Abstract of Thesis

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Title: Developing a framework for assessing climate change impacts on human health at local and regional levels
(地域ならびに局所を対象とした気候変動による健康リスクの評価枠組みの開発)

Climate change is complex phenomenon that is driven by variables at all scales. Its impacts can be felt at global to local and individual levels. If we consider that there is now almost unanimous consensus among scientists that greenhouse gas accumulation in the atmosphere due to anthropogenic emissions is causing the climate to change (McMichael et al. 2006), the main remaining knowledge gaps concern the extent of this change and, specifically, the impacts that it will have on humans and the environment. This presents a problem when attempting to quantify the impact of climate change on specific health outcomes. Therefore, there is now a requirement to develop methodologies to project the impact of climate change at local levels, considering all potential risk factors and health outcomes (Field et al. 2014). The complexity of climate systems means that results or outputs from an assessment of a risk factor or health outcome in one region are not necessarily applicable to other regions, which may have different environmental, social, economic and infrastructural characteristics. This wide range of spatial variety highlights the need for case based research into climate change impacts. However, as with all risk assessments, it is preferable to have a common framework or methodology upon which to base local studies. Another emerging requirement for climate change impact research is the need to place climate change related health risks in context with other sources of risk. All regions and individuals are faced by multiple risks from different sources. Quantifying the risk that climate risk factors pose to different human health outcomes in a unit that is directly comparable to risks from non-climate sources is, therefore, a useful tool for placing climate related health risks in a multiple risk context. This research aims to develop standardised approaches to quantifying the risk of human induced climate change on health at local and regional levels, using an evolutionary, case-based approach. The final outcome of the research is to provide a methodology which enables climate change related health risks to be quantified in a common risk unit, at a local and regional scale.

A case-based approach is taken to analyse two specific risk factors, which are currently difficult to quantify - infectious diseases and heat waves. Building upon the findings of these two studies and the limitations of the quantification methods used, a framework is proposed to quantify the impact of climate change on health outcomes at a local level. Three main objectives are used to formulate the structure of the research, with a final objective developed to collate the findings into higher level implications for research and policy making in the field of climate change impacts on human health and risk assessment in general. Chapter 1 provides some introduction to climate change and the ways in which it impacts human health. This chapter also describes the problems faced when analysing human health risks from climate change and identifies key research and knowledge gaps. The structure of the study is described and the research questions that it aims to address are explained. In context, this thesis aims to (1) understand the impact of the climate on infectious disease prevalence in two East Asian countries: Japan and the Republic of Korea, with a focus on malaria; (2) determine the variables affecting vulnerability to heat waves and combine and map this vulnerability with heat wave exposure data at a local level; (3) develop a framework that all risk factors and health outcomes can be quantified on the same scale, using Disability Adjusted Life Years (DALYs) as a common unit.

Chapter 2 tackles the first specific objective of understanding the impact of climate on malaria prevalence in Japan and the Republic of Korea includes investigating and comparing past trends of incidence of malaria, the influence of climate, and developing a method to identify areas at risk of re-emergence. The malaria situation in both countries is compared, with reasons for the differences investigated. The link between climatic factors

(mean monthly minimum temperature, mean monthly maximum temperature, monthly precipitation and mean monthly relative humidity) and malaria incidence is statistically analysed in the Republic of Korea. Temperature is identified as the major climatic influence on malaria transmission rates at a monthly level for the study region. Based upon this finding, a biological, temperature dependent model - a base reproduction rate model - is combined with climate model outputs to plot current and future climatic suitability for stable malaria transmission in the study regions. This approach to modelling infectious disease risk is critically assessed.

The second objective is addressed in Chapter 3. This objective is to determine the variables affecting vulnerability to heat waves and to quantify and map these at a local level. The main aim of this Chapter is to produce an output that can be useful for identifying high-risk areas for policy makers and stakeholders. A key facet of this topic is combining a vulnerability assessment with spatial analysis of heat exposure, to provide information that can be used to prioritise countermeasure selection. The analysis is conducted in Osaka City, Japan, to provide real world context and to enable comparison to vulnerability studies in other locations. Principle Component Analysis (PCA) of vulnerability indicators is conducted to construct three principle components determining vulnerability to heat waves. These are (1) socioeconomic factors; (2) social isolation; (3) physical characteristics. The principle components are mapped individually, to identify differences in the spatial distribution of each. They are then weighted, based upon the PCA results, and combined to produce an overall vulnerability index score, which is divided into 8 risk categories, based upon standard deviation of the scores. The vulnerability index score is combined with outputs from a fine scale assessment of exposure to extreme heat across the city, based on observations from weather stations located around the city. The combined output enables the most vulnerable and exposed areas to be identified simultaneously. This method of quantification and dual vulnerability and exposure assessment is useful for effective implementation of countermeasures to reduce the impact of heat waves at a local scale.

Chapter 4 covers the third research objective. This objective has a broader scope, in that it develops a framework that all risk factors and health outcomes can be quantified on the same scale, using Disability Adjusted Life Years (DALYs) as a common unit. The framework is designed to be transferrable to different regions, which will aid understanding of the spatial differences in risk. Producing DALYs as an output unit also fulfils the requirement to place climate change risks in context with other risks. Cardiovascular disease and meteorological disaster related injuries in Osaka Prefecture, Japan are used as worked examples of how the framework can be used to assess climate change impacts on human health at both a regional and local scale, for two fundamentally different health outcomes. The example health outcomes were selected due to their importance to the study region and the strong differences in the nature of their impact on human health. The idea was to demonstrate the applicability of the suggested framework on a chronic and an acute health outcome, which would produce outputs quantifying the impact of climate change on each, on a common scale. This framework, therefore, provides a useful reference for producing standardised but transferrable human health impact assessments, as well as producing a result to allow for risk comparisons in a multiple risk environment. As a conclusion to the study, the limitations and key contributions of the methods and findings are discussed. Recommendations for the future direction of study are identified and explained in context. Recommendations for the use of the climate change human health impact quantification framework are provided, with a specific focus on the uses for policy makers.

Chapter 5 addresses the final objective of the study. This chapter collates the findings, limitations and implications of the subsidiary objectives and draws meaningful conclusions. The conclusions in this chapter aim to contribute to scientific advancement in the field of climate change impact assessment and provide direction to organisations and individuals required to take action and implement risk reduction policy related to climate change and human health. Recommendations are provided in how to improve the methodologies provided, with particular attention given to real world applicability. Future research pathways are also discussed, based upon the implications of the research conducted in the thesis. These two concepts formed the backbone of the study, as research in the field of risk analysis should be focused on advancing understanding and communicating this understanding in a transparent, clear and unbiased manner to stakeholders and policy makers alike.

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論文審査の結果の要旨及び担当者

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論文審査の結果の要旨

人間活動が地球温暖化を引き起こしていることは科学的合意となってはいるものの、関連する知見が不十分なために、将来の気候変動に対するインパクトは幅をもって推計されているのが現状である。温暖化による人間社会への影響は多岐にわたり、その中で優先的に対応に必要な影響を把握するには、共通的な尺度を用いた評価が求められている。そこで本研究では、温暖化によって引き起こされる複数の環境影響を共通的尺度で評価するための枠組みの構築を行っている。本研究では、気候変動モデルで算出された温暖化シナリオを与件として、地域的に発現する影響リスクとして定量評価するとともに、異なるエンドポイントを取り上げ、かつ局所でも評価できる枠組みを構築している。

第１章では、地球温暖化によるインパクトを平均気温の上昇が引き起こす有害因子ならびにその伝搬プロセス、有害因子そのものへのヒトのばく露解析と有害性評価から構成されるリスク論によって整理している。さらに、リスクの地域性を把握するためには、地域的地形の特徴、土地利用の特性、人口密度、都市インフラの整備状況、微気象的要因を考慮することの必要性を指摘している。

第２章では、温暖化によってマラリアを媒介する蚊の生息区域の空間的分布の変化を与件として、マラリア罹患リスクを推定するとともに、温暖化に伴って将来おこりうるマラリアによる健康被害を朝鮮半島、日本列島を取り上げて推算をおこなっている。今世紀末には、朝鮮半島が広範囲にわたって年の半分がマラリアに罹患しうる地域となることが推算され、日本では太平洋側を中心に罹患しうる地域が広域化しうるとの知見を得ている。

第３章では、大阪市を対象として、リスク因子としての気温上昇に注目し、地域スケールでの熱波へのばく露評価を行うとともに、年齢、世帯構成人数、失業率等を空間的にミクロに分解して、気温上昇による直接的被害において脆弱な地域を主成分分析の適用を通じて明らかにしている。さらに、得られた主成分の意味づけを行い、第一主成分は個人属性、第二主成分は社会的属性、第三主成分は空間的属性であることを明らかにし、大阪市内で具体的に脆弱な地域として西成区など市の中心部を特定している。

第４章では、大阪府域をとりあげて、温暖化によってもたらされる異なる種類の影響評価として、心疾患の増加、極端気象によるリスクの増加をとりあげ、これら異なるエンドポイントのリスクを質調整生存年数(Disabled Adjusted Life Year, DALY)を通じて比較をおこなっている。心疾患のリスクは、既往研究より 28℃を超過する頻度の関数で推定し、極端気象によるリスクは水災害による被害をとりあげて推算している。その結果、DALY を計測指標とすることで、相対リスクで見た場合、心疾患によるリスクが極端気象による死亡リスクに比して 10 倍に上ることを明らかにしている。この結果より、共通的尺度を用いた評価を通じて、自治体が温暖化のリスク管理対策に優先順位をつける際の根拠となりうることを提示している。

以上のように、本論文は、環境工学分野、特に地球規模で引き起される複数のリスクの評価において異種のリスクを比較可能とする枠組みならびにその適用結果を提示することで、地域ならびに局所における温暖化事象に起因する複数のリスク管理戦略の明確化に関する研究の発展に大いに貢献する成果を提示している。

よって本論文は博士論文として価値あるものと認める。