Title:

Impact of Melting Glaciers on Norway due to due to less stable discharge from glacier areas, more slides, and changing the accessibility of mountains/routes/huts: A case Study on Melting Glaciers on Norway

Umer Naseer

Pages :51

Course Code: SO345S

Master's in international Northern Development

15 November 2018

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Acknowledgment:

First of all, I am very thankful to my parents who always pray for my success and because of their prayers and efforts finally I completed my research work. I am highly thankful to my Supervisor **Ivar Svare Holand** who helped in offering deeper insights and expertise in undertaking the research. His friendliness and coperation has given me the great motivation to complete my work on a proper time. I must pay gratitude to the Ivar Svare Holand for sharing his pearls of wisdom with me during the entire research course. I also thanks to all my faculty teachers who provided me the great knowledge about my area of interest.

Abstract:

The balance of the planet has changed significantly over the past 150 years because people have spent the life on the earth beyond the means. According to WWF, the environmental degradation is caused by burning fossil fuels including oil, gas, and coal. It has also resulted from the breeding of methane-producing livestock. The following study is focusing on the change in the balance of the planet by particularly focusing on the issue of melting glacier on Norway. The objective of the study is to analyze the impact of Melting Glaciers on Norway due to due to less stable discharge from glacier areas, more slides and changing the accessibility of mountains/routes/huts. In order to do the empirical investigation, the study has taken the qualitative approach and used the previous papers as the secondary tool to conduct the study. The results should that the melting glaciers can highly impact the people living in Norway and the main driver behind the melting glacier is associated with rainfall. Despite accomplishing the objective, the study still has some limitation such as time constraint and depending on qualitative approach solely, which creates the gap to be filled by future researchers in their researches.

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Chapter 1: Introduction

1.1 Background:

The change in the climatic conditions impacts the natural and human systems globally by creating troubles that are already seen in multiple parts of the world. Consequences like droughts and floods lead to make the land unproductive and sterile. The increase in the sea levels and the storm results in lurking the coastal communities and the infrastructure of the company. The change in the temperature and rainfall can lead to crop failure, a binge of infectious diseases and the higher risk of wildfires (Norwegian Environment Agency, 2018). These are only the examples from a list of the consequences occurring from climate change affecting the natural system and human system directly. Additionally, the social and financial assemblies are also impacted by a number of indirect effects.

In an era, which is integrated and globalized to the higher extent, the indirect effects would not be just limited to the areas where the climate is affecting only, instead, it will also create impacts far beyond the border of the country. This, as a result, is getting very essential for Norway and the businesses operating in the country to prefer about such challenges especially the impact of melting glaciers to nature and the country (Norwegian Environment Agency, 2018). Moreover, the preference should not be just limited to the country borders only, but the government should also see the impact of climate change to the other parts that may also impact the Norwegian people followed by its economy and nature. This entire concept is called transnational impact of climate.

1.2 Problem Statement:

The modifications in the natural environment of the country impact adversely on the human system and the environment as well. Being integrated to globalization to a greater extent, one would not be affected within the boundaries only, but it will also create a higher impact beyond the borders. Keeping this in mind the following study aims to analyze the potential impacts of melting glaciers on Norway due to climate change. The study will examine the impact of melting glaciers as a result of climatic changes including less stable discharge from glacier areas, increase in slides and the changing accessibility of the mountains/routes/huts. The potential deterioration in the quality of air and the environmental conditions has not occurred suddenly. It is the outcome of the long history of human greed, industrialization, and preferring the self-interest over the interest of the whole society and future generations. It is high time the governments, private sectors, and civil society organizations across the world took up the issue of climate change and

analyze its impacts at the regional and global level. This study recognizes this need and analyzes the impacts of global warming and changing weather on the sea ice of the Arctic region. The study focuses on how it might affect the living conditions in Norway and what steps should be taken by Norway to address this issue. The study is focused on Norway as to how climate change will affect individuals and society in Norway, and what strategies can be adopted to address this issue.

1.3 Objective of the Study:

The purpose of the study is to analyze the impact of deterioration due to climate change on the melting glaciers of Norway.

1.4 Research Objectives:

To examine how the melting glaciers in Norway can become a natural hazard in both summer and winter due to climate change. Following are the sub-objectives of the study:

To analyse the impact of less stable discharge from glacier areas on Norway in summer and winter.

- To investigate the impact of an increase in slides on Norway in summer and winter

To assess how a change in accessibility of mountains/routes/huts can become the natural hazard for Norway.

1.5 Research Question(s):

The major research question to be explored in the study is as follows:

How can the melting glaciers in Norway become a natural hazard in both summer and winter due to climate change?

Following are the sub-questions of the study:

What is the impact of less stable discharge from glacier areas on Norway in summer and winter?

What is the impact of an increase in slides on Norway in summer and winter?

How can the change in accessibility of mountains/routes/huts become the natural hazard for Norway?

1.6 Significance of the Study:

The study is significant as it will help to offer an in-depth overview on the climate changes that occur due to melting glaciers in Norway and will enable to view that to what extent the melting glaciers impact can become a natural hazard for the country.

1.7 Limitations:

Despite accomplishing the objective of the study, the researcher will bind to have limitations such as due to the minimal time, the researcher will have the time constraint to conduct the study. Moreover, as per the minimal time, the researcher would not be able to cover the climate impacts of the melting glaciers which leave a gap to be fulfilled in the future research.

Chapter 2: Literature Review

2.1 Floods linked to icebergs:

The iceberg streams discharge usually at the end of summer and likely to be high in hot summers and the river level is likely to low at the same time. The huge flood recorded in the series of 105 yearlong floods at Lovatn and oldevatn happened in 1941. It was the dry year without having inflow from icebergs. In 2006, in-iceberg Rivers dried up due to warm and dries summer, while rivers having the inflow of icebergs were flooded. Icebergs melt quickly when the hot and humid air hit the icebergs. The fragment of the hot cyclone strike at West Norway in 7th September leading up to huge rainfall up to 200 mm for more than 2 days in Sanford and extreme thawing on regions of Jostedalsbreen, Folgefonni, and in the southern region of Ålfotbreen. It has noticed a particular discharge at Boyumelven in Fjærland while which has been recorded as the huge flood in the history of 40 years.

Another disaster was recorded in 1979 due to tropical air hits over Jostedalsbreen, which lead to heavy rain flooding in Jostedalen 1979. These disasters have been recorded as some of the huge iceberg streams resulted in floods. Iceberg-dammed lakes caused huge floods to river sima (Elvehøy et al, 2002). The progress of around 40 000 000 m of water with the help of ice barrier in 1 ½ days is considered to be connected to be linked to a lessening of the ice that is directly connected to alterations in the mass amount and to climate changeability (Engeset et al., 2005).

2.2 Icebergs in Norway and their effect on climate:

The last iceberg reserve in Norway determined 1627 icebergs including 714 icebergs in southern Norway and 913 icebergs in northern Norway (Ostrem et al., 1988). The icebergs consist of the total area of 2609 km2 (around 1% of an entire field of shore Norway) which involve the area of 1592 km2 in southern Norway and remaining 1017 km2 in the north side of Norway. The whole iceberg mass in Norway has been estimated roughly (Ostrem et al., 1988).

It seems that there is a positive connection between the iceberg area and iceberg mass including 164 km3; 100 and 64 km3 in southern and northern Norway, reciprocally. When all icebergs thaw, the sea level is likely to increase~0.34 mm in Norway. Almost 1593 icebergs having an area b9 km2 occupy an area of 809 km2, which is 31%, while the 34 (2%) highest icebergs in Norway consist of an area of 1800 km, which is 68%. The 1593 icebergs consisting of an area 9 km have an approximated volume of ~51 km.

The 24 greatest icebergs have an estimated mass of 113 km in Norway. The record of continuous iceberg volume balance is in the north of Sweden is from Storglaciären, while another largest continuous volume balance record is from Storbreen located in central southern Norway. Mostly other volume balance is recorded in the early 1960s in Norway (Andreassen et al., 2005). In 2005, volume balance calculations were taken out by the Norwegian Water sources and Energy administration (NVE) for 13 icebergs Norway, which involves 10 in the south of the Norway and 3 in the north of Norway.

The measured icebergs in the south of Norway provide a west and east crosscut from the maritime Ålfotbreen having a normal aggregated 3.7 m water proportionate, to the international Gråsubreen in eastern Jotunheimen having an average aggregation of 0.8 m. six icebergs have been assessed in the south of Norway, there is a consistent record of more than 43 yr. The record goes back at Engabreen in the north of Norway to 1970. During the previous 45 years, worldwide icebergs have been recorded as negative volume balance, while mostly icebergs have a direct volume balance direction, in the 1990s specifically. High winter snowfall in the period of 1989–1995 was in western Norway leading up to increase in icebergs of more than 80 m (Nesje, 2005).

The period between 2001–2004 was assumed not a positive volume balance for icebergs in Norway due to low winter aggregation and in between 2002 and 2003 huge summer thawing. In Scandinavia, which includes Svalbard the overall balance of volume on the marine icebergs in west Norway, is best connected with the winter equivalence, while the overall volume balance on international icebergs in south Norway and there is the perfect relation with the summer balance on Svalbard (Nesje et al., 1995).

This is also shown in long-term aggregated iceberg volume records. There is a high connection between the North of Atlantic vibration indicator and yearly winter and overall volume balance on marine icebergs in Norway has been shown (Nesje et al., 1995), the most dominant aspect is the positive connection between snowfall while the aggregation season which is October to April and in winter December to march.

Norway is dependent on around 98% of the hydropower electricity, which is generated 15% from the icebergs. Summer melting causes a huge portion of water discharge from icebergs, most of the rivers run off more than 80% during the summer season. In 2002, summer was recorded extremely hot in Norway. In the hot climate, icebergs thawing tends to be high. Comparatively the river Nigardsbreen located in jostedelan, where icebergs occupy the 75% of the catchments, occurred an iceberg thawing equal to an in-between river flood mostly in August. Huge iceberg thawing commonly leads to huge debris transport.

Warm and moist air multitudes caused another disaster that was recorded in 1979 over Jostedalsbreen, which resulted in huge rainfall causing a flood in Jostedalen 1979. These disasters have been recorded as some of the huge iceberg streams resulted in floods. Iceberg-dammed lakes caused huge floods to river sima (Elvehøy et al, 2002) and rivers Folgefonni, Jostedalen located on the east side, from Brimkjelen at Tunsbergdalsbreen, Muldalselven at Sunnmøre and Rana from Lake Svartisvatn.

2.3 Icebergs in Norway and their effect on climate:

1627 icebergs were determined in the last reserve of the iceberg (Ostrem et al., 1988) including 714 icebergs in southern Norway and 913 icebergs in northern Norway. The icebergs consist of a total field of 2609 km2 (around one % of an entire field of mainland Norway) including the area of 1592 km2 in southern Norway and rest of the 1017 km2 in northern Norway. The whole iceberg mass in Norway has been estimated roughly (Ostrem et al., 1988).

It seems that there is a positive connection between the iceberg area and iceberg mass including 164 km3; 100 and 64 km3 in southern and northern Norway, reciprocally. When all icebergs thaw, the sea level is likely to increase∼0.34 mm in Norway. Almost 1593 icebergs having an area b9 km2 occupy an area of 809 km2, which is 31%, while the 34 (∼2%) highest icebergs in Norway occupy an area of 1800 km2 which is 68%. Those 1593 icebergs having an area b9 km2 have an approximated mass of ∼51 km3. The 24 greatest icebergs have an estimated mass of ∼113 km3 in Norway. The record of continuous iceberg mass balance is from Storglaciären that is in the north of Sweden.

While another huge consistent record of the balanced volume is from Storbreen located in the central south of Norway. Mostly other volume balance is recorded in the early 1960s in Norway. In 2005, volume balance as assessed by the water and energy management sources of Norwegian (NVE) for 13 icebergs Norway, which include 10 in the south of the Norway and 3 in

the north of Norway. The measured icebergs in southern Norway provide an east-west cut cross from the marine.

Ålfotbreen having a moderate aggregation of 3.7 m water balanced, to the international Gråsubreen in the east of Jotunheimen having a moderate aggregation of 0.8 m. six icebergs have been evaluated in the south of Norway, there is a maintained record for more than 43 years. The record goes back At Engabreen in the north of Norway to 1970. During the previous ~45 yr, mostly the glaciers of the world have been considered as negative volume balance, while some of the glaciers have a direction in positive volume balance, particularly on the 1990s. High winter snowfall in the period of 1989–1995 was in western Norway leading up to increase in icebergs of more than 80 min 1 yr. (1993–94 at Briksdalsbreen; Nesje, 2005).

The period of 2001 to 2004 was considered as negative volume balance for icebergs in Norway caused by low winter aggregation and in 2002 and 2003 huge summer thawing. In Scandinavia involving Svalbard the overall volume balance on the marine icebergs in west Norway is best connected with the winter equivalence, while the overall volume balance on international icebergs in south Norway and there is the best connection with the summer balance on Svalbard (e.g. Nesje et al., 1995, 2000b). This is also shown in long-term aggregated iceberg volume records. There is a high connection between the North Atlantic oscillation index (Jones et al., 1997 with later updates) and yearly winter and overall volume balance on marine icebergs in Norway has been shown (Nesje et al., 2000b; Reichert et al., 2001; Six et al., 2001), the most dominant aspect.

2.4 The future iceberg development in the context of the past:

Icebergs thaw away rapidly in early Holocene due to high temperature in summer which leads to an increase in solar insolation to the northern fraction and lesser winter snowfall. Jostedalsbreen thaw away around 7600 Cal yr. BP (Nesje et al., 2001). The moderate summer temperature was recorded at that time around 0.7 °C degree than the present.

2.5 Forward-looking:

Many species move northwards when the climate becomes hot and new species tend to move towards Norway. Both environment and inborn species get affected negatively. Specifically, those which are exposed and endangered. In big areas of the peaks, forest tends to cover for the long time period. The growth takes too long. For various parts of the country, the growing climate

is assumed to occur for around 1 to 2 months and it occurs for 2 to 4 months in a few areas in the time to 2100.

This can provide a great opportunity in terms of agriculture. Agriculture sector should plan to take measures for plant illness etc. a hot season can also impact the potential for conventional competitive functions includes cross-country-skiing, specifically in the basin.

More often snowfall can be challenging for the agriculture sector and augment erosion. Generally, floods are assumed to increase, however, there are local variations. Rainy climate can affect the infrastructure of the buildings and increasing threats for failure in infrastructure. Various areas of south and east Norway have hotter climate droughts. This can cause consequences to the agriculture sector. It is also assumed that acidification can occur in Norway waters due to the increase in carbon dioxide.

Few areas of south and east of Norway are likely to have less rainfall in summer. This can become challenging for the agriculture sector. There are also signs of acidification in Norwegian waters, due to increased concentration of carbon-di-oxide. This can harm the species calcareous shells in long run.

2.6 Climate change and other pressures:

The climate change in Norway also affects the other aspects and cannot be separated from them. Moreover, climate change brings threat to habitat, the dispersion of aliens, pollution and unnecessary utilization of natural resources. In many cases, change in climate can also result in other negative impacts. Commonly Icebergs around the globe are back down (Dyurgerov, 2005).

Increased icebergs thaw can result in more natural disasters related to iceberg fed catchments. The mass records of the icebergs have significant potential to back up or records of iceberg volume (mass balance) changes have significant potential to facilitate or increase the influential temperature records in summer and winter drizzle alteration and to highlight regional or global climatically conditions and drizzle changes prior to the influential period (e.g. Dyurgerov, 2003).

2.7 Climate Change in the Arctic:

Vihma (2014) asserts that the pace of climate change in the Arctic is almost twice as fast

as the global climate change. Vihma (2014) highlights that the most prominent indicators of climate change in the Arctic can be seen by observing the decline in the sea ice cover. The decline was first recorded through satellite remote sensing data and the changes since the first satellite record have been approximately 50%. Vihma (2014) argues that sea ice cover is a sensitive indicator in the context of climate change and it has significant impacts on other components of the climate system.

Kjellstrom (2016) asserts that one of the impacts of climate change is the increased heat exposure at the workplaces. The architects and built-environment experts will have to consider the factors of heat exhaustion and severe heat stroke. Kjellstrom (2016) argues that the changing climate conditions will have significant occupational health effects and work potential of the employees may be affected.

2.8 Weather Patterns in the Arctic:

Wilhite, Morrow, and Shulski (2017) describe that there have been certain weather patterns in the United States observed recently that originated from the rapidly warming Arctic. Hence, there is a need to analyze how changing weather patterns in the Arctic can impact water and agriculture resources and affect different sectors. Wilhite et al. (2017) assert that the warming Arctic will result in persistent weather patterns. There will be day-to-day variations in weather and weather whiplash will be observed at the extremes. Wilhite et al. (2017) mention that changes in the Arctic will cause strong warming and the decline in sea ice cover will influence mid-latitude weather. According to Wilhite et al. (2017), the major change drivers in the Arctic are human-induced greenhouse gas emissions.

The balance of the planet has changed significantly over the past 150 years because people have spent the life on the earth beyond the means. According to WWF, the environmental degradation is caused by burning fossil fuels including oil, gas, and coal. It has also resulted from the breeding of methane-producing livestock. The rapid pace of urbanization has also reduced vast swatches of forests that could have absorbed carbon dioxide from the air (WWF, 2018). According to National Geographic, climate change will affect living conditions in five ways (National Geographic, 2018). It will reduce the resources of freshwater and saltwater that is the foundation of economies and communities.

The crop changes will also be experienced because a warmer world will be characterized by more droughts, pests, and flooding. The temperature of the world will have risen by several

degrees by 2100. The world will also face wild weather in the form of devastating droughts, torrential hurricanes, raging heat waves, and crippling ice storms.

The fifth factor is the health risk because people will also experience weather-related health risks regarding water control, waste treatment, and hygiene education. The Arctic region is formed by the Arctic Ocean, adjacent seas and the parts of Northern Canada, Alaska, Greenland, Finland, Norway, Iceland, Sweden, and Russia. The study will focus on how climate change affects individuals and society in the Norwegian environment. The climate change issue that will have a central theme of the current study in the Norwegian context is a natural hazard, both summer, and winter. The Arctic region experiences volatility in snow and ice cover.

The people in the region face extreme cold weather conditions. There has also been a decline in Arctic sea ice due to the phenomenon of global warming. The cold climate of the region is highly vulnerable to the air pollutants and toxins. The latest readings published by the Norwegian Ice Service reported the ice cover in the Arctic in the Svalbard area to be 40% below the ice cover that was observed in 1981 (Norwegian Ice Service, 2018).

Until recently, the sea off Greenland's north coast had been termed as the "last ice area". However, the melting effects of a hotter planet have been experienced up to this point as well. The major concerns shown by the experts were that Norwegians are not used to the extreme heat. One of the initiatives that have been considered recently is the plantation of palm trees (Cooke, 2018). These trees are known for their cold-hardiness; however, the climatologists are not sure whether the trees will survive the winter. The melting of ice in the Arctic has raised concerns whether and how long the parts of the Arctic region will withstand the warming climate.

2.9 Glaciers Discharge in Norway:

The glaciers have highlighted a system of discharge which is highly impacted by snow and glacier meltwaters. The following study has been done by Engelhardt et.al (2013) in order to see balance in the rates of discharge for the three main glaciers catchments in the area of western Norway. The three-dimensional approach has been taken by the study from west to east.

The model input was gridded, and the values of precipitation very being recorded at the regular resolution. The model was subjected to the snow accumulation and transformation of snow to evaporation and melt.

The study has performed calibration and validation for every catchment depending on the

measurements of the seasonal glacier mass balance and to know the daily discharge rates. The discharge sources were the melting of snow, melting of glacier and rain that were examined as per the three-dimensional variation and temporal evolution. From the model, it was explored that the rise in the contribution from glacier to discharge is less than that of 20 percent in the 19th century and has increased to 30 percent in the late 2000 era.

The fall in the rainfall by 10 to 20% in the similar period has been overreacted culminating in the rise of the annual discharge by 20%. The annual discharge and melting glacier are highly correlated with the yearly and winter rainfall. The increased in the variation in both glaciers melt and annual discharge are getting highly correlated with the differences in the summer temperature. Hence, the glaciers in the several continental climates are particularly susceptible to fall in the annual and summer discharge with the constant rise in summer and decline in the glacier extent **(**Engelhardt et.al, 2013**).** This, as a result, might result into significant changes in the discharge system of glaciers followed with the rise in the decline in the year, particularly for the catchments in less particularly for the catchments in the maritime climatic conditions.

The contribution of the glaciers to the discharge in a changing climate has been the area of study for many types of research in many regions of the world such as Farinotti et.al (2012); Immerzeel et.al (2012) and Sachner et.al (2012). By means of the climate model data, there have been various studies showing the rise in the discharge and the reason behind highlighted was the rise in the discharge in the spring season because of the onset of snowmelt, however, the decrease in the next year was due to the glacier extent according to Huss et.al (2008). The glacier meltwater could also have an effect on the hydrological system of the larger watersheds. The study done by Huss indicated that for the catchments having the size of 100,000 km2 and an estimated one percent glacier covered can lead to raising the glacier discharge to 25 percent.

2.10 Changing accessibility in Mountains:

The issue of accessibility is very major for the people in Norway, particularly in the mountain areas. A study done by the researchers examined the variations in the physical accessibility of the western Norwegian mountain area in order to recognize the driving forces of the change. The variation in the availability was calculated in the travel time among the permanently and seasonally occupied farmsteads. In addition, the travel time ranging from the new

access points in the mountains was also calculated in the study. It was found that 75% of the calculated access routes to the seasonal homesteads have stayed unchanged as per the constant use of maintained work and has been improved as per the development of paths into the roads (Either & Pothoff, 2016). Additionally, the new routes have taken place due to the road construction. The regrowth of paths as per the desertion of seasonal farming has also declined the accessibility.

The change in the availability has resulted in focusing the activities in those parts of the study that is accessible easily. The manageable change can culminate from the difficult interaction of the driving forces that incur change. The essential drivers interrelating with the old construction and neglecting of seasonal farming can be classified as the socio-economic and technical change (Either & Pothoff, 2016). Thus, the importance of the cultural commitment of the local people of a minor amount of enthusiast should not be undervalued.

2.11 Land Slides:

According to the number of recorded landslide events has raised exponentially since 1960. It is however not possible to draw the conclusion that whether this rise is due to the rise in the capability of the natural release of slides due to climate change (Forland et.al, 2007). Any kind of natural change in the frequency is masked by the mixture of increase in the number of infrastructures and reliable registration.

It is the possibility that some of the hazards like debris flows and floods that are highly linked to the heavy rainfall have become more frequent and positive trends are being observed in the rainfall variables in the majority of the places (Jaedicke et, al, 2008). Though, the link among the variables was not found that strong in the study. Therefore, it can be suggested that a wetter climate will minimize the stability.

2.12 Glacier Mass Balance of Norway from 1961-2010:

Glaciers around the world come under the most often used natural phenomena to demonstrate the current issue of global warming. Withdrawing glacier tongues and the lessening of glacierized areas are evident all across the world. Transformation in glacier volume can have an impact on both the sea level and the river runoff regime downstream. Similarly, the mountain glaciers in Norway have connected streamflow, and are of precise importance as the electricity sector is dependent on hydropower. The temporal and spatial distribution of glacier mass-balance and discharge dimensions from glacier catchments is consequently biased towards demands from hydropower utilization.

This study aims to investigate the temporal and spatial distribution of the glacier mass balance of the mainland Norway for the period of 1961-2010 with the help of a distributed temperature-index collective balance model that consists of a capable direct solar radiation. This model is driven by the gridded data sets related to the precipitations and temperature in the horizontal resolution of 1 km. Furthermore, the model parameters are adjusted and authenticated by using a comprehensive data set of the glaciers' direct mass balance measurements for both summers and winter balances of the Norwegian glaciers (e.g. Kjøllmoen and others, 2011). It is evident to note that the mass balance measurement of the glaciers is only available for around 42 glaciers in Norway. For 20 years, the long-term mass measurements were available for ten glaciers.

Nonetheless, the study conducted by Rasmussen and Conway (2004) have demonstrated that there is a robust positive co-relation of season balanced related to one glacier to others that are closer to each other and the vertical gradients of the seasonal mass balanced which are close to linear. Hence, there is a high transferability of the current measurements to different glaciers in Norway. Highly driven by the data of seNorge, the model offers a complete view of the spatial, seasonal glacier mass for the first time, which ranges between 1961 and 2010 for all the mainland's in Norway. According to Stranden (2010), this approach is highly useful to offer an overview of both the spatial and temporal variability of glacier mass as the glacier monitoring cover only a small portion of the glacier and has uneven temporal coverage.

These results can be used to evaluate the spatial patterns in the mass balance during the study period can also be incorporated for other hydrological applications. Regions that are smaller, it may be appropriate to use the locally set parameters. However, in the respective study, the precipitation input derived from seNorge is fixed by implementing the precipitation gradients that produce an agreement between the observed winter mass balance and average model mass balance. The melt models of parameters can be optimized with the consistent summer balance (Sharma et al., 2000). The model annual and seasonal mass balances for Norway for the period of 1961-2010 show a significant variability on a year-to-year basis. Nevertheless, winter and yearly balances of mass reveal positive trends between 1961 and 2000 which are followed by a substantial decrease in both winter and summer balances between 2000 and 2010.

According to Tobin et al., (2012), the consequent yearly mass balance for the first decade of the 21st century is just a snapshot of what can be expected in the future. In the particular study, the discharge series are modeled for three glaciers catchments in Norway for the period of 1961-2012, and yearly contributions of glacier melt, and snowmelt are quantified. The glacier

catchments can have a significant effect on the streamflow regime because of the glacier and snow meltwater contributing to the discharge. However, in the critical study, the distributed temperature mass index has been applied to three glaciers catchments in Norway (>50 glacier coverage). The pattern of spatial about the watershed follows the gradient, which is in the climate from east to west continentally. The model analyses annual mass balances along with daily discharge rate for the period of study 1961 and 2012.

Furthermore, the time series of the yearly discharge is divided into the contributing water sources, snowmelt, rain and glacier melt. Both the discharge components and the annual release can be used to analyze and study the changes that prevail in the runoff regimes, by evaluating the temporal evolutions and the spatial variation (Engelhardt, 2014).

2.13 Modern Glaciological Investigations:

Highly standardized measurements had begun in Norway almost 100 years ago when a few scientists started to establish the survey points in front of the chosen glaciers for the yearly position measurements for every terminus. A geologist P.A Oven made a systematic analysis, whose figures were also mentioned in the annual reports, who also took pictures of many glaciers in Norway. The old glass negatives that belong to the author consist of wealth information from 1890 to 1910. In this, the Norwegian Army and a meteorologist took several photographs of the Avarice and the Jostedalsbreen caps (Schuler et al., 2008). A renowned French geographer known as Charles Rabot took some photographs in Scandinavia in the 1880s.

Some photographers have intensive information about the positions of the chosen glaciers during the time. Later on, a professor named as Werner Werenskiod started a stretched series of glaciers measurement in the mountains of Jotunheimen. A number of his research students completed their fieldwork under his supervision. His keen interest in the study of glaciers is recorded in some scientific papers. Further, he has also studied the history of glaciological research in Norway. It is evident to state that many of the advances in the glaciers have occurred. Norwegians have also undertaken some inquiries related to glaciers. Comprehensive mass balances investigations began in 1962.

The prolonged series of collective balance observations that were made in Norway concerned with Storbreen, which was a valley in the Jotunheimen Mountain where the mountains have been discovered since 1949. For the five other glaciers that are located in Norway, some observations cover a 30 years long time span. It is evident to state that some of these observations will continue in the future (Westermann et al., 2013).

2.14 Climate Change and Melting Glaciers on Norway:

It has been noted in the research that the idea of climatic change encourages the Cryosphere of the earth that refers to the frozen water part of Earth (Bamber & Payne, 2004). However, it is important to monitor the changes regarding the variations of length and mass balance of the melting glaciers that occurs in response to a change in the climate. Particularly, it occurs in the winter precipitation and hot temperature and requires major importance especially in cold areas like Norway (IPCC, 2001; Dyurgerov, 2003, 2005). For more than a century, the severe fluctuations in the glaciers have been observed and evaluated in different parts of the world. The length of the glaciers is mostly evaluated and measured parameter that aims at providing a clear filtered signal of climatic change in the particular region.

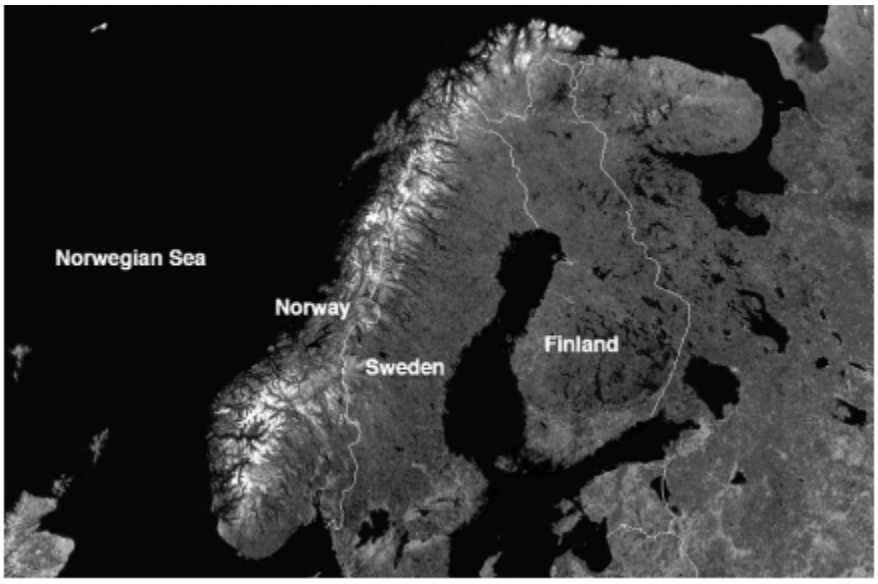
Moreover, melting glaciers creates a major effect on Norway and majorly it is due to changing the accessibility of mountains and climate. This reason particularly affects the water resource management, evaluation of natural hazard in Norway hence there must be planning g recreation in Norway to reduce adverse effects. In addition, the measurement of mass balance usually provides a direct signal of change in the climate that usually causes variations in the melting glaciers.

Presently, the world glacier monitoring services have collected the data in order to obtain the effects of melting glaciers on Norway due to lack of stable discharge from glacier areas all around the world which resulted into minimizing the effects (Dyurgerov, 2005). It has been also noted that an increase in the discharge of water increases the rate of melting glaciers that might lead to adverse effects of occurring natural hazards in Norway. If there is a way of Frontal variations of mountain glaciers than it could support in raising the global temperature. There is a potential in the glacier volumes or mass balances to support the influential record of hot temperature and changes in the winter rainfall (Dyurgerov, 2003).

The evacuation of the melting glaciers has been considered as a definite sign for the occurrence of global warming (Dyurgerov & Meier, 2000; Dyurgerov, 2005; Orlemans, 2005). There are data points in the glacier length that occurs before the period of annual or continuous measurements which creates several variations in the winter precipitation and summer temperature (Nesje, 2005). Although, it is very complex to handle the climatic change and interpreting the data.

In spite of the fact that glacier evacuation effects the entire climatic change, number of research papers have done a systematic study in order to record the real-time impact. There are some of the glaciers that include Storglaciaren in Sweden, Storbeen and Nigardsbreen in Norway and Grindelwald Glacier in Switzerland that has been studied in a detailed manner. The most prominent one in most of the research papers focuses on Holocene glacier changes or variations in various regions of Norway as spotted in figure 1.

Figure 1



It elaborates that during the era of little ice age, there is a combination among the melting glaciers and modern climate that creates a mass balance. The possible effects have been notably seen in the Norwegian glaciers that have been affected by the less stable discharge from glacier areas between the years 1961-1990 as presented in the project of Regional climate (RegClim, 2005).

2.15 Present Glaciers in Norway and the effect of Climate change:

It has been found that the last present inventory of glaciers in inventors has evaluated around 1627 glaciers in number (Ostrem et al., 1988). Out of which, 714 are from southern Norway and 913 are from Northern Norway. With respect to the details, the total area of the glaciers is around 2609 kilometer per square out of which 1592 km per square is in southern Norway and 1017 Km per square in northern Norway. There has been a possible impact and relationship between the area and volume of a glacier in both Southern and Northern Norway.

The study also reflects the fact that if the glaciers in Norway melts away, then it could definitely result in the rise of sea level into 0.34mm (Ostrem et al., 1988). The largest glacier in Norway covers around an area of 809 km per square thus the total of 1593 melting glaciers covers a total volume of 51-kilo meter. In addition, the glaciers in Norway are mostly connected with two different areas including the western part of Southern Norway and the mountainous area that is located in the central. Norway has been always among the most dominating ice caps including jostedalsbreen and Folgefonni and other glaciers.

With respect to northern Norway, there is a maximum of the glaciers that are concentrated in the Nordland that is the narrowest and extended part of Norway having 68-degree latitude. The Norwegian glacier map has been among the oldest that was published in the year 1853 thus the inventories of the melted glaciers have been made in intervals (Liestol, 1958). As per the present inventory of Liestol, it is clear that the total number of glaciers are approximately 1750 and covers a total area of around 3900 km per square. As per the topographic maps that have been used by Liestol, it is clearly a source material that could differentiate the cartographically between the snowfields and the true glaciers. There was also another inventory, but it was less detailed that has been made and prepared to show up all the glaciers in Scandinavia which has been considered as an improvised version in the Southern part of Norway (Liestol and Ostrem, 1963).

With respect to the detailed glacier inventory that has been prepared for Southern Norway in 1960 and northern Norway in 1973 (Ostrem and Ziegler, 1969). The clear concept regarding the glacier's existence is related to glaciation level, however, the glaciation level refers to the critical height of the mountain at which the glacier could be from above. However, those mountains which are higher the glaciation level has been considered to carry around one or two glaciers. Those mountains which are lower than the critical level could not be able to collect a sufficient amount of snow to form a glacier (Ostrem and Ziegler, 1969).

2.16 Holocene Glacier Changes:

There are a maximum number of glaciers in Norway that has experienced a maximum amount of Holocene Glacier change during the season of little ice age (Bogen et al., 1989). However, the majority of the glaciers in Norway usually disappears during the middle Holocene and re-formulates during the late Holocene (Matthew & Shakesby, 1984; Nesje et al., 1991). There

are only a few high lying glaciers in Norway and other mountainous regions which usually helps to survive in the entire era of Holocene.

With respect to the region of Northern Norway, there are a little number of glaciers that formed in Norway during the Late Holocene (Griffey & Worsley, 1978; Ballantyne, 1990; Winkler, 2003). At most of the outlets of the Jostedalsbreen, there is an occurrence of maritime plateau glacier that has been formed in Western South Norway in the mid of the 18th century (Faegri, 1934; Bogen et al., 1989; Bickerton & Matthews, 1993). In Norway, there are major glacier changes that reported a spatially detached peak in the years 1750 and 1800 AD (Erikstad & Sollid, 1986).

In the middle of the 18th century, the results have been reported from northern Norway that shows a synchronous LIA at the maximum range which affects the melting glaciers (Karlen, 1979; Winkler, 2003).

There have been several exceptional cases in the northernmost glacier's regions including peninsula that showed an advance leading to the LIA maxima especially in the last decades of the 19th and 20th century (Tyede & Liestol, 1977; Bogen et al., 1989; Winkler, 2001; Ballantyne, 1990). The movement and retreat in the melting glaciers occur either more or less in both regions southern and Northern Norway. At some time, it seems to be slow but at some time it gets advanced due to less stable discharge from glacier areas and more changing accessibility of mountains and Routes (Hoel & Werenskiod, 1962). The fastest and rapid glacier retreat has been seen in the 20th century in Norway (Faegri, 1948).

2.17 Recent Glaciers and Mass Changes:

Jostedal glacier that is the biggest glacier in Norway main retreat ends during the late 1950 and 1960 thus the terminus response and lag time seem to be very short in the glaciers of Norway (Paterson, 1994). The stationary glaciers come in the front position and come in advancement after some of the years in the 1980s. Due to the long response time and more changes in the accessibility of mountains and Routes, other glaciers in Norway did not start advancing. Due to the negative mass balance in the year 1996, the advances on some of the short outlets have been ceased. Other reasons include the changing climates and warm summers that was really high from the year 2000-2003 and cause huge mass loss.

There are most of the outlet glaciers which has long reactions continues to make advancement. In addition, it has been seen that the distance that has been retained is greater and influential since the maximum LIA and makes the recent resurgence of the event (Winkler et al., 1997). The level of glacier expansion has been narrowed to the maritime glacier regions of the Southern and northern area (Kiollmen, 2000).

2.18 Glaciers mass Balance and Discharge Models:

It is important to gain knowledge about the mass balance of glacier as it is interrelated and connected with the discharge of meltwater and is not seeming to be limited to the local effects. With the increase in the research, the scientific communities have been focusing to improve the knowledge attainment regarding the natural processes and variations in the climate. It has become important to obtain the measurement of the glaciers and the discharge from the catchments of glaciers in the whole of Norway. Now, the measurement gaining has become easy and accessible for all the locations and heterogeneous space and time. Moreover, measurements of the mass changes are still sparse in comparison to the large number of glaciers that differs in each country with respect to its climatic settings, size, and sensitivity (Bahadur, 1999).

There are several models which could be used to accomplish the required measurements by filling the missing values and to extend the measurement of the data with respect to both time and space. There are some mass balance models that could be used to represent the natural processes that could also help cities to control the climatic variations and the process of melting glaciers.

There are most of the models that support in simulating the natural processes however, it creates a lot of complexities but is classifies as the physically based models where there is a real physical equation of an empirical model that relies on two variables, input, and output. There is a wide range of different conceptual models that could take into different physical laws and regulations by relying on the empirical relationship that might create a significant hypothesis with the melting glaciers as it defines the high degree of accuracy. There are some of the models that do not need any adjustments as the relevant process have been considered.

Although, it needs a lot of input and computation power in order to obtain high power output. In addition, there are some of the measurements of input in the domain that are not really available for the entire model thus there are some of the measured mass balance variables that evaluates additional uncertainty. There are some of the physical models that usually relies on

physics law and describes the process of melting glaciers (Bertheir, 2006). At some points, there is a lack of input data hence the main requirement is that there is a development of conceptual and empirical models. Conceptual models in evaluating the glacier mass balance mostly rely on the empirical relationship and require a deep understanding of the system. However, the conceptual models in the mass balance could not be easily transferred to other domains and are not considered as suitable to put on the change for the variations in the climatic regions (Hock, 2009).

There are some of the adjustment parameters that rely on the characteristics of local domains and specific climatic change that is not considered as valid in the change setting of temperature and mostly it leads to misleading forecasting.

There must be the right choice of the model in order to strongly associate the availability of the input data in order to obtain the study objectives (Hock, 2009) hence, these are also considered as energy balance model (Le Meur, 2007). In addition, there is an extensive range of conceptual model that includes temperature index models and radiations in short waves (Farinotti, 2012). Most of the time, melting of snow and ice usually occurs when the temperature is at 0-degree centigrade thus the glacier melt is usually correlated to the air temperature and also determines the energy (Braithwaite & Raper, 2007). Glacier mass balance could be calculated by:

$$M = \frac{Q_{\text{melt}}}{\rho_w \cdot L_f}$$

In the above formula, pw is denoted as the water density and Lf is considered as the latent heat of fusion. However, it could be also calculated by mixing the balance of energy.

$$Q_{\text{melt}} = \frac{1}{A} \int_A (Q_R + Q_H + Q_L + Q_G + Q_R)\, dA,$$

The research papers also suggest about the mass balances in Norway especially the winter mass balance and summer mass balance that made rise to the monthly temperature and monthly precipitation for around 10% (De Woul & Hock, 2005; Andreassen, 2006). With respect to the mass balances of five different glaciers, there are various annual sensitivities in the melting glaciers due to less stable discharge from the areas of glaciers and changing accessibility of mountains/Huts or Routes.

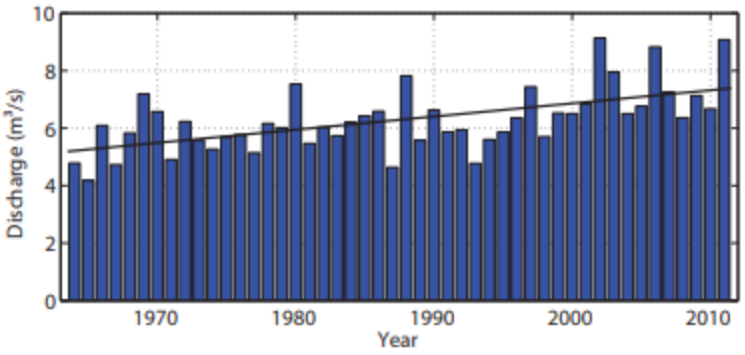
It has been also noted that in the month of June into August there is a high melting sensitivity in Norway while, in the month of September and October there is a higher winter balance sensitivity (Doll, Kaspar & Lehner, 2003). In some of the period, there is a mean precipitation that affects 80% to the melting glaciers in Norway. However, when there is a high air temperature then there are less likely effects of melting glaciers. Then research clearly suggests that there is a significant effect of melting glaciers that is most likely due to high mass balance and discharge from different glacier areas and high change and variations in the accessibility of routes/mountains/huts (Doll, Kaspar & Lehner, 2003).

2.19 Discharge Contribution from Norwegian Glaciers:

Most of the glaciers and future changes in it have an influential effect on the glacier catchments (Huss et al., 2008b). However, by relying on the percentage of the cover of the glacier, there are some changes in the temperature and precipitation of melting glaciers and have a contrasting effect on the environment (Dahlke et al., 2012). With the increase in the glacierization within the catchment, the discharge seems to be less dependent on the precipitation changes and in the air temperature (Braun, 2000). Moreover, it has been noted that the sum of annual discharge in the west of Norway increases over the last year and the increase seems to be more prominent in the year 2000 when there are more slides and changing accessibility of mountains/Routes/Huts. The increase has been noted for around 30% high than in the past years in Norway (Engelhardt, 2013a).

With respect to the index of North Atlantic Oscillation, there is a high increase in the precipitation in Norway between the year 1985 to 1995 (Hurrell, 1995) but it had settled an influential impact on the discharge from the catchment of the glacier in Norway. Another reason that has been highlighted in the study is that there is a large amount of snow that even settled to minimize the meltwater production, but the season of summers has the high tendency of melting down the efficiency of snow. The graph below shows that the increase in the summer season in Norway have increased the discharge of glaciers.

Figure 2



The above figure is also a mass balance model that illustrates the meltwater analysis thus it has been carried out by calculating the melt components of snow. The components usually sum them up and re usually referred to as a glacier melt. The figure follows the illustration from the year 1970 to the year 2010 which shows a major increase.

Figure 3

The above figure shows the location of the study sites within the area that are glaciers in Southern Norway.

The study finds out that when there is a similar climatic condition the result shows that there is a high correlation with the temperature and is negatively correlated with the precipitation with the increase on glaciers (Hock, 2005). Moreover, the glaciers in South Norway negatively correlates with the increase continentally from the west towards east. It is very challenging to make a glacier mass balance along with various error sources. There is a cycle of melting down glaciers that could lead the glaciers of melt in a day.

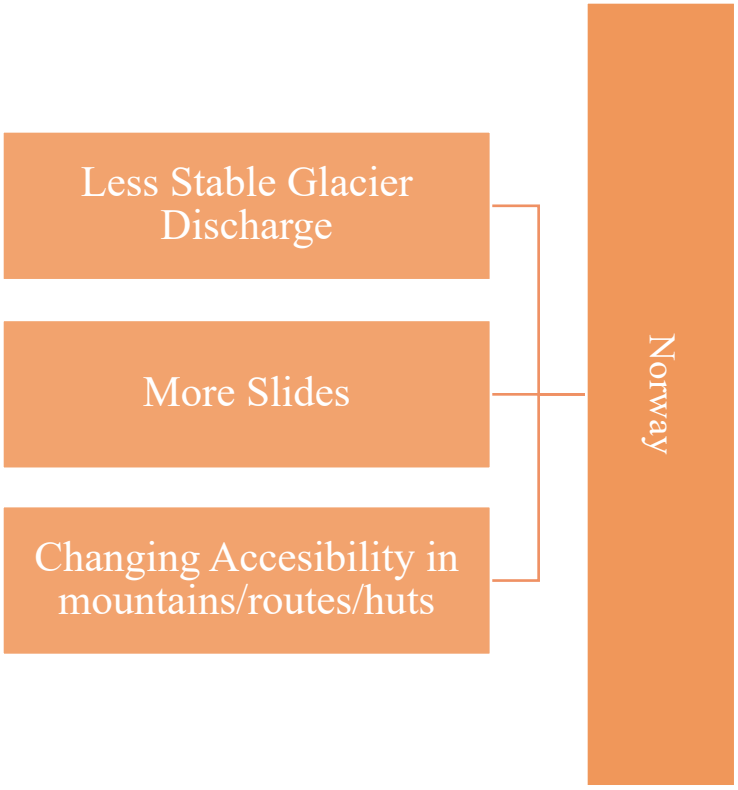
There is a high acceleration of the climate change that influences the stream flow which is a very important factor thus the rivers have been seen to be highly influenced by the melting water. By evaluating the changes in the mass of the glaciers and characteristics of discharge for the future conditions of climate, the proper climatic model might be obtained. In order to generalize the

model, it is important to reduce the area of glaciers and also cause decrease and minimization in the glacier volume (Hock, 2005).

Chapter 3: Theoretical Framework:

The theoretical framework in the study demonstrates the relationship between the dependent and the independent variable (s). In the present study, the dependent variable is Norway and the independent variables are less stable glacier discharge, more slides and change accessibility in the mountains. The following study has analyzed the research question by means of the proposed dependent and independent variables and proposing that whether the association between the variables insignificant or not.

The main motive of the theoretical framework is to analyze the effect of the sub-variables of the melting glaciers on Norway. The core focus of the study is to examine the association between the dependent and independent variables and show the use of theories in the study. The following framework is the illustration of the dependent and independent variable impacting each other.



3.1 Theory of Glacier Sliding:

The theory of glacier sliding shows that the resistance to sliding due to the hindrances either small or big is higher as compared to the hindrances that can be controlled (Weertman, 1964). By calming the assumption that ice is always linked with a bed at either side of the hindrance.

3.2 Alpine Theory:

The alpine glaciers are occurring as the part of the daily life cycle where the snow and ice have been coming and going since so many years. Under the Alpine theory, the glaciers have withered ten times and the most interesting change according to the theory has been taken place 7000 years' back (Schmundt, 2005). This has occurred not because of the less snow but due to the fact that the sun has made the ice melt and due to another reason that the line of the timer is bigger than before.

The following above theories have been taken these theories are connecting to the issue of melting glaciers and highlighting the reason behind the shrinking of the glaciers.

4. Chapter 4: Research Methodology

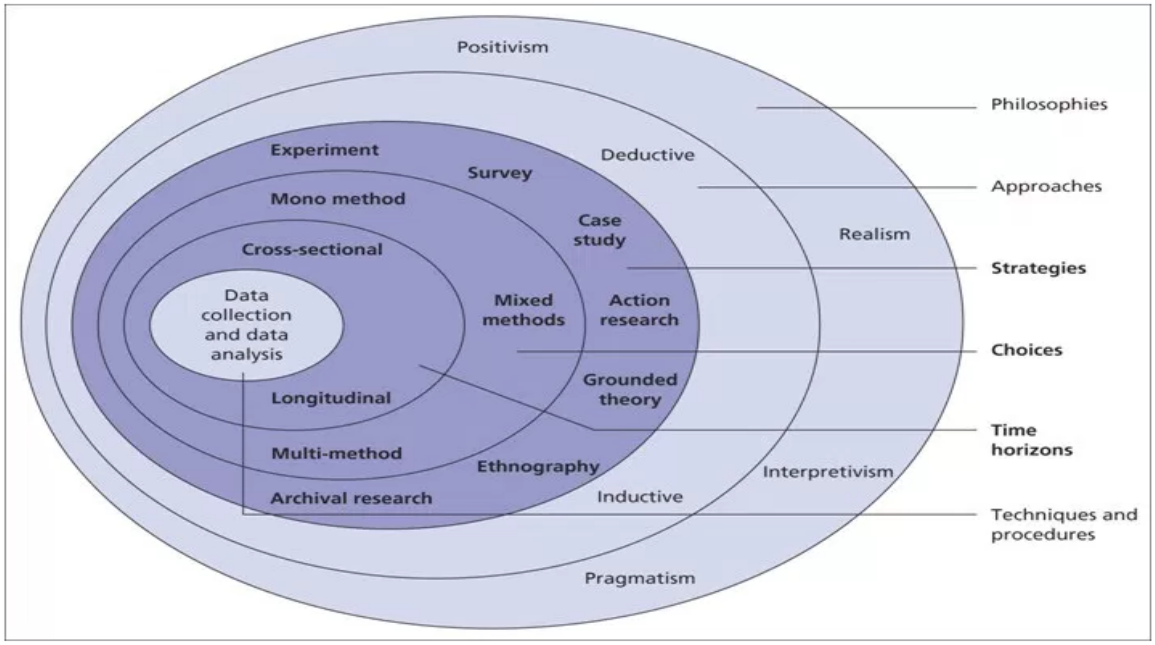
4.1 Introduction:

Research methodology in the study contains several methods that are being taken to complete the study. The following research is relying on the empirical perspective which can be either qualitative or quantitative (Grosoehme, 2014). The empirical investigation of the study will help in applying theories to the proposed topic and the methodology will help to find out that what strategies and research choices have been used to cover the study. In order to comply with the ethical boundaries of the study, the methodology will also cover the ethical area of the study with the motive to highlight the thoughts of the researcher.

4.2 Research Design:

The research design consists of a number of layers that are identified by the researcher by peeling off the research onion proposed by Saunders et.al. The onion has both layers including the inner and outer layer which comprises philosophy, choice, strategy, approach, time horizon, and data gathering process. In short, research design helps to highlight the way in which the study has been taken place (Saunders et.al, 2015).

Figure 4



4.3 Philosophy:

The research philosophy is defined as the first layer of the research onion. The philosophy of the research tells about the philosophical perception of the study. The philosophy mainly relies on three types including positivism, realism, and interpretivism. The present study depends on the qualitative approach and the data for the study is gathered by means of the secondary tool which is different research articles and papers.

The researcher has preferred the approach of interpretivism as the study is giving its central focus to evaluate the data by means of the qualitative research method. The reason behind taking the interpretivism approach is that the research will be touching the deeper roots of the proposed topic. The objective is to analyze the impact of melting glaciers on Norway. In order to do so, the researcher will be taking the approach of vulnerability assessment.

Through the qualitative approach, the researcher will be able to investigate the impact of melting glaciers on Norway and will be able to get the deeper insights of the proposed topic. The detailed analysis of the data will enable the researcher to dig the data deeply through the deeper empirical observation of the data gathered.

One more benefit for choosing the qualitative approach is that in spite of the minimal time given to the researcher to undertake the study, the qualitative approach will still offer the measurable outcome by doing an in-depth empirical investigation of the proposed research question.

4.4 Approach:

The research approach is the second layer of the research onion. The research approach here demonstrates the decisional method preferred by the researcher in the study. It can be in two forms; deductive or inductive. Due to the fact that the study has preferred the existing model, it can be stated that the study is relying on a deductive decisional tool. Apart from this, one more reason to prefer the deductive approach is that the author has an adequate amount of knowledge about the topic but has limited time to complete it. The deductive approach will therefore also help to minimize this risk factor.

The deductive approach over here shows that the author has taken the existing research model. The present research model in the study has been adapted from the past papers and theories that are considered while evaluating the melting glaciers impact to broaden the understanding of the topic and take a deeper look to the research question.

Under the deductive approach, the study has primarily created the basic reasoning statements that are also known as the problem statement and proposed a research question on the basis of that problem statement. Then the study has been validated empirically through the theories to draw a viable conclusion. Therefore, the approach has helped the researcher significantly to reach a reliable conclusion on the basis of higher certainty and reliability.

4.5 Strategy:

It is the third layer of the research onion that demonstrates about the on which the research is based upon. The strategy under the qualitative approach can be based on experiments, case studies, theories and action research (Saunders et.al, 2015). The researcher has conducted the study by means of applying the present method and using theories from the previous researches. The theories and method will be based on the examination of melting glaciers and the ways through which it can be analyzed. The present study has taken the vulnerability assessment approach for the examination.

The study has taken the data from the previous researches to see what methods have been used previously for the analysis of the melting glaciers on Norway. The study is based on the archival research strategically. It means that the research is relying on the previous papers and articles that are related to the melting glaciers issue and that involves the multiple methods used by the researcher to examine the impact of the more slides, less glacier discharge and variations in the mountains in Norway.

For the data analysis, theories have been taken by the researcher that is focusing on the methods to assess the melting glaciers impact on Norway and to analyze that to what extent it can impact the climatic conditions of Norway. The researcher has done this in order to draw the reliable conclusion from the proposed statement and to demonstrate the implications of the research. The motive behind taking the theories is that it will enable the researcher to explain the previous methods used by the researcher to assess the climatic conditions of Norway and ways in which melting glaciers can be assessed followed with its impact.

4.6 Choice:

The research choice is the fourth layer of the research onion. It tells about the choice that is preferred by the researcher. It can be of three main types including mono-method, mixed method and multi-method. The whole process of data collection and analysis is dependent on the choice of research preferred by the researcher.

As the researcher has completely taken the qualitative approach to conduct the study, it can be demonstrated that the choice of research taken is mono-method. The researcher has completely taken the single approach by solely relying on the secondary data and theories with respect to melting glaciers and its impact. The researcher has taken the data from different research papers. The articles and research papers are an in-depth understanding of the opinions of past scholars with respect to the topic.

The research papers taken from the study has been subjected to the impact of melting glaciers on the climatic conditions of Norway followed with its vulnerability assessment. The motive behind opting for the single approach is to explore the solution and examination of the glaciers by means of dividing it into three main variables including more slides, variations in mountains and glacier discharge.

4.7 Time Horizon:

This aspect of the research onion tells about the degree to which the researcher has taken the time to complete the study. The time horizon in the study illustrates that it can either be

longitudinal or cross-sectional. The present study has taken the cross-sectional approach to undertake the study as the researcher has minimal time to complete the study. Due to this time limitation, the study is bound to go with the cross-sectional approach. Another reason to go with the cross-sectional approach is the specific country chosen for the research.

Taking the cross-sectional approach over here also means that the researcher has targeted the melting glacier study to a specific country. Moreover, the study is also purely based on the in-depth observations that also makes the research exploratory in nature. The motive behind taking the cross-sectional approach is that it enables the researcher to illustrate the patterns of the study effectively and analyze the cause and effect relationship to link the variables clearly with each other. In short, the cross-sectional study has enabled the researcher to get higher validation in demonstrating the change in one variable with the change in the study variable.

4.8 Data Collection:

In order to collect the data, there are multiple methods of data collection if we see it from the perspective of qualitative research. The qualitative study can be undertaken by gathering the data through the focus group interviews, narrative inquiry, action research and using the secondary tool as a source to gather data from the past papers.

Due to the fact that data collection is entirely relying on the qualitative analysis, it can be demonstrated that the researcher has focused on the observatory side of the study by linking it with theories related to the topic. As the data has been gathered by means of the secondary data the researcher doesn't need to have any other data collection. The study has also focused on the documental revision approach and has also preferred the authentic past papers and case study as a medium of information to conduct the study and analyze the proposed issue.

The qualitative approach has helped the researcher to gather the data and get reliable and deeper insights about the melting glacier issue and it has also enabled the researcher to rely on the secondary data taken in the section of the literature review with the motive to have the historical analysis. The past papers and articles have let the researcher to inevitably have the proper glimpse on the subject of study from multiple dimensions and to make a good contrast with the previous papers and the present one.

Sample Population

Due to the fact that the research is mainly relying on the qualitative analysis of data, the researcher does not need to gather the primary data by means of the surveys and interviews. The

gathering of data is entirely relying on the secondary source and for this reason, the study has no sample population.

The underlying focus over here is the past papers and theories and methods related to the examination of melting glaciers on Norway. The study is giving its central focus to the papers that are linked with the less glacier discharge and variations in the mountains followed with the increase in slides. Moreover, the study is focusing on the different papers used by the researchers to assess the melting glaciers impact on Norway.

Additionally, the researcher is giving its focus on the three main variables that have been originated from the proposed research question. The researcher will also compare the findings of the primary data with a critical review of the literature, and the similarities and differences will be highlighted in the findings section of the study.

The study will be qualitative, and findings will highlight the key themes of the study. The study will follow a theoretical approach and the impacts of changing climate and weather patterns will be analyzed for Norway. However, since the changes are experienced across the region, the findings will be equally significant for other countries as well.

Ethical consideration

The ethical consideration in the study is one of the underlying factors considered in every study by the researchers. At the time of formulating the research, the study has made this sure that any person or source that is being used or referred in the research are informed rightly about the purpose by telling the reason behind taking the other's data. Hence, the researcher has ensured the confidentiality of the study while referring to the secondary data in the literature review. The data has been cited adequately to comply with ethical boundaries.

The researcher has justified the data by referencing it properly. The underlying objective of the study is to discover the new horizons of the proposed question and examine the vulnerabilities of the melting glaciers on Norway. Though, if the researcher will not prefer the ethical values of the study, it will culminate into affecting the human psyche in a negative manner. Hence, the study has been made by ensuring complete advocacy and discretion in the study to provide security to the data taken from the past researches. Moreover, the ethical consideration also helps to raise the level of honesty of the research paper by also increasing the reliability of the researcher. The study has also made this sure that the study done by the researcher is very significant for the country in evaluating the adverse impacts of the climatic change and will also help to take certain measures in future.

There has been dishonesty done by the researcher in the study as each and every past papers and article have been referenced accurately by the researcher by taking the consent of the researchers. Every statement taken in the study is entirely defensible and the data has been cited with authentic sources throughout the paper (Armstrong, 2017).

Concisely, the research methodology section tells about the methods and approaches undertaken by the researcher to conduct the study. The study is depending on the qualitative approach by taking the secondary data as the main medium to gather the data. The researcher has taken the interpretivism approach under the philosophical perception and deductive approach for the decisional tool. For the research choice, the study has focused on one method only which is the qualitative analysis that makes it a mono-method study.

The present study has taken the cross-sectional approach to undertake the study as the researcher has minimal time to complete the study. The motive behind taking the cross-sectional approach is that it enables the researcher to illustrate the patterns of the study effectively and analyze the cause and effect relationship to link the variables clearly with each other. The study has been made by ensuring complete advocacy and discretion in the study to provide security to the data taken from the past researches. There has been dishonesty done by the researcher in the study as each and every past papers and article have been referenced accurately by the researcher by taking the consent of the researchers.

Chapter 5: Data Analysis

The analysis of the data is used to observe and refine the data in the newer form. The collection of the data and examining it are the two main important conducts of the study and for the reader as well because it shows the complete data under the one head of the study. Hence, the data analysis of the present study is contributing to the helpful tool to define the data and highlighting about what has been explored in the study by the researcher.

According to the theoretical literature mentioned above, the results showed that melting glaciers have a significant impact on Norway and focusing on the topic of potential deterioration is very essential for the researchers. To the first research question which was melting glaciers impact, the findings have explored that the glaciers have highlighted a system of discharge which is highly impacted by snow and glacier meltwaters.

The study done by Engelhardt et.al (2013) in order to see balance in the rates of discharge for the three main glaciers catchments in the area of western Norway showed that the fall in the rainfall by 10 to 20% in the similar period has been overreacted culminating in the rise of the annual discharge by 20%. The annual discharge and melting glacier are highly correlated with the yearly and winter rainfall. The increased in the variation in both glaciers melt and annual discharge are getting highly correlated with the differences in the summer temperature. Hence, the glaciers in the several continental climates are particularly susceptible to fall in the annual and summer discharge with the constant rise in summer and decline in the glacier extent **(**Engelhardt et.al, 2013**).**

Some more researchers have investigated this area including Farinotti et.al (2012); Immerzeel et.al (2012) and Sachner et.al (2012). By means of the climate model data, there have been various studies showing the rise in the discharge and the reason behind highlighted was the rise in the discharge in the spring season because of the onset of snowmelt, however, the decrease in the next year was due to the glacier extent according to Huss et.al (2008). The glacier meltwater could also have an effect on the hydrological system of the larger watersheds. The study done by Huss indicated that for the catchments having the size of 100,000 km2 and an estimated one percent glacier covered can lead to raising the glacier discharge to 25 percent.

Moving on to the second research question which the impact of more slides on Norway is, the analysis revealed that recorded landslide events have raised exponentially since 1960. It is however not possible to draw the conclusion that whether this rise is due to the rise in the capability of the natural release of slides due to climate change (Forland et.al, 2007). Any kind of natural change in the frequency is masked by the mixture of increase in the number of infrastructures and reliable registration.

For the icebergs, the icebergs consist of the total field of 2609 km2 (around one % of an entire field of mainland Norway) including the area of 1592 km2 in southern Norway and rest of the 1017 km2 in northern Norway. The whole iceberg mass in Norway has been estimated roughly (Ostrem et al., 1988). This is also shown in long-term aggregated iceberg volume records. There is a high connection between the North of Atlantic vibration indicator and yearly winter and overall volume balance on marine icebergs in Norway has been shown (Nesje et al., 1995), the most dominant aspect is the positive connection between snowfall while the aggregation season which is October to April and in winter December to march.

To the last research question which the changing accessibility of mountains impact on Norway is, it can be interpreted that the change in the availability has resulted into focusing the activities in those parts of the study that is accessible easily. The manageable change can culminate from the difficult interaction of the driving forces that incur change. The essential drivers interrelating with the old construction and neglecting of seasonal farming can be classified as the socio-economic and technical change (Either & Pothoff, 2016).

Apart from the three variables, the study also highlighted some interesting findings regarding the glaciers that transformation in glacier volume can have an impact on both the sea level and the river runoff regime downstream. Similarly, the mountain glaciers in Norway have connected streamflow, and are of precise importance as the electricity sector is dependent on hydropower. The temporal and spatial distribution of glacier mass-balance and discharge dimensions from glacier catchments is consequently biased towards demands from hydropower utilization.

Additionally, for the Arctic region of Norway, Vihma (2014) asserts that the pace of climate change in the Arctic is almost twice as fast as the global climate change. Vihma (2014) highlights that the most prominent indicators of climate change in the Arctic can be seen by observing the decline in the sea ice cover. The decline was first recorded through satellite remote sensing data and the changes since the first satellite record have been approximately 50%. Vihma

(2014) argues that sea ice cover is a sensitive indicator in the context of climate change and it has significant impacts on other components of the climate system.

The climate change issue that will have a central theme of the current study in the Norwegian context is a natural hazard, both summer, and winter. The Arctic region experiences volatility in snow and ice cover. The people in the region face extreme cold weather conditions. There has also been a decline in Arctic sea ice due to the phenomenon of global warming. The cold climate of the region is highly vulnerable to the air pollutants and toxins. The latest readings published by the Norwegian Ice Service reported the ice cover in the Arctic in the Svalbard area to be 40% below the ice cover that was observed in 1981 (Norwegian Ice Service, 2018).

Therefore, it can be interpreted that melting glaciers creates a major effect on Norway and majorly it is due to changing the accessibility of mountains and climate. This reason particularly affects the water resource management, evaluation of natural hazard in Norway hence there must be planning g recreation in Norway to reduce adverse effects. In addition, the measurement of mass balance usually provides a direct signal of change in the climate that usually causes variations in the melting glaciers.

The evacuation of the melting glaciers has been considered as a definite sign for the occurrence of global warming (Dyurgerov & Meier, 2000; Dyurgerov, 2005; Orlemans, 2005). There are data points in the glacier length that occurs before the period of annual or continuous measurements which creates several variations in the winter precipitation and summer temperature (Nesje, 2005). Although, it is very complex to handle the climatic change and interpreting the data.

Coming towards the models, there are several models which could be used to accomplish the required measurements by filling the missing values and to extend the measurement of the data with respect to both time and space. There are some mass balance models that could be used to represent the natural processes that could also help cities to control the climatic variations and the process of melting glaciers.

The study also reflects the fact that if the glaciers in Norway melts away, then it could definitely result in the rise of sea level into 0.34mm (Ostrem et al., 1988). The largest glacier in Norway covers around an area of 809 km per square thus the total of 1593 melting glaciers covers a total volume of 51-kilo meter. In addition, the glaciers in Norway are mostly connected with two different areas including the western part of Southern Norway and the mountainous area that is

located in the central. Norway has been always among the most dominating ice caps including jostedalsbreen and Folgefonni and other glaciers.

With respect to northern Norway, there is a maximum of the glaciers that are concentrated in the Nordland that is the narrowest and extended part of Norway having 68-degree latitude. The Norwegian glacier map has been among the oldest that was published in the year 1853 thus the inventories of the melted glaciers have been made in intervals (Liestol, 1958). As per the present inventory of Liestol, it is clear that the total number of glaciers are approximately 1750 and covers a total area of around 3900 km per square. As per the topographic maps that have been used by Liestol, it is clearly a source material that could differentiate the cartographically between the snowfields and the true glaciers. There was also another inventory, but it was less detailed that has been made and prepared to show up all the glaciers in Scandinavia which has been considered as an improvised version in the Southern part of Norway (Liestol and Ostrem, 1963).

There are most of the models that support in simulating the natural processes however, it creates a lot of complexities but is classifies as the physically based models where there is a real physical equation of an empirical model that relies on two variables, input, and output. There is a wide range of different conceptual models that could take into different physical laws and regulations by relying on the empirical relationship that might create a significant hypothesis with the melting glaciers as it defines the high degree of accuracy. There are some of the models that do not need any adjustments as the relevant process have been considered.

There are some of the physical models that usually relies on physics law and describes the process of melting glaciers (Bertheir, 2006). At some points, there is a lack of input data hence the main requirement is that there is a development of conceptual and empirical models. Conceptual models in evaluating the glacier mass balance mostly rely on the empirical relationship and require a deep understanding of the system. However, the conceptual models in the mass balance could not be easily transferred to other domains and are not considered as suitable to put on the change for the variations in the climatic regions (Hock, 2009).

Moreover, it has been noted that the sum of annual discharge in the west of Norway increases over the last year and the increase seems to be more prominent in the year 2000 when there are more slides and changing accessibility of mountains/Routes/Huts. The increase has been noted for around 30% high than in the past years in Norway (Engelhardt, 2013a).

The issue of snowfall can be challenging for the agriculture sector and augment erosion. Generally, floods are assumed to increase, however, there are local variations. Rainy climate can affect the infrastructure of the buildings and increasing threats for failure in infrastructure. Various areas of south and east Norway have hotter climate droughts. This can cause consequences to the agriculture sector. It is also assumed that acidification can occur in Norway waters due to the increase in carbon dioxide.

Few areas of south and east of Norway are likely to have less rainfall in summer. This can become challenging for the agriculture sector. There are also signs of acidification in Norwegian waters, due to increased concentration of carbon-di-oxide. This can harm the species calcareous shells in long run.

The climate change in Norway also affects the other aspects and cannot be separated from them. Moreover, climate change brings threat to habitat, the dispersion of aliens, pollution and unnecessary utilization of natural resources. In many cases, change in climate can also result in other negative impacts. Commonly Icebergs around the globe are back down (Dyurgerov, 2005).

Chapter 6: Conclusion

Concisely, the objective of the research was to analyze the impact of melting glaciers on Norway. The study aimed to do this by means of choosing the qualitative approach. In order to conduct the qualitative approach, secondary data has been served as the main medium. The empirical investigation of the proposed research questions resulted in highlighting the following findings from the literature:

- glaciers have a significant impact on Norway and focusing on the topic of potential deterioration is very essential for the researchers.
- The annual discharge and melting glacier are highly correlated with the yearly and winter rainfall. The increased in the variation in both glaciers melt and annual discharge are getting highly correlated with the differences in the summer temperature.
- The glacier meltwater could also have an effect on the hydrological system of the larger watersheds. The study done by Huss indicated that for the catchments having the size of 100,000 km2 and an estimated one percent glacier covered can lead to raising the glacier discharge to 25 percent.
- landslide events have raised exponentially since 1960. It is however not possible to draw the conclusion that whether this rise is due to the rise in the capability of natural release of slides due to the climate change
- The manageable change can culminate from the difficult interaction of the driving forces that incur change. The essential drivers interrelating with the old construction and neglecting of seasonal farming can be classified as the socio-economic and technical change.

6.1 Recommendation for Future Research:

As per the Limitations, highlighted above, it can be suggested that the future research can be done by taking the specific glacier and analyzing its impact on the specific region as it will help to see have the study in the specific area. Moreover, the time constraint made the study, cross-section, however, future researchers are suggested to take the longitudinal approach and go for a deep observation. Moreover, other variables are suggested to take in the future research that can have an intense impact on the Country.

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