

Problem Statement: Modeling Heat-Related Mortality and Adaptation in Switzerland under Climate Change

Problem Background

Switzerland faces a growing public health threat from increasingly frequent and severe heatwaves due to climate change. Record-breaking hot summers occurred in 2003, 2015, 2018, 2019, 2022, and 2023, highlighting heat as a growing threat to public health (FOEN, 2024-a; MENAFN, 2024). These heatwaves have resulted in significant excess mortality, highlighting a serious yet persistent challenge for Swiss public health and climate adaptation policy. In the summer of 2022, Switzerland reported 671 heat-related deaths from June to August, three times higher than the average from the previous decade and with around 60% directly attributed to human-induced climate change (University of Bern, 2022; FOEN, 2024-b, and 715 heat-related deaths in 2023 (FOEN, 2024-b). Future climate scenarios forecast that annual heat-related mortality could quadruple from roughly 300 deaths per year to over 1,200 by mid-century, highlighting the urgent need for more effective interventions (Climate Change Post, n.d.).

Heatwaves differ from typical disasters as they often act as silent killers, increasing heat mortality through direct physiological stress (heatstroke, heat exhaustion) and indirect exacerbation of chronic diseases (cardiovascular conditions, respiratory disorders, diabetes, and dementia (Ragettli et al., 2024).

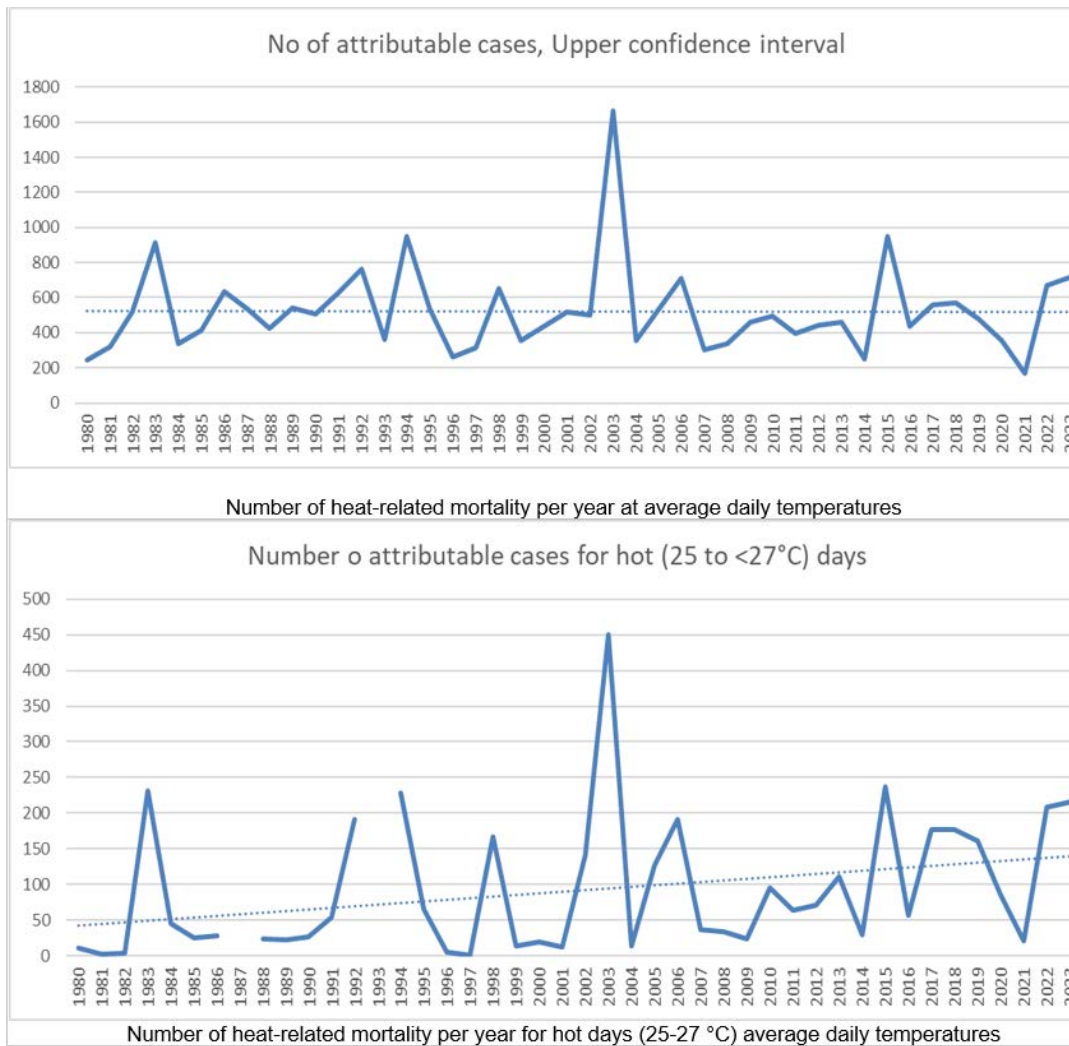
Vulnerability is strongly differentiated demographically and socio-economically. Elderly individuals (particularly over 75), chronically ill patients, and socially isolated populations are consistently identified as most vulnerable. Additionally, elderly women have shown heightened susceptibility due to biological factors such as impaired thermoregulatory capacity (MENAFN, 2024). Furthermore, these vulnerable populations, including socially isolated seniors and economically disadvantaged groups, have limited adaptive capacity and thus bear the brunt of the increasing mortality (Orlando et al., 2021; Osberghaus & Abeling, 2022).

Problem Focus

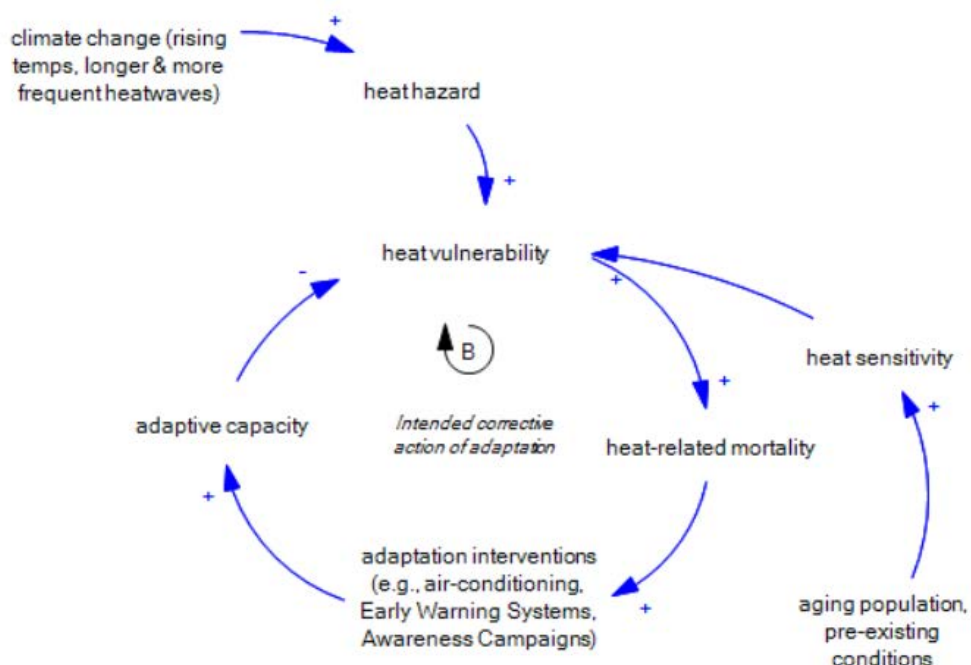
Despite nearly two decades of awareness following the deadly 2003 heatwave, Switzerland's adaptation response remains fragmented. The persistence of high heat-related mortality, despite public awareness and investments in adaptation strategies such as Heat-Health Action Plans (HHAPs) and Early Warning Systems (EWS), indicates a systemic issue within the adaptation policy landscape. Some regions (including major urban centers such as Basel and Zurich) lack comprehensive policies (University of Bern Media Relations, 2023). At a national level, policy inadequacy has been officially recognized, exemplified by the landmark ruling of the European Court of Human Rights in 2024, stating that Switzerland's insufficient climate policy violated the rights of elderly women, emphasizing governmental failures in protecting vulnerable populations (MENAFN, 2024).

Additionally, socio-economic disparities persist as key barriers to effective adaptation. Heat mortality disproportionately affects low-income individuals, isolated elderly persons, and those residing in inadequately insulated homes without cooling capabilities (Ragettli et al., 2024). While indoor temperatures above 24 °C significantly increase mortality risks, many residences, particularly in urban and lower-income areas, regularly exceed this threshold during heatwaves due to inadequate infrastructure and economic barriers to installing air conditioning or effective cooling systems (Ragettli et al., 2024). Biological and demographic factors compound these socio-economic vulnerabilities, with an ageing Swiss population inherently more susceptible to heat stress. In Switzerland, population aged 65+ is projected to reach between 30% and 46% of the total Swiss population by 2060 (Lewis & Ollivaud, 2020; PopulationPyramid, n.d.). Furthermore, heat advisories often fail to reach socially isolated or immigrant populations, perpetuating disparities in heat vulnerability. These combined factors suggest that climate adaptation measures are continually being outpaced by accelerating climate impacts.

Reference mode



The trend for heat-related mortality per year for all average daily temperature is relatively stable, with a slight decrease. However, for hot days (25-27 °C average daily temperature) as illustrated above and very hot days ($\geq 27^\circ\text{C}$) (not illustrated separately), there is an upward trend for heat-related mortality (FOEN, 2024-b). This trend is expected to continue or increase even more due to the **2 driving factors**: heatwaves getting longer, hotter and more frequent due to climate change, which will continue to increase the heat hazard, and the aging Swiss population, which will continue to increase the proportion of people who have higher heat sensitivity, as portrayed in the CLD below. Moreover, **adaptation efforts** seem to have an insufficient effect on adaptive capacity to effectively close the balancing loop, as seen in trends above.



The CLD is based on the Heat Vulnerability Index (HVI), which is most often expressed as a function in which exposure to heat multiplied by sensitivity to heat increases vulnerability, while adaptive capacity decreases it through subtraction (Lagelouze et al., 2024).

Target Audience

Potential audience could be policymakers, public health officials, municipal authorities, and climate adaptation planners in Switzerland.

Model Purpose and Questions

The purpose would be to provide insight into the mechanisms and systemic interactions that sustain heat-related mortality despite existing policy and infrastructural investments, thereby guiding intervention strategies. Potentially this could allow to explore how adaptation policies can be improved to build resilience among vulnerable populations.

To systematically understand and ultimately reduce heat-related deaths, it is crucial to analyze how various factors—climatic, demographic, socio-economic, and policy-related—interact over time.

The model could explore the persistence of heat-related mortality, illuminating feedback loops and leverage points where effective interventions may reduce vulnerability and improve adaptive capacity.

Specifically, the model could aim to answer:

- Why do heat-related mortalities continue to increase despite public awareness and adaptation investments? (potentially three factors: demographics, increasing heat hazard, and insufficient adaptation)
- How do policy gaps at cantonal and national levels contribute to persistent excess deaths during heatwaves?
- What leverage points exist within the system (policy, infrastructure, socio-economic support) to substantially reduce heat-related mortality?
- How do socio-economic inequalities exacerbate vulnerabilities, limiting the effectiveness of adaptation policies? (not sure about this one)

Time Horizon

Given the slow-changing nature of demographic and climatic factors, a suitable time horizon for the model could be approximately 30 years (2025–2055). This timeframe allows examination of medium-to-long-term adaptation policy impacts, climate projections, and demographic trends in aging.

Key Mechanisms and Variables

- **Climate Impact Dynamics:** Rising temperatures, frequency and duration of heatwaves.
- **Population Demographics:** Age distribution, proportion of elderly, socially isolated groups, economically disadvantaged populations, chronically ill populations.
- **Health Dynamics:** Rates of chronic disease exacerbation, heatstroke incidence, mortality rates.
- **Adaptation Policies:** Implementation and coverage of HHAPs, public cooling infrastructure, public awareness campaigns, effectiveness, and regional policy variation (effectiveness, coverage, and disparities in cantonal implementation of HHAPs)
- **Socio-economic Factors:** Accessibility to cooling, housing insulation quality, income levels, social isolation levels.
- **Risk Perception and Behavioral Response:** Public behavior changes driven by public awareness of heat threats, perceived heat risk, responsiveness to advisories and warnings.
- **Infrastructure and Capacity Constraints:** Availability and use of cooling centers, healthcare response capabilities.

Excluded Mechanisms:

- Detailed physiological models at individual scale.
- Short-term emergency response details at a micro-level (e.g., detailed hospital management during heatwaves).
- Economic modeling of adaptation investments beyond broad socio-economic categorizations.

Aggregation and Level of Detail

- The model will employ a relatively high level of aggregation to remain policy-relevant and tractable. It will aggregate data at the cantonal or country level (depends on what data I can find), potentially distinguishing regions by adaptation policy implementation and socio-economic characteristics. Population stocks should explicitly capture vulnerable demographic groups (elderly, socio-economically disadvantaged). Detailed physiological mechanisms will be represented implicitly, with primary emphasis placed on macro-level policy, behavioral, and socio-economic mechanisms.

Sources of Inertia and Stocks

- **Population at Risk:** Elderly, chronically ill, and socially isolated populations. (Size and growth rate of elderly populations vulnerable to heat stress.)

- **Adaptation:**
 - Infrastructure quality (e.g., residential cooling capacity, building insulation quality, urban green space).
 - Implementation and coverage of cantonal and national Heat-Health Action Plans (policy implementation stocks).
- **Social Awareness and Behavioral Change:** Cumulative public awareness, perception and responsiveness to heat risks (risk perception) (behavioral adaptation stocks).

(Each stock represents accumulated historical investments, demographic trends, and social learning processes that significantly influence short-term responses and long-term adaptation potential.)

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