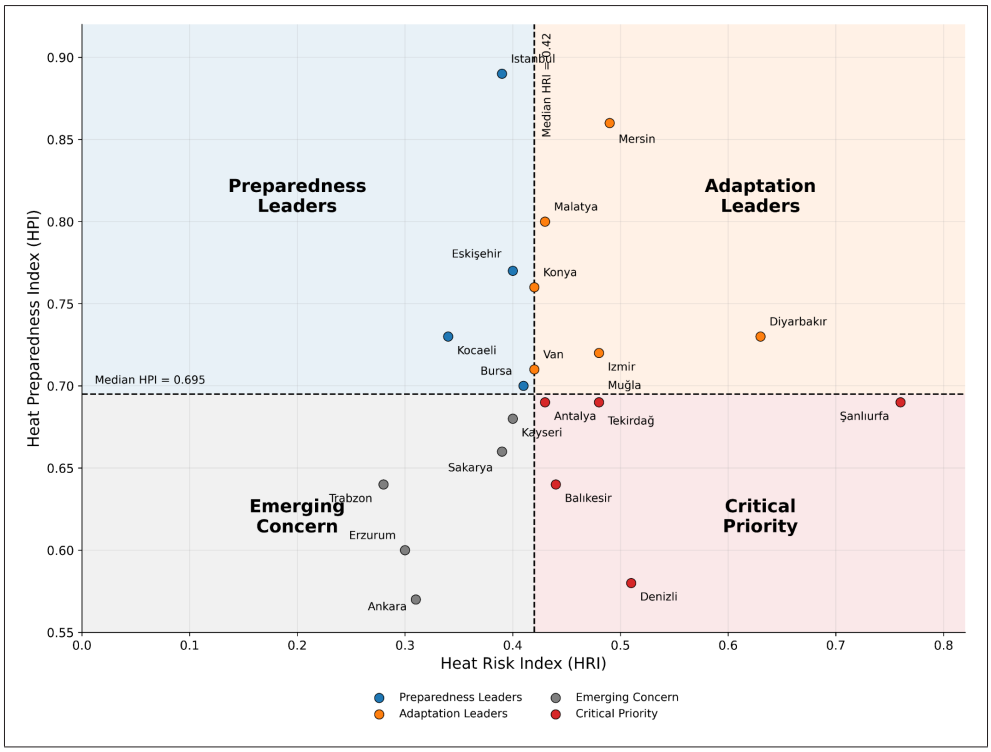

Figure 2. Heat Risk–Preparedness Matrix of municipalities classified using median HRI and HPI values, resulting in four strategic municipal profiles.

capacities, indicating that preparedness is shaped not only by climatic conditions but also by differences in planning approaches, documented governance arrangements, and the integration of heat adaptation into local policy frameworks. This finding is consistent with the broader climate adaptation literature, which emphasises that local adaptive capacity is shaped by institutional arrangements, governance structures, resource availability, and the extent to which climate considerations are mainstreamed into municipal planning (Gori Nocentini, 2024; Grafakos et al., 2020; Rogers et al., 2023).

The institutional context of the planning instruments evaluated also warrants consideration when interpreting differences in documented preparedness. SECAPs follow the standardised methodology, including baseline emission inventories, climate risk and vulnerability assessments, mitigation and adaptation actions, and periodic monitoring (Bertoldi, 2018; Davide et al., 2025). IDEPs, by contrast, have developed within Türkiye's evolving national and local climate governance context, which has recently been formalised through the YİDEP regulatory framework (Regulation on Local Climate Change Action Plans (YİDEP) and Provincial Climate Change Coordination Boards, 2026). Nevertheless, the two instruments can substantially overlap in their substantive scope, particularly in incorporating greenhouse gas inventories, climate risk and vulnerability assessments, and mitigation and adaptation actions. The distinction between plan types should therefore not be interpreted as an inherent hierarchy of preparedness. Rather than assigning preparedness on the basis of plan type, the HPI evaluates the heat-specific content documented within each plan, including risk assessment, mitigation and management measures, implementation capacity, and monitoring. At the same time, differences in institutional context, methodological guidance, and reporting requirements may influence how these components are articulated within individual plans. These differences should therefore be considered as contextual factors when interpreting cross-municipal variation in HPI scores.

The four preparedness profiles further illustrate these divergent pathways. Preparedness Leaders and Adaptation Leaders exhibited very similar average preparedness levels (HPI ≈ 0.77 and 0.76, respectively), despite markedly different risk profiles. Adaptation Leaders combined higher climatic exposure and demographic sensitivity with lower adaptive capacity, resulting in higher overall heat risk despite comparable preparedness. A complementary pattern emerged for Emerging Concern and Critical Priority municipalities: although both exhibited comparatively limited preparedness, Critical Priority municipalities were characterised by substantially higher heat exposure and lower adaptive capacity. These contrasts demonstrate that the observed profiles reflect different configurations of exposure, sensitivity, adaptive capacity, and preparedness rather than climatic exposure alone.

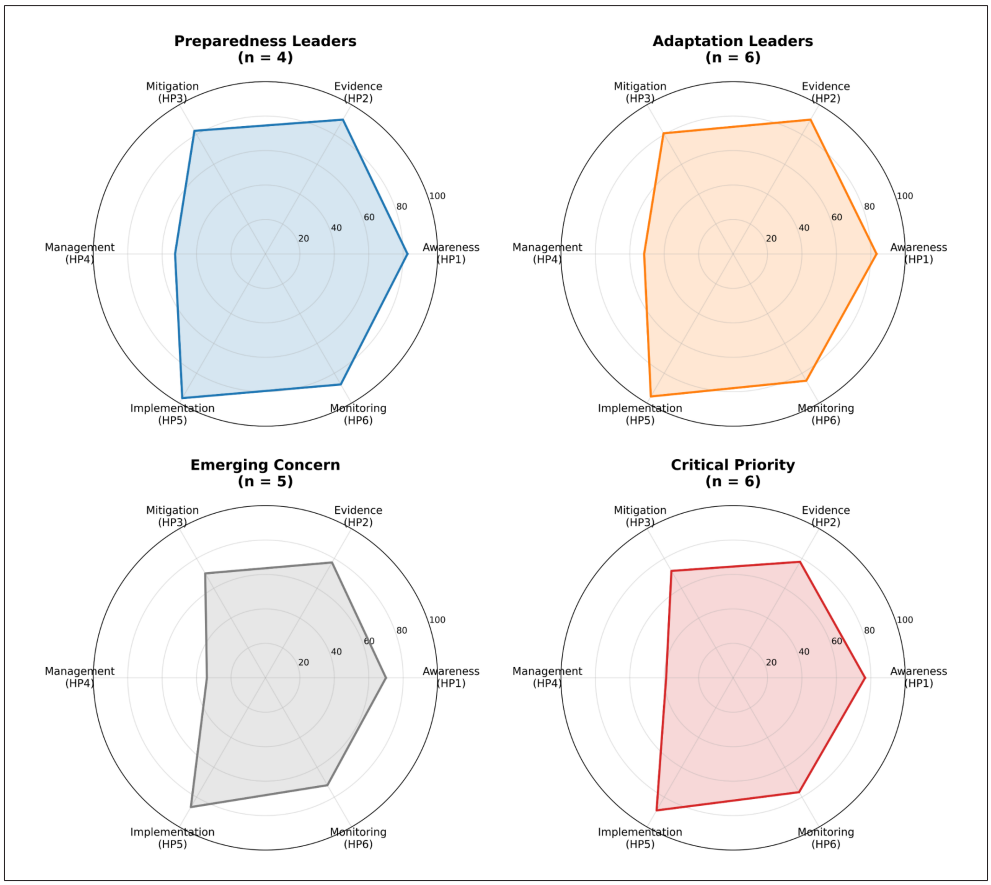

Figure 3. Domain-specific preparedness patterns across the four profiles identified through the Heat Risk–Preparedness Matrix. Radar charts present the mean normalised preparedness scores (%) for the six HPI domains within each profile. Domain scores were normalised by the maximum possible score of each domain before averaging across municipalities.

Among municipalities on the high-risk side of the matrix, preparedness further differentiated Adaptation Leaders from Critical Priority municipalities, with the former showing stronger performance particularly in evidence and vulnerability assessment and operational heat management. Şanlıurfa illustrates the most pronounced mismatch, combining the highest heat exposure, highest sensitivity, and lowest adaptive capacity with only moderate preparedness, resulting in the only negative HPG. Strengthening operational heat governance, including HAPs, heat-health early warning systems, and targeted protection for vulnerable populations, is therefore particularly important for municipalities where high risk coincides with limited preparedness. Despite marked differences in heat risk between Preparedness Leaders and Adaptation Leaders, their domain-specific preparedness profiles (Figure 3) are remarkably similar. Together, these patterns reinforce the importance of institutional and governance capacities in shaping how municipalities prepare for and respond to heat risk (Keith et al., 2023; Rogers et al., 2025; Zhang et al., 2024).

Beyond differences in overall preparedness, the domain-specific preparedness profiles (Figure 3) reveal a remarkably consistent structural pattern: operational heat management was consistently the lowest-scoring preparedness domain across all four profiles, while substantially higher scores were observed for awareness, evidence generation, mitigation, implementation, and monitoring. Climate plans commonly recognised heat-related risks and proposed broad mitigation strategies, yet comparatively few incorporated dedicated HAPs, heat-health early warning systems, cooling centres, protocols for vulnerable populations, or heat-specific emergency response procedures. The consistency of this structural imbalance across profiles suggests that this domain represents a systemic gap in municipal preparedness rather than an isolated weakness confined to specific municipalities. This operational gap may also reflect broader implementation constraints. Municipalities in Türkiye differ in their fiscal capacity and rely to varying degrees on intergovernmental transfers, a substantial component of which is linked to population size (Kiziltan & Yereli, 2023; Neyapti & Oluk, 2021). These structural conditions may affect the resources available for translating

strategic commitments into operational heat-management measures. However, as these relationships were not directly tested in the study, they should be interpreted as contextual factors rather than as demonstrated drivers of HP4 performance. This pattern is consistent with international evidence showing that, despite growing recognition of extreme heat in climate adaptation planning, the translation of strategic commitments into operational heat-response mechanisms remains uneven across cities (Boehnke, 2025; Holtan et al., 2026; Rose & Göçmen, 2025).

From Climate Adaptation to Heat Governance

The findings suggest that a fundamental shift is required in the way municipalities conceptualise and operationalise urban heat adaptation. Although most municipalities have incorporated heat-related issues into broader climate adaptation agendas, preparedness remains primarily framed within long-term environmental planning rather than as an operational public health and emergency management challenge. This pattern is consistent with the higher preparedness scores observed for evidence generation, heat mitigation, and implementation capacity, compared with the consistently lower performance of operational heat management. Consequently, municipalities appear to be more effective at identifying heat risks and proposing urban cooling strategies than at establishing governance mechanisms capable of protecting populations during extreme heat events.

This reflects an important distinction between climate adaptation and heat governance. Climate adaptation primarily aims to enhance the long-term resilience of urban systems through measures such as urban greening, ecosystem-based adaptation, energy-efficient buildings, sustainable mobility, and climate-sensitive spatial planning (Cui et al., 2024; S. Ren et al., 2025; Santamouris, 2020). While these interventions reduce future heat exposure, they do not necessarily ensure protection during individual heatwave events. By contrast, heat governance integrates urban planning with public health, emergency management, meteorological services, and social welfare to establish coordinated operational responses to acute heat-related risks (Keith et al., 2023; WHO, 2026).

Within this broader landscape of heat action planning, Heat–Health Action Plans (HHAPs), as promoted by the World Health Organization, place particular emphasis on protecting population health through coordinated preparedness and response (WHO, 2008, 2026). International experience demonstrates that effective heat governance depends not only on reducing urban temperatures but also on operational measures such as heat-health early warning systems, cooling centres, surveillance of heat-related illness, targeted risk communication, occupational heat protection, and clearly defined institutional responsibilities. The comparatively low scores for the Heat Management Policies domain indicate that these operational components remain underdeveloped across Turkish MMs, regardless of their overall preparedness level.

The findings suggest that municipalities in Türkiye have made substantial progress in the first phase of heat adaptation by recognising heat as a climate-related planning issue. The next phase should focus on institutionalising operational heat governance, where preparedness is assessed not only by the existence of adaptation strategies but also by the capacity to anticipate, coordinate, and respond effectively to extreme heat events. The recently adopted YİDEP Regulation (Regulation on Local Climate Change Action Plans (YİDEP) and Provincial Climate Change Coordination Boards, 2026) represents an important institutional step in this direction by establishing a more systematic framework for climate risk assessment, implementation, monitoring, and cross-sectoral coordination at the provincial level. However, these provisions do not in themselves guarantee heat-specific operational preparedness. The emerging YİDEP framework therefore provides an important opportunity to translate strategic climate planning into operational heat governance through stronger integration of spatial planning, public health, emergency management, and social protection.

Policy Implications

The Heat Risk–Preparedness Matrix provides a practical framework for prioritising municipal interventions according to both existing heat risk and preparedness capacity. Rather than applying uniform adaptation strategies, the findings support a differentiated policy approach tailored to each preparedness profile. For Critical Priority municipalities, the immediate priority should be establishing the core components of operational heat governance, including HHAPs, heat-health early warning systems, cooling centres, targeted communication for vulnerable populations, and stronger integration of public health agencies within municipal emergency management systems (WHO, 2026). Given their comparatively high heat risk, delays in implementing these measures may leave vulnerable populations insufficiently protected during extreme heat events.

Municipalities classified as Emerging Concern should prioritise anticipatory adaptation by strengthening institutional coordination, incorporating heat considerations into urban planning, and developing operational response protocols before heat risk intensifies. In contrast, Adaptation Leaders should build on their existing planning capacity by reinforcing cross-sectoral coordination among planning, public health, meteorological, and emergency management agencies, with greater emphasis on protecting vulnerable populations during extreme heat events. Preparedness Leaders are well positioned to focus on continuous improvement and innovation through initiatives such as digital heat risk dashboards, neighbourhood-scale heat monitoring, AI-supported early warning systems, and systematic evaluation of adaptation effectiveness. They may also play an important

role in disseminating good practices and supporting capacity building across municipalities with lower preparedness.

Notably, the governance requirements introduced by the YİDEP Regulation closely correspond to several dimensions of the HPI developed in this study—particularly evidence-based risk assessment (HP2), implementation capacity (HP5), and monitoring and updating (HP6). This correspondence suggests that the proposed framework may also provide a useful benchmark for evaluating the heat-specific preparedness of future YİDEPs. However, the Regulation does not explicitly require heat-specific operational mechanisms such as HAPs, cooling centres, or dedicated protocols for heat-vulnerable populations. This is particularly important given that Heat Management Policies (HP4) emerged as the weakest preparedness domain across all four municipal profiles. The effectiveness of the emerging YİDEP framework for extreme heat will therefore depend on whether its broader climate-governance requirements are translated into heat-specific operational mechanisms linking spatial planning, public health, disaster risk reduction, and emergency management. More fundamentally, municipal heat preparedness should be evaluated not by the existence of climate adaptation plans alone, but by the operational capacity to anticipate, coordinate, and respond effectively to extreme heat events.

Limitations and Future Research

The analysis covered 21 MMs for which relevant climate planning instruments were publicly available, and the HPI captures preparedness as documented in these plans rather than their actual implementation or effectiveness. Although the HPI applies a common heat-specific assessment framework across planning instruments, differences in the institutional contexts, methodological guidance, and reporting structures of SECAPs and IDEPs may influence how preparedness components are documented and should therefore be considered when interpreting cross-municipal comparisons. The HRI provides a comparative assessment at the metropolitan scale and therefore does not represent intra-urban variations in heat risk. Although the use of standardised indicators, equal weighting, and median-based thresholds provides a transparent basis for comparison, alternative indicator selections, weighting schemes, or classification thresholds may influence relative municipal positions. Future research could extend the framework to incorporate evidence on policy implementation and outcomes, examine the influence of different planning frameworks on documented heat preparedness, and test the sensitivity of municipal classifications to alternative weighting and threshold specifications.

CONCLUSION

Extreme heat is emerging as one of the most significant climate-related threats to cities, yet whether municipal preparedness is commensurate with local heat risk remains poorly understood. This study addressed this gap by developing an HPI and applying it to 21 MMs in Türkiye through a systematic evaluation of municipal climate-related planning documents across six preparedness domains. By integrating the HPI with a multidimensional HRI, the study provides a novel framework for assessing the alignment between urban heat risk and municipal preparedness. Unlike conventional assessments of heat risk or adaptation planning in isolation, the HPG framework integrates these dimensions to identify relative mismatches between municipal preparedness and heat risk.

The findings demonstrate considerable variation in municipal preparedness across Türkiye, reflecting different configurations of heat risk, planning capacity, and documented governance arrangements. The Heat Risk–Preparedness Matrix identified four distinct preparedness profiles, demonstrating that municipalities follow multiple pathways towards heat resilience rather than a single adaptation trajectory. A key finding is that Turkish MMs have largely succeeded in integrating heat into climate adaptation planning but have made less progress in developing operational heat governance. Across all preparedness profiles, Heat Management Policies consistently represented the weakest preparedness domain, indicating that operational measures remain underdeveloped regardless of overall preparedness level. This suggests that the principal challenge is no longer recognising heat as a climate adaptation issue but translating strategic planning into operational systems capable of protecting populations during extreme heat events.

In Türkiye, the newly introduced YİDEP framework provides an immediate institutional context in which the proposed approach could be applied to assess whether emerging local climate plans translate broader climate-governance requirements into heat-specific preparedness. Beyond the Turkish context, the proposed framework provides a transferable approach for evaluating municipal heat preparedness using existing planning documents and identifying mismatches between heat risk and preparedness across different institutional and climatic contexts. As climate change continues to amplify extreme heat, future urban resilience will depend not only on reducing long-term heat exposure but also on strengthening the governance capacity to anticipate, coordinate, and respond effectively to heat-related emergencies.

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APPENDICES

Table A1. Operational definitions of heat exposure indicators

Mathematical definition	Variable definitions
$HE1 = \frac{1}{N}\sum_{i=1}^{N} T_{mean,i}$	=hourly near-surface air temperature. =the total number of summer observations.
$T_{95} = P_{95}(T_{max})$ $HE2 = \sum HW_d$	=the 95th percentile of the daily maximum temperature distribution for the 2020–2025 period. =The local threshold for each grid cell. if day belonged to a heatwave sequence and otherwise.
$HE3 = \sum I(T_{min} > 20℃)$	=an indicator function equal to one when the condition is satisfied and zero otherwise.
$HE4 = \sum I(T_{max} > 35℃)$	=indicator function equal to one when Tmax > 35°C, otherwise zero.
$HE5 = \max(T_{\max})$	Maximum daily maximum air temperature recorded during the summer period.
$CDD_d = \max(T_{mean,d} - 22)$ $HE6 = \sum_{d=1}^{n} CDD_d$	=for each day. HE6=total Cooling Degree Days

Table A2. Normalised values of heat exposure and adaptive capacity indicators

Cities	HE1	HE2	HE3	HE4	HE5	HE6	AC1	AC2	AC3	AC4	AC5	AC6
Ankara	0.39	0.72	0.07	0.07	0.60	0.16	0.15	0.65	1.00	1.00	0.77	0.52
Antalya	0.50	0.84	0.40	0.12	0.47	0.30	0.52	0.39	0.62	0.48	0.48	0.33
Balıkesir	0.44	0.58	0.23	0.05	0.61	0.18	0.68	0.20	0.55	0.24	0.24	0.49
Bursa	0.38	0.45	0.20	0.03	0.56	0.14	0.71	0.35	0.52	0.30	0.23	0.23
Denizli	0.58	0.94	0.34	0.24	0.61	0.36	0.42	0.40	0.48	0.36	0.39	0.21
Diyarbakır	0.85	0.58	0.68	0.75	0.85	0.71	0.13	0.55	0.22	0.21	0.26	0.06
Erzurum	0.00	0.94	0.00	0.00	0.16	0.01	0.26	0.42	0.40	0.52	1.00	0.79
Eskişehir	0.39	0.47	0.05	0.09	0.66	0.15	0.25	0.47	0.74	0.48	0.65	0.42
Istanbul	0.48	0.42	0.68	0.01	0.54	0.21	0.70	0.35	0.76	0.58	0.35	1.00
Izmir	0.65	0.77	0.62	0.29	0.68	0.43	0.59	0.32	0.74	0.67	0.43	0.63
Kayseri	0.21	0.80	0.02	0.02	0.40	0.06	0.10	0.63	0.48	0.42	0.46	0.24
Kocaeli	0.39	0.23	0.26	0.01	0.55	0.12	0.84	0.13	0.60	0.24	0.24	0.98
Konya	0.41	0.72	0.12	0.06	0.54	0.18	0.11	0.70	0.40	0.42	0.62	0.44
Malatya	0.46	0.63	0.16	0.13	0.54	0.24	0.14	0.60	0.48	0.39	0.84	0.60
Mersin	0.47	0.81	0.40	0.07	0.48	0.26	0.36	0.44	0.50	0.24	0.26	0.39
Muğla	0.63	0.70	0.67	0.21	0.62	0.43	0.67	0.29	0.73	0.33	0.21	0.27
Sakarya	0.31	0.21	0.13	0.01	0.42	0.07	0.88	0.11	0.43	0.21	0.10	0.06
Şanlıurfa	1.00	0.61	1.00	1.00	1.00	1.00	0.11	0.58	0.00	0.00	0.00	0.00
Tekirdağ	0.53	0.67	0.50	0.05	0.56	0.25	0.38	0.27	0.42	0.12	0.26	0.19
Trabzon	0.00	0.00	0.05	0.00	0.00	0.00	1.00	0.00	0.58	0.52	0.68	0.47
Van	0.14	1.00	0.05	0.00	0.16	0.03	0.00	1.00	0.15	0.18	0.27	0.36

Table A3. Normalised values of heat sensitivity indicators

Cities	HS1	HS2	HS3	HS4	HS5	HS6	HS7	HS8	HS9	HS10	HS11	HS12
Ankara	0.07	0.39	0.06	0.41	0.21	0.00	0.00	0.51	0.76	0.51	0.32	0.16
Antalya	0.04	0.37	0.09	0.04	0.22	0.25	0.29	0.66	0.65	0.82	0.32	0.20
Balıkesir	0.02	1.00	0.00	0.00	0.02	0.39	0.37	0.87	0.00	0.75	1.00	0.13
Bursa	0.10	0.45	0.13	0.46	0.09	0.36	0.30	0.40	0.33	0.50	0.47	0.19
Denizli	0.02	0.61	0.07	0.08	0.02	0.43	0.46	0.68	0.66	0.77	0.60	0.18
Diyarbakır	0.03	0.06	0.58	0.55	0.00	0.71	0.85	0.00	0.99	0.34	0.07	0.47
Erzurum	0.00	0.40	0.27	0.17	0.00	0.49	0.56	0.41	0.12	0.11	0.40	0.39
Eskişehir	0.01	0.61	0.00	0.39	0.04	0.13	0.13	1.00	0.79	0.95	0.63	0.06
Istanbul	1.00	0.22	0.07	0.49	1.00	0.19	0.14	0.50	0.67	0.19	0.24	0.16
Izmir	0.12	0.63	0.02	0.71	0.07	0.21	0.23	0.74	0.95	0.74	0.60	0.20
Kayseri	0.02	0.43	0.19	0.16	0.02	0.41	0.37	0.33	0.56	0.88	0.40	0.42
Kocaeli	0.21	0.27	0.18	0.44	0.03	0.25	0.24	0.29	0.55	0.38	0.28	0.21
Konya	0.01	0.46	0.22	0.18	0.04	0.57	0.52	0.33	0.36	0.93	0.40	0.32
Malatya	0.01	0.55	0.15	0.31	0.00	0.39	0.56	0.63	0.96	1.00	0.44	0.43
Mersin	0.03	0.47	0.19	0.30	0.07	0.43	0.49	0.51	1.00	0.91	0.46	0.33
Muğla	0.02	0.69	0.01	0.14	0.04	0.21	0.35	0.90	0.10	0.72	0.56	0.00
Sakarya	0.07	0.49	0.13	0.33	0.04	0.36	0.38	0.43	0.47	0.00	0.50	0.19
Şanlıurfa	0.03	0.00	1.00	0.37	0.01	1.00	1.00	0.00	0.63	0.53	0.06	1.00
Tekirdağ	0.06	0.39	0.13	0.31	0.01	0.42	0.37	0.46	0.11	0.67	0.44	0.19
Trabzon	0.05	0.79	0.08	0.15	0.02	0.27	0.36	0.78	0.94	0.05	0.57	0.24
Van	0.01	0.03	0.54	1.00	0.00	0.79	0.90	0.00	0.16	0.42	0.00	0.56

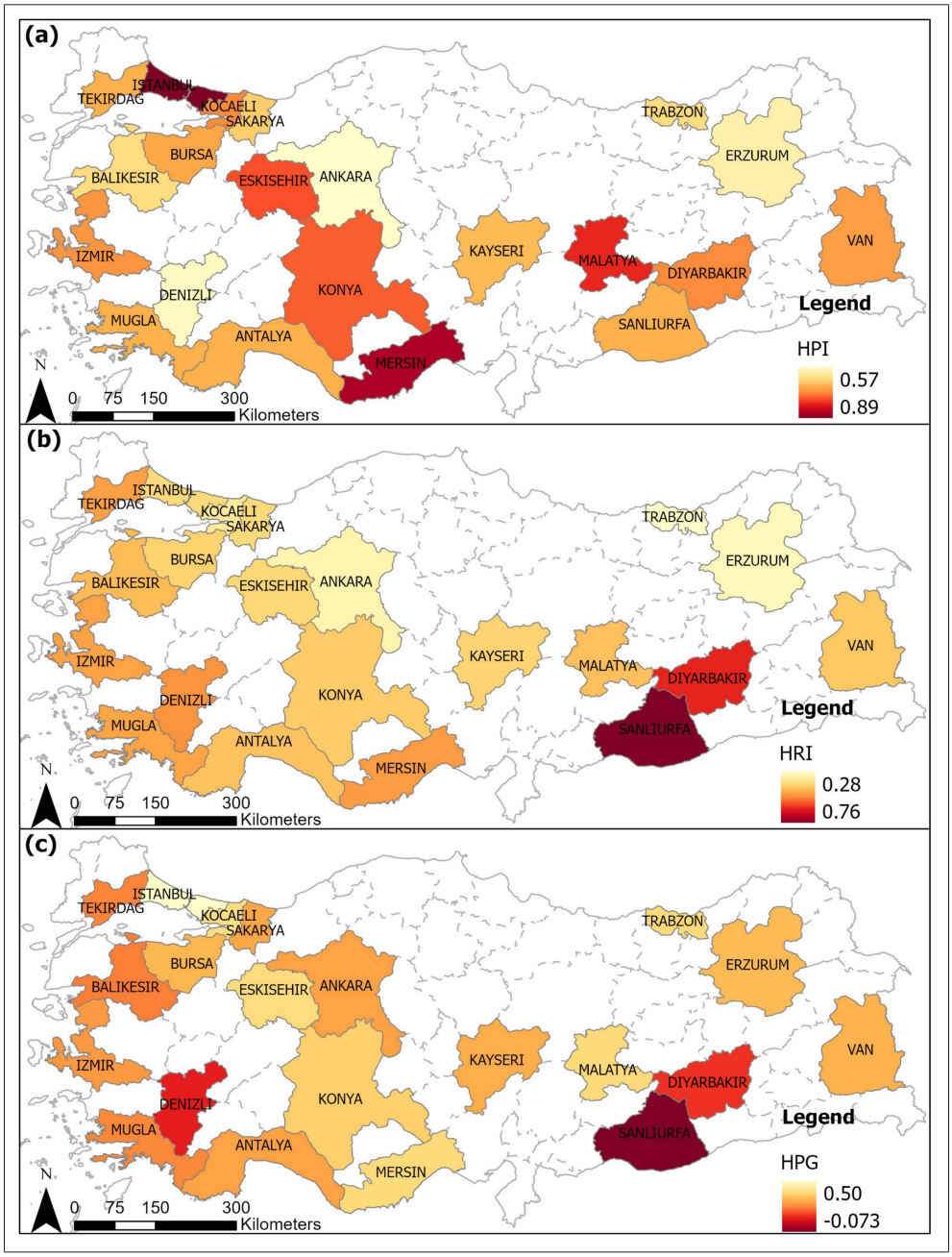

Figure A1. Heat preparedness, risk and gap profiles of MMs.

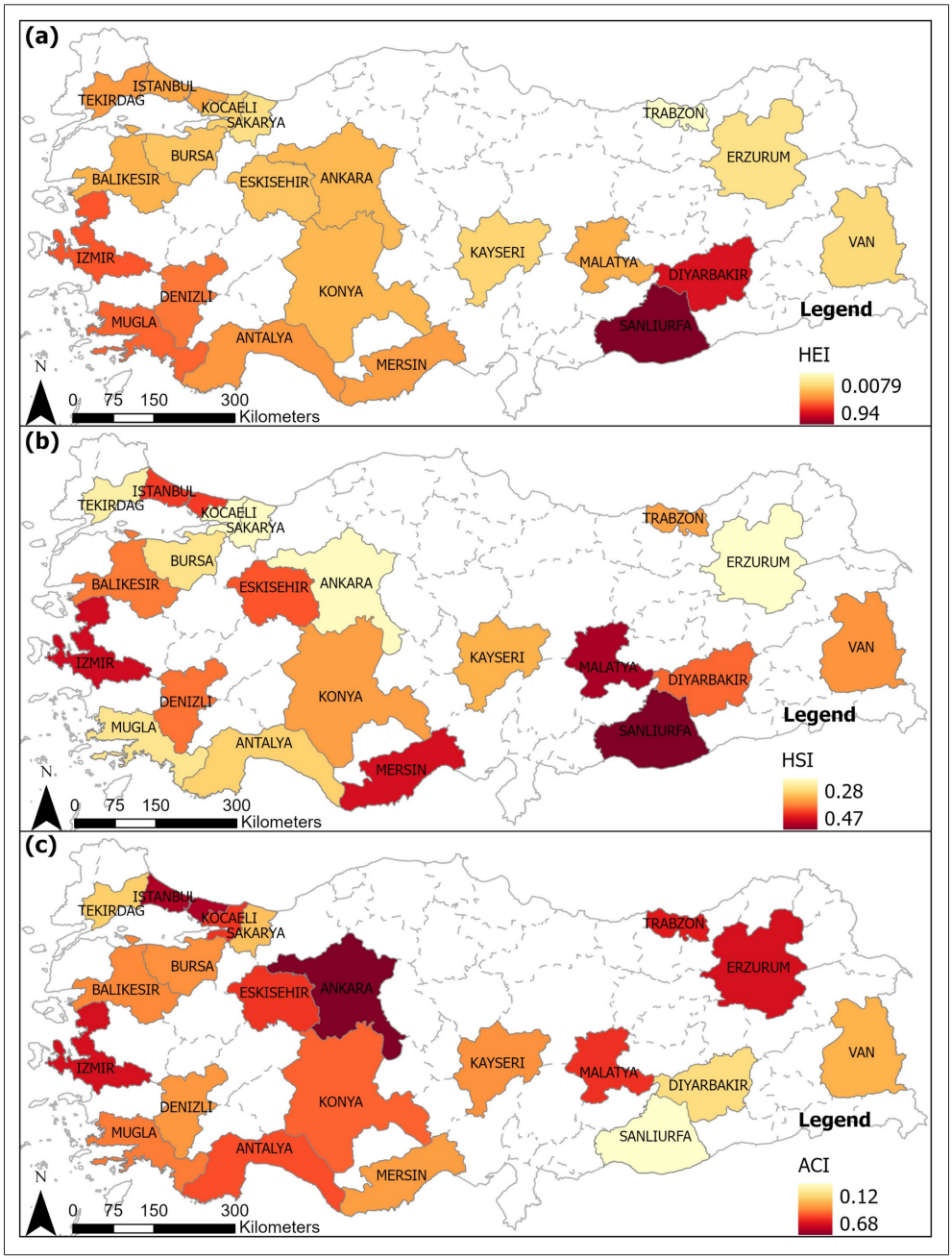

Figure A2. Heat exposure, sensitivity and adaptive capacity profiles of MMs.