[redacted]

Critically reflect on the practice, and potential contribution to society, of geographical research in the 21st century.

1 – An introduction to geography and geographical research

1.1 – Introducing the Practice of Geography

Geography is a vast topic encompassing a multitude of sub-disciplines from geology to urban planning to risk analysis, and has been defined by the Royal Geographical Society (RGS) as being the "study of Earth's landscapes, peoples, places and environments" (RGS, 2016). Geographers examine where human activity and natural processes occur as well as what affects their distributions (Rubenstein, 2008), and are "concerned with thinking about (and understanding and explaining) spatial relationships" (Dorling and Shaw, 2002: pp.632). Two significant branches of this discipline are Human Geography and Physical Geography. The former is based on the social sciences and focuses on the cultures, political systems, and economies across the world thus seeking to explain what causes variations and inequalities between places and social groups. The latter, Physical Geography, emanates from the natural sciences and aims to understand the links between landscapes and environments (RGS, 2016). By studying Geography through research, we can better our understanding of the world around us through the relationships and transfer networks that underpin processes occurring on local, national, and global scales (Hargittai and Centeno, 2001).

Geography operates on all scales, from considering general theories regarding global flows and processes, to investigating small-scale cases on an individual basis. Knowledge of the world and of the environments around us is vital in the conservation and progression of our success as a species. For the earliest humans, the 'hunter gatherers', an extensive and comprehensive understanding of their surrounding landscape was crucial in order to obtain sufficient food and shelter. These were indispensable factors for their survival (Church, 2009). Later on, when the national and international trade of material goods began to establish itself between rich and powerful communities, a comprehensive awareness of the sources of materials and the exchange routes that they followed allowed for the expansion of these leading groups, and thus their power. A significant amount of this knowledge was purely geographical, under the form of maps (for which the 'research' was carried out by intrepid explorers) whose main purpose was to facilitate the development of trade and commerce (Philipponneau, 2004).

In the 21st century, advances in technology have increased our ability to assess and monitor changes across the world, as well as allowing us to use data and observations more effectively and efficiently. Physical Geography relies heavily on Geographic Information Systems (GIS) and mapping programmes in order to analyse and display the features of the Earth, often using remotely sensed data collected by satellites. This enables us to understand in more depth and detail how places and landscapes interact and respond to changes in their environments.

1.2 – Introducing Key Geographical Concepts

There are a number of concepts, developed through geographical research, which allow us to view the world as a more ordered and logical environment. One major concept is that of space and place. Space determines the physical extent of a geographical location and the patterns or distributions which it creates – as defined by Massey (2001), space is a surface. Place, on the other hand, defines a space to which humans have attributed a certain value, whether this be a social, economic, political, or cultural value (Tuan, 1977). This supports the idea that the world organises itself and is given meaning through the ways in which we interact with it (Cloke et al., 1991). These two key concepts are related to other geographical notions such as the interdependence which links changes between social, economic, environmental, and political connections; these are in turn driven by a diverse array of physical and human processes. Geography appreciates the various scales at which all these phenomena occur, from a personal scale to a local or national scale, to an international or global scale.

This essay will seek to investigate two main research topics – climate science and natural hazards – and will look into the different approaches that have been adopted for research in these domains. Climate science is the studying of the Earth's climate system, the long-term changes and variabilities which have occurred in the past and are predicted to occur in the future. This branch of science relies heavily on numerical quantitative models, rather than statistical or qualitative methodologies, in order to study the processes that drive our climate (ISU, 2016). Scientific modelling is an important part of climate science research as it allows us to process and display data using both spatial and temporal scales. Recent changes in the Earth's climate, as well as a more global and public awareness of these, have fuelled an increased interest in geographical research within the fields of climate science and scientific modelling. Due to the nature of our modelling systems, in order to have the most accurate and precise simulations, we must continuously update the input data as well as the algorithms and underlying equations which run the models. Thus, as discussed by Clifford *et al.* (2016), to create climate projections which are able to probabilistically predict the most likely future climate scenarios, we need to carry out the vital geographical research which allows us to explore the relationships and processes that occur across the human and physical worlds. These climate models are interpreted and used by governing bodies in order to form and develop the most effective environmental management policies.

2 – Review of Climate Science and associated Environmental Policies, and Natural Hazards

2.1 – Climate Science

Studying climate science enables us to reconstruct past changes in climate, a process most commonly carried out by using proxy data. Proxies are physical characteristics from which we can indirectly infer past climatic and environmental conditions such as temperature and CO_2 concentrations being calculated from the analysis of oxygen isotopes found in deep-sea sediment cores (Perego *et al.*, 2010; Anderson-Carpenter *et al.*, 2011). The most common sources of proxy data are ice cores, sediment cores, ocean cores, biological evidence (such as tree rings, fossils), and historical records (such as paintings, diary entries and writings) (Thomas *et al.*, 2016). Using proxy records allows us to gather data for time periods during which there is no available instrumental data, thus meaning that climates can be reconstructed on much longer time scales (on the order of millions of years). Being able to recreate past conditions is vital for our understanding of how the current state of the Earth came to be, as was established by Schumm and Lichty (1965) in a paper which describes the causality of time and space, and the varying effects that these have on the geomorphological development of landforms due to erosional processes. Their conclusion was reached after a considerable amount of research which allowed them to develop conceptual models that tested and proved theories regarding complex natural networks.

A seminar by [redacted] explored the recurrence of deadly flood events, especially in the UK, following a rise in the public awareness of global warming and its effects on hydrological extremes in the 21st century, notably due to anthropogenic climate change. However, there are still many uncertainties regarding the physical processes and feedback mechanisms associated with a warming climate due to their complexity and heterogeneity. River surveys, proxy data reconstructions, and historical document evaluation can be conducted in order to identify and analyse past flood events. Projections have been calculated with the aim of giving an insight into the possible future scenarios for the hydrological cycle, however an enduring barrier we currently face is the lack of adequate data (**figure 1**, below). This understanding of the Earth's climate can be used to improve Global Climate Models (GCMs) and to produce more reliable flood risk assessment and emergency response strategies. But at this current stage the error margins and uncertainties, as well as the heterogeneity of the spatial distribution of extreme flood events, are too great for scientists and academics to draw statistically significant conclusions (Hirabayashi *et al.*, 2013).

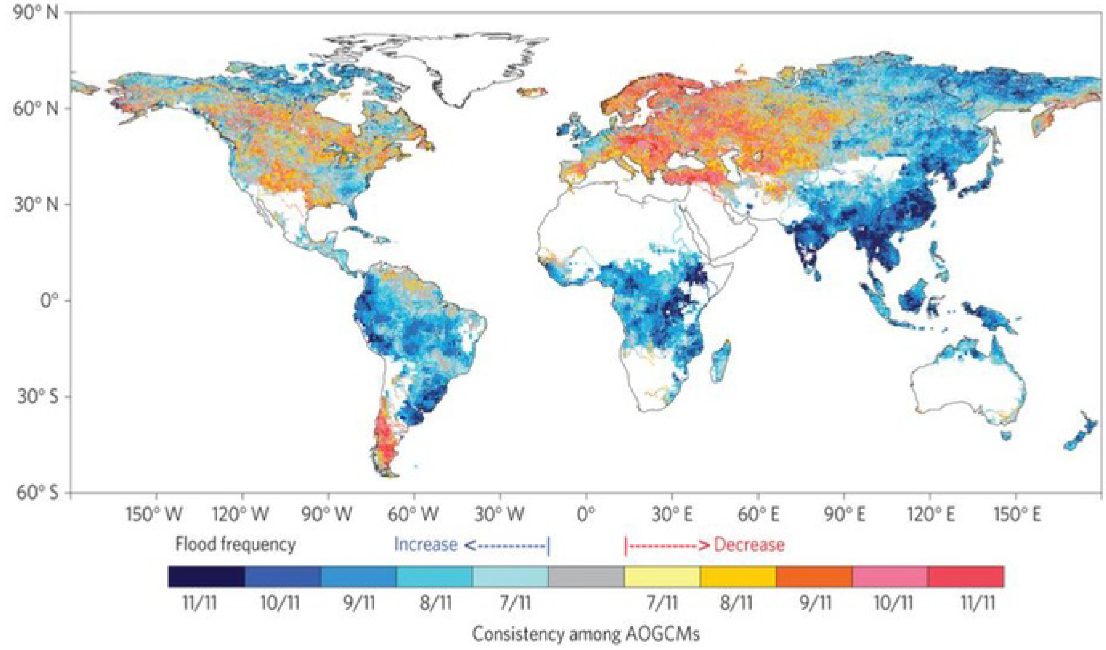

Figure 1 – Consistency of Global Climate Models (GCMs) in predicting the frequency of extreme flooding events across the world for a Representative Concentration Pathway (RCP) of 8.5 (the 'worst case scenario'). Dark blue defines areas with the highest consistency between models regarding an increase in flooding frequency, and red defines areas with the highest consistency between models predicting a decrease in flooding frequency. The varying shades define areas where there is inconsistency between GCMs. *[Source: Hirabayashi et al., 2013]*.

Linked to this topic is a seminar series [redacted] regarding climate reconstructions for the last few centuries in tropical countries such as South Africa, Peru and India. This type of historical climatology reconstructs previous states of the Earth's climate system, with regards to internal variability, external forcing factors of climate change, and the feedback mechanisms involved with these factors. These analyses enable us to investigate the history, development, and epistemology of interactions between climate and society, namely the history of cultural adaptation to climatic variability and climatic extremes, and the ways in which perceptions and knowledge of the climate has evolved. Aspects such as these are both vital elements in being able to understand the adaptability of human cultures and societies (Rohland *et* al., 2014). This technique of historical climate analysis allows us to investigate the social construction of a phenomenon such as El Niño. In order to fully appreciate the phenomenon, we require an understanding of the various types of scientific practices that have been and that are being used to study it, including aspects of its cultural history.

2.2 – Environmental Policies

Geographical research in the field of climatology is vital in the development of management policies on local, national and international scales. Effective risk management through the application of various environmental policies requires knowledge about the natural, economic, and social aspects of the system, however these systems are invariably complex and contain uncertainties and ambiguities (Mauelshagen *et al*., 2014). The models created by climate science data allows scientists to investigate the direct effects of certain environmental factors such as varying concentrations of CO2 and other greenhouse gases (GHGs), thus enabling us to produce a number of climate scenarios for futures with different concentrations of such gases (IPCC, 2014). With these models available to them, governing bodies and politicians have the necessary information to put in place the most effective and functional policies for the mitigation and adaptation of the impacts of climate changes (Harvey, 1974)

EU Emission Trading Scheme (EU ETS)

In order to meet GHG emission limits imposed by the Kyoto Protocol and to ensure its compliance, the EU created their own independent climate policy for the regulation of emissions (Ellerman and Buchner, 2007). One of the first large-scale policies put in place for the management of carbon emissions is the EU ETS (European Union Emissions Trading System), a scheme launched on 1st January 2005 which set up a trading market for carbon, and has now been signed by all 28 EU member states as well as Iceland, Norway and Liechtenstein (European Commission, 2016). This project follows the 'cap and trade' principle whereby an upper limit is set on the total amount of GHGs which can be emitted by the EU as a whole, and allowances which represent a certain amount of carbon are allocated to each member state. Within each member state, governing bodies distribute these allocations to various industries for the running of industrial and electricity-producing installations of over 20 MW (Environment Agency, 2013). These carbon 'credits' can be sold to and bought from other member states, thus setting an effective and quantitative limit on the volume of carbon which can be emitted by the EU as a whole (Ellerman and Buchner, 2007). As the third largest emitter of GHGs, after the US and China, the EU plays a key role in the management of global emissions, as well as setting an example to other countries and showing that management policies are effective and necessary (WRI, 2015). Following the implementation of these structural changes and new management policies on both an EU level and a member state level (e.g. the UK substituted much of its heavily polluting coal-based industry to run on natural gas instead), total EU GHG emissions have decreased by approximately 11% (**figure 2**, below). Schemes such as the EU ETS have been given full governmental support through policies like the Climate Change Act 2008, which defines that the UK must reduce its carbon emissions to below 1990 levels by at least 35% by 2020 and by at least 80% by 2050 (Environment Agency, 2013). These give clear objectives to policy makers, who tend to be only mildly, if not at all, interested in the science involved with the research of the area being studied.

The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 in order to assemble all of the most up-to-date geographical research regarding climate sciences, with the aim of forming a complete and comprehensive study of our current knowledge of the environmental changes that have already occurred as well as those that are predicted to occur depending on anthropogenic activity (The Royal Society, 2005). Policy makers use data from the IPCC's Assessment Reports (ARs) alongside data provided by schemes such as the EU ETS in order to implement changes with the objective of combating climate change.

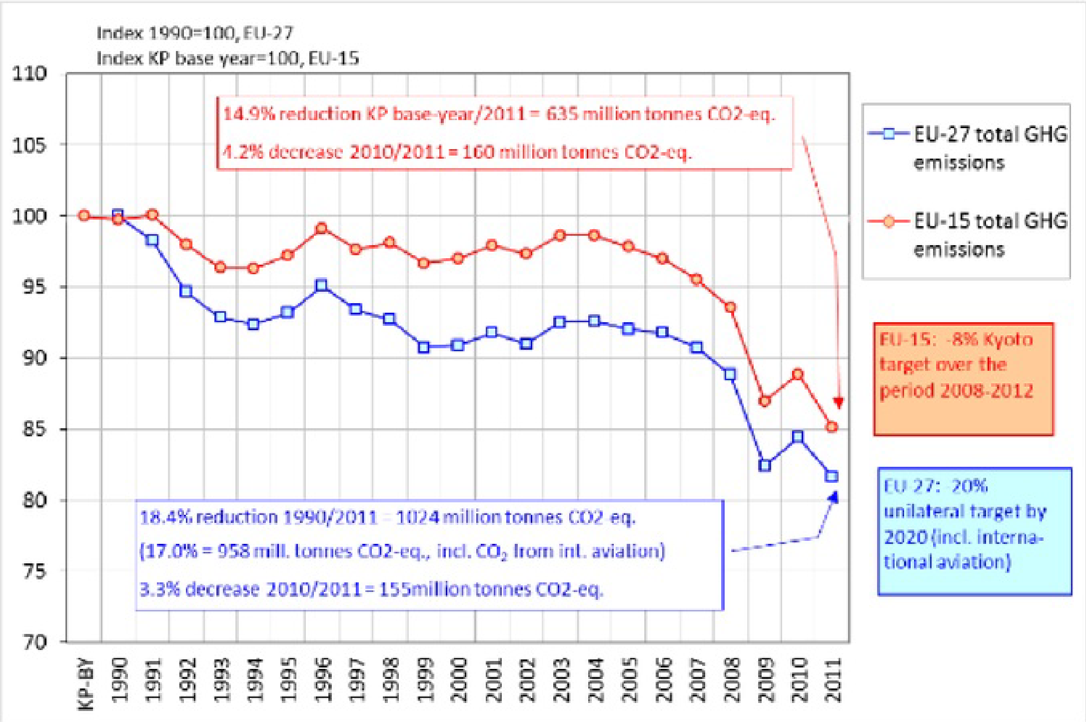

Figure 2 – Trends in EU greenhouse gas emissions for the period 1990 – 2011. Total emissions have decreased markedly since the scheme was put into action in 2005, and the EU is currently on-target for meeting its emissions objective under the Kyoto Protocol. *[Source: National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism provided by Directorate-General for Climate Action (DG-CLIMA), 2013]*. http://bit.ly/2gE4GuU

2.3 – Natural Hazards

As highlighted by the IPCC (2012) natural hazards and climatic extremes are defined not only by their magnitude, but also by the severity of the damage and by the consequences to the livelihood of all affected communities. Geographical research allows scientists to adopt a quantitative approach, a qualitative approach, or a combination of both, in the investigation and critical analysis of such issues. In-field research for natural hazards tends to use more quantitative data and evidence in order to produce model-based results.

A seminar by [redacted] introduced various types of models and simulations used in exploring and assessing wildfire behaviour, using data collected from land-based sensors, as well as from airborne and spaceborne sensors regarding characteristics such as the fire intensity, the rate of spread, and the fire growth perimeter. This data can be analysed through the use of computer simulation programs like Prometheus and FARSITE, which take into account spatial variations of the landscape such as topography or fuel types, together with meteorological factors such as wind speed/direction and precipitation levels in order to analyse the spread of fire on both a spatial and temporal scale (Finney, 2004). A study was carried out by Bachisio *et al.* (2007) in the Mediterranean maquis in order to check the accuracy and reliability of the FARSITE simulation model by running fire events on different types of fuels and in different meteorological conditions. These were calibrated to data collected from field research in real wildfire events during the dry season. Geographical research forms the basis of these investigations, and allows governing bodies and policy makers to use this scientific information regarding the behaviour and effects of wildfires in the development and implementation of appropriate management strategies for dealing with the associated hazards (Scott and Burgan, 2005).

3 – Assessing Geographical Research's Contribution and Relevance to Society

When undertaking geographical research, it is important to consider the various different approaches and methodological techniques that can be used. Louis (2007) stresses that the best approach may be new to you or one which you are unfamiliar with, and he explores the idea of working with indigenous communities in order to gain a more in-depth and insightful understanding of their perceptions. Over the last few decades, geographers and researchers have become more aware of their 'outsider-ness', whether this be due to their social status, gender, or race. Thus, taking the time to interact with the local populations on a more personal basis allowed Louis to conduct ethnographic research regarding some of the physical and cultural phenomena that affect these indigenous communities (Battiste, 2000; Smith, 2000), a point supported by Crazy Bull (1997: pp.17) who encourage "research and scholarships that preserves, maintains, and restores traditions and practices". Since geography is based around the search for new knowledge, or innovative ways of using existing concepts, an awareness of how processes are affected by their interconnectedness and relationships is critical (Howitt and Stevens, 2005).

A subject or topic's relevance within society is defined by the awareness and impact which associated academic research has on the wider world and general public. For example, research carried out in the field of climate sciences is currently of very high relevance in the government's development of effective environmental policies regarding the mitigation of and adaptation to future changes in the Earth's climates and environments (Bell, 2009). The more relevant a subject, the more our knowledge about it will be used in order to solve current problems that are of importance to society, such as the management of the natural environment (including land and water resources, the atmosphere, and geological hazards) (Church, 2009).

For the last 40 years or more people have been considering the relevance of academic research (Johnston and Sidaway, 2004). Massey (2001: pp.8) expressed her worry for "the status of the knowledge which [academic geographers] produce" due to the fact that governing officials fail to take on board the results of geographical research and scientific practices. This concern is equally shared by Dorling and Shaw (2002: pp. 632), in stating that governmental and policy-making bodies rarely consult geographical academics to aid them in forming the basis of effective management policies. Scientific research is not omniscient, hence why it must continuously be carried out, however despite not necessarily giving us the ultimate answers to our questions, it leads us closer to the truth. By engaging with the world in a more calculated and methodological approach (i.e. a more scientific approach), geographers can gain a more comprehensive understanding of the interconnections and interdependence of the world's systems (Stengers, 1997).

In order to assess the impact that geographical research has on the wider world, a number of frameworks have been put in place, such as the RAE (Research Assessment Exercise) and the REF (Research Excellence Framework). There is an increased need for academics to provide top-class research, and they must prove the relevance and benefit to society of their work and research in order to receive funding and support (Bell, 2009). The *Research Assessment Exercise (RAE)* encourages academic geographers to embed their work into wider debates and public issues (Massey, 2001), as this creates engagement and informs the general public of the major current local, national and global issues. Another scheme which measures the impact on the wider world of an academic's research is the *Research Excellence Framework (REF)*. This was set up in 2014 and enables a researcher to establish the extent to which their work is making a contribution to society. Schemes and frameworks of the likes of the RAE and the REF help funding bodies and national councils such as the NERC (Natural Environment Research Council) in deciding which areas of research would benefit the most from additional funding.

The question of relevance brings up the question of who the information is contributing the most to. The relevance of a certain topic will vary greatly depending on the country, the culture, the society, and the economy – it varies through both space and time. Since the 1970s, there has been an increased awareness regarding our impact on the environment, thus encouraging the application of geographical knowledge of the earth in order to manage our land-based and water-based resources in a more ecological and sustainable manner, such as in the management of land planning. (Coates, 1971; Cooke and Doornkamp, 1974; Mather, 1974).

Societies, particularly in the Global North and in the West, have experienced an increased exposure in the 21st century to some of the various geophysical hazards which have affected or could affect their regional or national area. In this context, geographical research is of utmost importance for the identification and development of mitigation strategies for hazards such as landslides, floods, and coastal hazards, through the carrying out of interdisciplinary field studies (Ives *et al*., 1976). This interdisciplinary approach so typical of geographical research is an aspect which sets Geography apart from other subjects, and is highly praised (Massey, 2001; Harvey, 1999). This type of research has none other than intensified in the 21st century through the development of GIS (Geographic Information System) software which are used as tools for the cataloguing and analysis of spatially and temporally distributed geographical data (Church, 2009). Giving increased accessibility to this knowledge allows governing bodies and officials, as well as to the general public, to question and evaluate the current policies and policy-making practises which are in place, thus revealing their potential flaws and limitations. This allows for the implementation of a more effective and appropriate type of policy intervention on all scales (Martin, 2001).

<u>4 – Concluding Remarks</u>

This essay has found that there is an interconnectedness and interdependence on a number of scales (from local to regional to national to global) between the activities of our society and the development of the natural environment. Geographical research within these areas of interest raises awareness and generates engagement around the associated issues, and examines the most appropriate was of tackling them. Research within the fields of science has benefited greatly from technological advances, such as the development of remote sensing in order to collect data via satellite imagery (Casetti, 1972), and in the 21st century our technological capabilities will do none other than advance.

Despite the deniers of anthropogenic climate change, there is an overwhelming majority of climate scientists who agree that human activity has had a significant influence on the current climatic changes which have occurred over the last few decades (Cook *et al*., 2013). Within this subject area, there is still a lot of research to be done in order to have a reliable understanding of the various possible ways in which the environment and the global climate will evolve.

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