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BLUE ECONOMY
Baltic Sea2Land

EVALUATION OF CLIMATE IMPACTS: AN EXAMPLE[1]

From climate data and local knowledge to climate change impacts: the German case study

Background

Climate change is another important aspect of socio-ecological interactions within the land-sea interface. Anthropogenic impacts from climate change may already be occurring across 80% of the world's land area, where 85% of the population resides (Callaghan et al. 2021). Among others, these impacts are largely driven by changes in variables such as temperature, precipitation or sea-level rise that pose additional pressure on socio-economic and natural systems. Given that tourism is a major economic activity in Fehmarn and is largely concentrated over the summer months, evaluating the additional pressures of climate change on natural resources and people during those months becomes important to define adequate adaptation measures. Furthermore, planning for adaptation is better assisted by having a spatial representation of the expected climate impacts, which in turn allows to identify priority areas for action.

Developments towards making the biophysical spatial data more accessible and frequently updated (e.g. satellite, global-consistent and gap-filled weather data) over the last decade open new possibilities to conduct spatially explicit impact assessments. Although growing amounts of available data are welcome, their potential is only fully unlocked when related to local knowledge and landscape characteristics. In the following sections it is summarized how climate, satellite data and local knowledge were integrated to produce local climate impact maps assisting the exploration of adaptation measures. A set of methods combined into a common analysis framework were applied to evaluate the main climate change impacts – urban heat, water supply and flood risk.

Data collection

Data required for the quantification of climate impacts (see figure below) were obtained from authoritative data sources. These included historical temperature over the summer months from ERA5 reanalysis – ECMWF[2]. Temperature projections over the summer months at Fehmarn were extracted from

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[1] Originally published as a part of: Ruskule, A., Veidemane, K., Pikner, T., Printsmann, A., Palang, H., Arikas, D., Siegel, P., Costa, L., Burow, B., Piwowarczyk, J., Zielinski, T., Romancewicz, K., Koroza, A. 2021: Compendium of methodologies on how to address land-sea interactions and development trade-offs in coastal areas. Interreg Baltic Sea Region Programme funded project "Land-sea interactions advancing Blue Growth in Baltic Sea coastal areas" (R098 Land-Sea-Act).

[2] https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5

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43 models in KNMI's Climate Change Atlas[3] feeding into the Intergovernmental Panel on Climate Change (model results were then averaged over 2030 and 2050). Mean ensemble projection of sea-level change in the Baltic used in AR5[4] with data extracted from the Integrated Climate Data Center at University of Hamburg[5]. Surface temperature data was obtained for the summer of 2020 using Landsat8 data from USGS[6] and approximated to air temperature following the relationship proposed in Mildrexel et al (2011). Local expert knowledge on the maximum and lowest dike height was combined with dike location survey data to infer on the dike heights across the Fehmarn coast. Expert information on the maximum surge height was taken to inform the modelling of flood risk. Data and knowledge on data usage, reservoir capacity and water supply infrastructure bottlenecks from Fehmarn's *Wasserbeschaffungsverband* were used to constrain a statistical model of water supply to Fehmarn under climate change.

Methods and steps for evaluating climate impacts

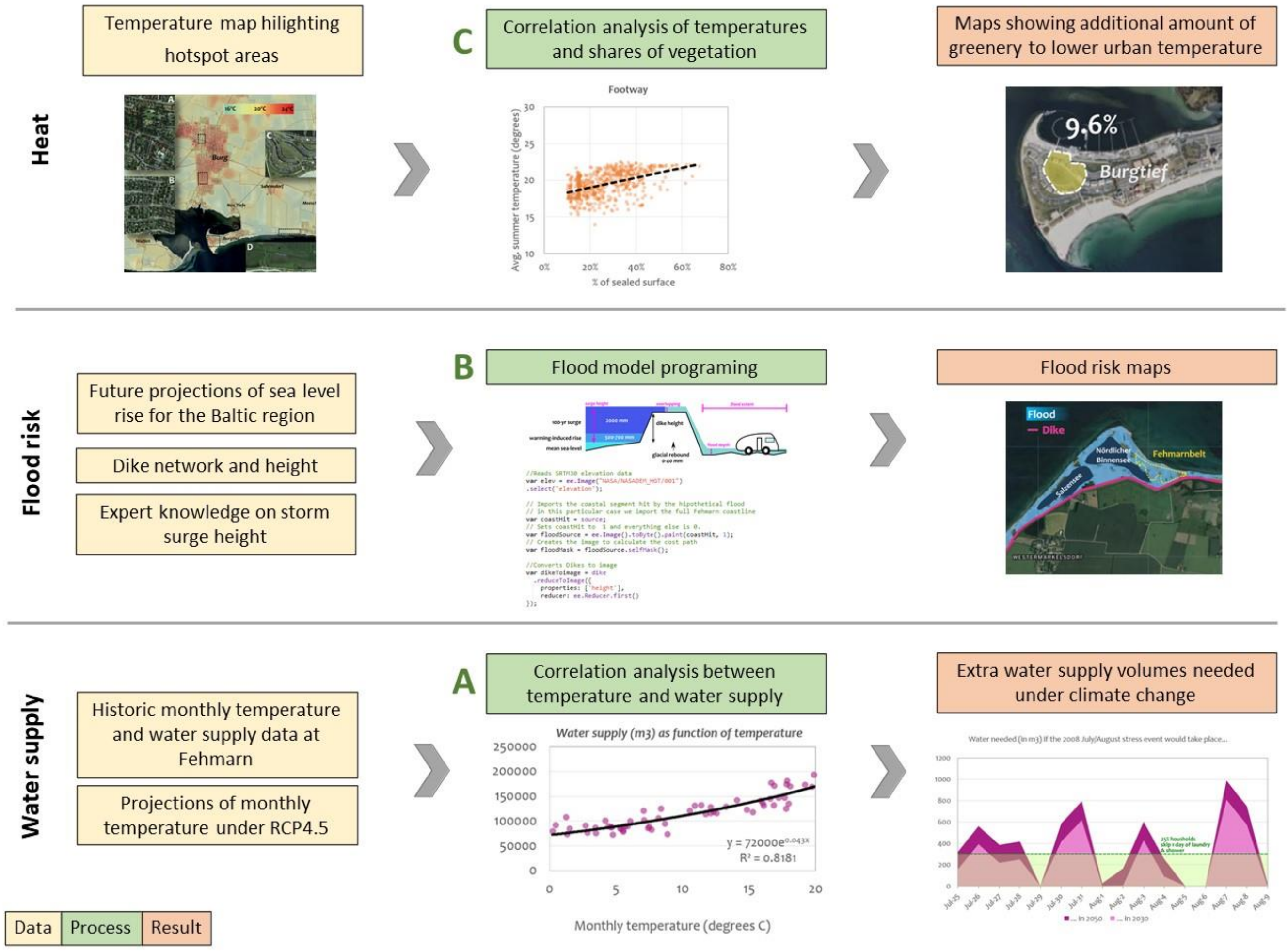
Figure summarises the main analytical steps for the evaluation of climate impacts followed in the Fehmarn case study. Because estimating climate change impacts over diverse areas such as heat, flood risk or water supply, there is no standard methodology that can be applied. Nevertheless, a common analysis framework – reading from left to right in figure – can be appointed consisting of gathering relevant data on climate/weather and relevant socio-economic and landscape features potentially impacted; establishing a quantitative relation between past climatic stresses and the impact of a particular socio-economic or land space dimension (e.g. month temperature vs. water supply, surge height vs. flood level); and finally integrating the future evolution of climate in order to evaluate the impact on socio-economic and natural systems. Within such a framework the most relevant and difficult step is quantifying the relations between a given climate-related variable and the associated socio-economic or landscape impact. For the case of climate change impact on water supply a simple statistical model was established correlating monthly data on temperatures with that of monthly water supply (see A in figure). Water supply and temperature were found to be positively and non-linearly correlated. An exponential function was fitted to the data and found to conveniently reproduce the past (2016–2020) variability of water supply. Following, projected temperature data for the year 2030 and 2050 is introduced in the function which allows estimating additional water volumes in those years to those supplied between 2016–2020.

[3] https://climexp.knmi.nl/plot_atlas_form.py

[4] https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf

[5] https://icdc.cen.uni-hamburg.de/las/getUI.do

[6] https://www.usgs.gov/science-explorer-results?es=Landsat+8



An overview of the analytical steps followed to generate climate impact information

For the case of flood risk, a flood model was conceptualised and programmed in the Google Earth Engine, established incorporating expert data on surge levels, regional sea-level rise, and dike height (see B in figure). Expert knowledge on extreme surge levels at Fehmarn was combined with regional sea-level projections to set the 2100 surge-level height under climate change at 2.7-meters. Inundation according to varying levels of surge heights was simulated with the model. Although a full validation of the model on past flood data was not possible, it was observed that the model highlights flood prone areas in locations previously affected by floods, such as the case of the storm surge in 1989 of about 2.2-meters (Source: Landesregierung Schleswig-Holstein) at Wulfener Hals camping place. Next, flood risk maps under a 2.7-meter surge were derived. Finally, regarding heat, summer air temperatures along the street network of Fehmarn are correlated with land-cover to establish a relation between temperature and percentage of sealed surface (see C in figure). This allows estimating backwards what would be the necessary extra amount of greenery (meaning less sealed surface) to achieve a particular temperature outcome. For the case of Fehmarn, the extra amount of green area needed to lower summer temperatures of locations that are typically above 21 °C in the summer to an average of 20 °C was estimated.

References

Callaghan, M., Schleussner, C.F., Nath, S. et al. 2021: Machine-learning-based evidence and attribution mapping of 100,000 climate impact studies. *Nature Climate Change* 11: 966–972. DOI: https://doi.org/10.1038/s41558-021-01168-6.

Mildrexler, D.J., Zhao, M., Running, S.W. 2011: A global comparison between station air temperatures and MODIS land surface temperatures reveals the cooling role of forests. *Journal of Geophysical Research* 116: G03025. DOI: https://doi.org/10.1029/2010JG001486.