Czech University of Life Sciences Prague

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Bachelor Thesis

Economic Analysis of Global Climate Change Impact upon Society on a Micro Level in the Netherlands

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Objectives of thesis

evaluate the effects of global climate change on the Netherlands. How much investments have been made into construction of dikes to prevent flooding of the country. Were these investments beneficial and are the Netherlands safe from the flooding?

Methodology

The literature review will be constructed using extractions from books, online sources and certain studies. the pratical will be made from investments and calculating benefits, net return

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The proposed extent of the thesis
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Recommended information sources

The Oxford Companion to Global Change

BURROUGHS, William James. Climate change: a multidisciplinary approach

HOUGHTON, J. Global warming: the complete briefing

GRAFTON, R, Linwood PENDLETON H and NELSON Harry W. A Dictionary of Environmental Economics, Science, and Policy

Changing estuaries, changing views; Erasmus univ., Rotterdam & Radboud univ., Nijmegen

STIVE, M., KONINGSVELD, van M., MISDORF, R., The Netherlands: challenges for the 21st century

KNMI Climate Change Scenarios 2006 for the Netherlands

NASA website: www.nasa.gov

Delta Programme Commissioner; online: www.deltacommissaris.nl

Deltawerken; online: www.deltawerken.com

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Prague March 7. 2013

Declaration

I declare that I have worked on my diploma thesis titled “Economic Analysis of Global Climate Change Impact upon Society on a Micro Level in the Netherlands” by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any third person.

In Prague on 15.3.2013 ____________________

Jana Marková

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I would like to thank Ing. Petr Procházka, MSc, PhD. for his advice and support during my work on this thesis.

Ekonomická analýza na mikro úrovni vlivu globální změny klimatu na člověka v Holandsku

Economic Analysis of Global Climate Change Impact upon Society on a Micro Level in the Netherlands

Souhrn

Tato bakalářská práce, “Ekonomická analýza na mikro úrovni vlivu globální změny klimatu na člověka v Holandsku“, je rozdělena na dvě části. Teoretická část se zabývá úvodem do problematiky změny klimatu, čím je to spuštěno a jaké má následky. Také se zabývá situací v Holandsku, výstavbou bariér, přizpůsobivost proti záplavám a jinými nezbytnostmi.

Praktická část se soustředí na scénáře, převzaty z Holandského národního meteorologického institutu, a také, jaké následky může Holandsko očekávat, pokud se tyto scénáře vyplní. Dále se soustředí na efektivitu a výnosnost z konstrukce záplavových bariér.

Cílem této práce je odpovědět na otázky: Je Holandsko v bezpečí na dalších sto let? Jak výnos měli a mají bariérové konstrukce?

Klíčová slova: změny globálního klimatu, Holandsko, zvyšování hladiny moře, konstrukce bariér, budoucí následky, čistá budoucí hodnota, scénáře od KNMI, míra výnosnosti

Summary

This bachelor thesis, Economic Analysis of Global Climate Change Impact upon Society on a Micro Level in the Netherlands, is divided into two parts. The theoretical part introduces the problematic of climate change, its triggers and affects. It also describes the situation in the Netherlands, the construction of barriers, adaption to prevent flooding and other necessities related to the rising sea level.

The practical part is concentrated on scenarios, which are taken from The Royal Netherlands Meteorological Institute, and the effects that await the Dutch if such scenarios are to be fulfilled. It also concentrates on the effectiveness and benefits of the barrier constructions.

The aim of this thesis is to answer the question: are the Netherlands safe for the next 100years? And how beneficial was the construction of barriers?

Keywords: global climate change, the Netherlands, sea level rise, dike constructions, future effects, net present value, KNMI scenarios, internal rate of return

Acronyms

CO2	Carbon dioxide
GCM	General Circulation Model
GDP	Gross Domestic Product
GRACE	Gravity Recovery and Climate Experiment
ICESat	Ice, Cloud and Land Elevation Satellite
IRR	Internal Rate of Return
KNMI	The Royal Netherlands Meteorological Institute
NASA	National Aeronautics and Space Administration
NPV	Net Present Value
RCM	Regional Climate Model

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1. INTRODUCTION

Global climate change is happening over centuries. The big changes that have been studied over the past century are the changes of greenhouse gases in the atmosphere, the different temperature trends on continents and sea level rise connected with the melting of glaciers. All of these factors have been in central debate of many companies. But sea level rise can be a great problem for low-lying countries as there is the possibility of flooding the land and therefore disappearing from maps. The Netherlands, situated west of Europe and surrounded by the North Sea and Wadden Sea, has half of its country lying below sea level. The fact that the authorities have built barriers, dikes and dunes or reclaimed land from the sea to prevent flooding is a great benefit otherwise some areas could have been under water now. The construction of storm surge barriers in the Netherlands has influenced many other countries. But there is the question as to how long the barriers can withstand the increasing sea level rise and have the constructions brought any benefits.

2. AIMS AND METHODOLOGY

2.1. Aims

The aim of this thesis is describe the effects of global climate change on the world, to detect what triggers it and any future predictions. This will be done through studied literature. This thesis will also introduce the Netherlands and describe the history of what led to the construction of barriers. It is also written to prove that the barriers constructed are built efficiently for the protection of the Netherlands and will protect the country for another 100years.

2.2. Methodology

The methodology will be done by constructing certain scenarios based on the Royal Netherlands Meteorological Institute. The scenarios are based on the amount of precipitation, sea level rise, the Netherlands if they did not have any barriers. The calculation of the benefits of the barriers is computed by calculating the net present value and the internal rate of return based on a future scenario of cost and benefits of investments.

3. CLIMATE CHANGE

3.1. Introduction

The Earth's climate has been fluctuating ever since it was formed. Over the past centuries the climate has been changing. We can see these changes mainly on the landscape of today's continents. Today, climatic changes are a central debate in many organisations and even politics. To understand the reason for these changes we need to recognize the different impacts that contribute to these changes and also the impacts it has on the world.[1] Very often we are witnesses of new climatic records being broken. Climatic extremes aren't anything new in today's world, but we can only call these changes a trend after a couple years pass.[2]

1.2. Definition

- "*Global change in the earth's climate*"[3]
- "*Shift in meteorological conditions which last for many years and usually involve the typical parameters such as temperature or rainfall*" [2]
- "*A long-term change in the Earth's climate, or of a region on Earth"* [4]

It is also necessary to mention the difference between weather and climate as many people tend to misinterpret and give these two the same definition. And so, weather is what we get everyday depending on what is happening in the atmosphere at a specific moment.[1]

3.3. Measurement of Climate Change

There are several ways how we can measure climate change. The main measurements are made of temperature, precipitation, snowfall, cloudiness, etc. But

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[1] BURROUGHS, William James. *Climate change: a multidisciplinary approach*. 2nd ed. New York: Cambridge University Press, 2007, xi, 378 p. ISBN 05-218-7015-1

[2] HOUGHTON, J. *Global warming: the complete briefing*. 4th ed. New York: Cambridge University Press, 2009, xviii, 438 p. ISBN 05-217-0916-4

[3] GRAFTON, R, Linwood PENDLETON H and NELSON Harry W. *A Dictionary of Environmental Economics, Science, and Policy*. Northampton, MA: E. Elgar Pub., c2001, liii, 362 p. ISBN 18-406-4126-6.

[4] CONWAY, E. *What's in a name? Global Warming vs. Climate Change, NASA. Posted 12.05.2008.ref. 14.12.2012. online:* *http://www.NASA.gov/topics/earth/features/climate_by_any_other_name.html*

it is very hard to get data from past years as the mechanisms for measuring were not that good and so some empty data may occur.

One of the instruments used for measurements are satellites. The first satellites used for measurement were only capable of measuring cloud cover and temperatures but the upgraded satellites are now able to measure snow cover over continents and ice covers on the poles. It is also thanks to microwave radiation that this measurement is possible.[1] Some of the satellites used especially by NASA are TOPEX/Poseidon which maps the exact characteristics of the ocean's surface, Jason is used for measuring the height of oceans and monitors circulation of the oceans, ICESat (Ice, Cloud and Land Elevation Satellite) studies the amount of ice on the polar ice sheets and how they contribute to sea level change globally and finally GRACE (Gravity Recovery And Climate Experiment) helps us better understand the flow of water on Earth.[5]

Another measurement is using "in situ" instrumental observations. These instruments are mainly used for temperature measurements and are placed in the ground. It is necessary to have the instruments placed correctly as there are many factors that may affect the sensors. There is the effect of direct sunshine but also heat radiated from the ground and so the position is crucial. [1]

An additional measurement that is used when we do not have any other data is the use of "proxy measurements". These are of course indirect measurements but give an idea of the surrounding. One of the measurements is tree rings. The thickness of tree rings is the most direct measure we can get from them. These rings do not only depend on the rainfall and temperature but also on groundwater which may give us misleading information about the amount of rainfall. [1]

3.4. Causes of Climate Change

One cause to climate change are ocean currents. These currents transport energy to higher latitudes and so any changes that would occur would have great implications on climate change. It is even possible that certain shifts may occur which would bring about greater changes in the climate. By modelling we are able to realise that

[5] LYNN, C., BEASLEY, D. NASA Satellites Measure and Monitor Sea Level. Posted 7.07.2005. ref. 10.01.2013. online: http://www.NASA.gov/home/hqnews/2005/jul/HQ_05175_sea_level_monitored.html

the currents are very sensitive to changes such as amount of rainfall or amount of icebergs broken off Greenland. These small changes may activate shifts that would carry warm surface water less far north and therefore change the climate above Europe drastically. [1]

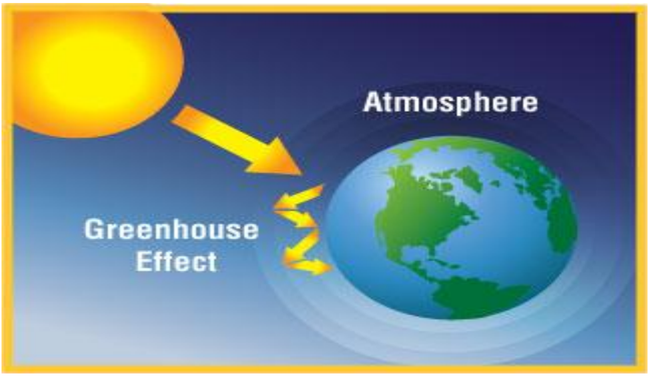
Another cause are volcanoes. When volcanoes erupt they produce a high mass of dust cloud which is exploited high into the atmosphere. The sulphur dioxide which is released converts into sulphuric acid aerosols and are held in altitudes and spread over the globe. The dust cloud absorbs much of the heat radiated from the sun and so there is cooler air in the lower levels as less radiation passes. The eruption of volcanoes produces cooler summers for the next two to three years. [1]

3.4.1. Greenhouse Effect

As everyone is aware, the main cause to Global Climate Change is the Greenhouse effect. We can understand the main principle of global warming if we consider the energy radiated from the sun, which warms the Earth's surface and heat radiation from the Earth and the atmosphere into open space. If these two radiations are not balanced then the balance can be restored again by increasing the Earth's surface. [2]

In diagram 1, the greenhouse effect, demonstrates how the greenhouse effect works. The sun radiates heat to the Earth's surface. Some of this heat is absorbed, some reflected back into space and some the heat is reflected back by the gases in the atmosphere this causing the greenhouse effect.

Diagram 1: Greenhouse effect



Source: Kids zone, 2007

The gases that form the atmosphere – nitrogen and oxygen, do not absorb any radiation or even release any. It is the gases that are less represented in the atmosphere that absorb some of the thermal radiation and therefore produce the so called blanket over the surface. These gases are water vapour, carbon dioxide and some other smaller gases.[2]

It is necessary to understand the different gases that are present in the atmosphere and which contribute greatly to global warming. One of them is carbon dioxide. This gas is and will be emitted into the atmosphere daily by humans and animals. Humans release carbon dioxide from respiration and from certain emissions. The carbon cycle is a great demonstration of how much carbon is released and absorbed to and from the Earth's surface.[6] Another greenhouse gas is methane. Even thought this gas is represented minimally in the atmosphere compared to carbon dioxide, the effect it has is eight times more than the molecule of carbon dioxide. Methane is released from wetlands or marshy areas where organic materials decompose. But it is also released from human activities such as leakage from a natural gas pipeline or oil wells, from enteric fermentation from livestock, decaying of rubbish and from wood burning. It is interesting to see the increase of methane in the atmosphere with the growing population from the Industrial Revolution. Nitrous oxide is also a much known gas of the greenhouse effect. Its concentration may be low in the atmosphere but it is increasing every year by approx. 0.25 percent. It is linked to natural and agricultural ecosystems mainly. The human impact is probably only from the excess use of fertiliser. [2]

3.4.2. Arctic Warming

We have been experiencing climate change in the Arctic very intensely. The temperature rise has doubled over the past decades in comparison to other parts of the world. Widespread melting of glaciers and sea ice and thawing of permafrost are all evidence to the warming of the Arctic.[7] These changes are all indications of environmental and societal significance to global warming. It is predicted that that these trends will accelerate in this century due to the increase of greenhouse gases.

[6] RICHARDSON, K. and DEFRIES, R.S. *Enviromental Change: Global Risks, Challenges and Decisions*. 1st pub. New York: Cambridge University Press, 20112011, xxi, 501 pages. ISBN 978-052-1198-363.

[7] HASSOL, S. J.. *Impacts of a warming Arctic: Arctic Climate Impact Assessment*. New York, N.Y.: Cambridge University Press, 2004, 139 p. ISBN 05-216-1778-2. Online: http://amap.no/acia/

One of the main contributors to the global sea level rise is the melting of land-based Arctic ice. It's not only climate change that has an effect on the Arctic, but it is also overfishing, chemical contamination from other regions, changes in land use that may have destructive features. Changes in the Arctic climate which include winters that are shorter and warmer, increased precipitation and the decrease in snow and ice cover are predicted for future centuries but it is not possible to say at what rate.[8]

It is necessary to clear why the Arctic is warming faster than other parts of the world. Firstly, as the snow and ice cover melts, land is revealed and more sunlight is absorbed which increases the temperature. Secondly, the gathering of greenhouse gases increases the energy received at the surface and this goes directly into warming than into evaporation as in the tropics. Thirdly, the depth that needs to be heated in order to cause some warming of surface air is quite shallow which results in an increased temperature raise.[8, 9]

Some of the future scenarios connected with the Arctic climate are the increase in precipitation and the decrease of snow cover. It is expected that the rate of precipitation will increase by 20% mainly due to rain. The snow cover in the Arctic has decreased by 10% over the past decades and it is predicted that it will decrease by another 10-20% by the end of this century. [7]

It is clear that the Arctic plays a major role in global climate change. The changes that occur in the Arctic have a global impact. One cause is the reflectivity due to melting of snow and ice cover. Thanks to gathering of greenhouse gases the snow cover disappears earlier in spring and starts to form later in the autumn. This reveals a darker water and surface area which absorbs more energy from the sun and therefore increases the warming of the surface. This in return causes faster melting which causes quicker warming forming a self-reinforcing cycle. Another cause is sea level rise. This is connected with the Arctic because if the total land-based ice melted it would correspond to eight meters of global sea level. It is necessary to say that as water gets warmer, it expands which makes it less dense and therefore takes up more

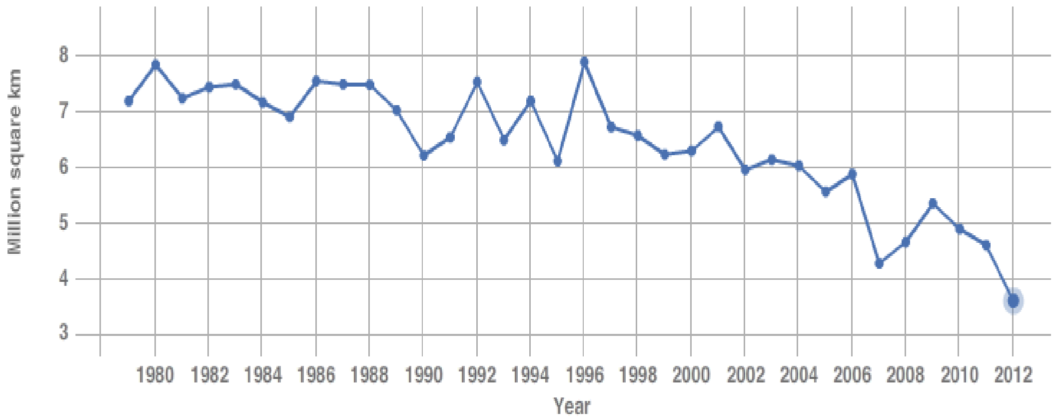
[8] CUFF, D. J. and GOUDIE A. *The Oxford Companion to Global Change*. New York: Oxford University Press, c2009, xxx, 684 p. ISBN 978-019-5324-884

[9] BRIDGMAN, H, OLIVER, J. E. and GLANTZ. M. *The global climate system: patterns, processes, and teleconnections*. 1st pub. New York: Cambridge University Press, 2006, xviii, 331, [8] p. of plates. ISBN 05-218-2642-X.

space. Since the 1960s the arctic glaciers have been in decline and it is predicted to accelerate over the next century. [7]

In figure 1, Arctic Sea Ice, we have an average September extent collected by NASA satellites. We can see that the ice extent has a tendency to decline rather than increase over the past ten years. And so we can only assume that the trend of declining will continue in the future.

Figure 1 Arctic Sea Ice



Source: NASA, 2013

3.4.3. Sea Level Rise

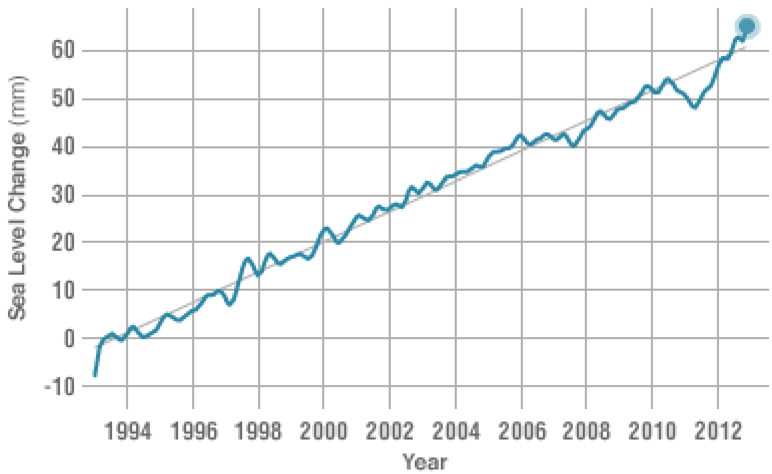
If we look back to the last ice age, we will see that the sea level was 5-6metres higher then it is today. But when the ice cover was at its maximum, when it stretched from Europe to southern England and from North America to the south of the Great Lakes, the water level was an enormous 100 metres below today's level. The great increase in sea level is definitely due to the melting of the great ice-sheets. During the twentieth century it was discovered that the sea level rose by 10-20cm. This rise is mainly due to thermal expansion of the oceans. Of course the melting of glaciers is also an important factor in sea level rise. On the other hand it is difficult to develop a trend from melting glaciers as it depends on the amount of snowfall in winter and the amount of sunshine during summer. [2]

Let us look closely at the causes of sea level changes. One of the basic and major causes is the temperature of the oceans. As the water gets warmer, it expands. The ocean itself has its own temperature in different areas and in different currents. But as water circulates the warmer water expands more quickly than colder and so the distribution of different changes in sea level depends on the location. Another cause is connected to the already mentioned ice sheets. The sea level changes when the mass of the water changes. This can occur by the exchange of land water or the stored water in the ice sheets. When the continents were covered in ice the sea level was rapidly lower but once the ice melted the sea level had risen. This links to snow cover of mountains, reservoirs, and irrigation systems. If water from the oceans is in some way extracted, there is always water that re-enters the ocean causing changes to the mass of it. [10],[11]

The effect sea level rise has on climate change is that along with the change of currents, the amount of snowfall, the heat radiated back by greenhouse gases and the thermal expansion of water, we may witnesses a different type of climate as amounts of precipitation may rise in areas where it isn't typical. [6]

In figure 2, Sea level rise, we see the increasing sea level rise from 1993 to present. The latest measure shows the total increase of 65mm. As we can see, there is a steady trend in the rising sea level with slight fluctuations, but we can only expect the steady increase, perhaps not rapid but visible.

Figure 2: Sea level rise



Source: NASA, 2013

[10] HOUGHTON, John Theodore. *Climate change 2001: the scientific basis : contribution of Working Group I to the third assessment report of the Intergovernmental Panel on Climate Change*. New York: Cambridge University Press, 2001, x, 881 p. ISBN 05-210-1495-6

[11] OLDFIELD, F. a DEFRIES R. S.. *Enviromental Change: Key Issues and Alternative Approaches*. 1st pub. Cambridge: Cambridge University Press, 2005, 363 s. ISBN 05-215-3633-2.

3.4.4. Oceans

As already mentioned, oceans are a great contributor to sea level rise. They hold 97% of the World's water making them the main factor in the hydrological cycle. The oceans are also the main carrier of the world's heat. Some of the main carriers are the North Atlantic Current and the Gulf Stream. These currents are the cause of different temperatures of countries on the same latitudes. One of the examples is Western Europe and Siberia or Canada. If a slight temperature change would occur, the currents could easily change the climate of certain regions. The changes that occur in the climate such as change in air pressure, storm paths or trade winds can be accounted for the ocean-atmospheric interactions. The main interaction that occurred was the El Nino Southern Oscillation. El Nino mainly affects the temperature of the tropical Pacific but the changes can be seen worldwide due to increase of rainfall and changes in temperatures. [12],[13]

[12] RICHARDSON. *Climate Change: Global Risks, Challenges and Decisions*. New York: Cambridge University Press, 20112011, xxi, 501 pages. ISBN 978-052-1198-363

[13] SILVER, C.S. and DEFRIES, R. S. *One earth, one future: our changing global environment*. Washington, D.C.: National Academy Press, c1990, xiii, 196 p. ISBN 03-090-4141-4

4. THE NETHERLANDS AND FLOODS

4.1. Definitions

- "*Dike: an embankment for controlling or holding back the waters of the sea or a river*" [14]
- "*Dune: a sand hill or sand ridge formed by the wind usually in desert regions or near lakes and oceans*" [14]
- *"Estuary: the lower part of a river or stream that enters the ocean and is influenced by tidal waves"* [3]
- "*Flood plain: the area of land surrounding a water channel that is subject to flooding*" [3]

4.2. Introduction

Diagram 2: The Netherlands

Source: Google maps

The Netherlands is a small country with a large population. A population of approximately 16.5 million inhabitants spreads on the area of 41,526 km2. The Netherlands have a great number of waterways expanding over 5046km which mainly serve for the transport of ships over 50tonnes and also transport form port to port. Thanks to the large amount of waterways the Dutch have established a large amount of windmills, counting 1180, which are spread along the canals and have served for agricultural purposes and for pumping water. [15]

Below we can see how it is with economy of the Netherlands:

- GDP growth: 0.3%[16]

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[14] *Random House Webster's college dictionary*. Newly rev. and updated [ed.]. New York: Random House, c1995, xxxii, 1568 p. ISBN 06-794-3886-6

[15] BERKMOES RYAN VER, Zimmerman Karla. *The Netherlands*. 4th ed. Footscray, Vic: Oakland, CA, 2010. ISBN 17-422-0362-0.

[16] The Economist. The world in figures: Countries: Netherlands. Posted 21.10.2012, ref. 10.01.2013. online: http://www.economist.com/news/21566512-netherlands?zid=307&ah=5e80419d1bc9821ebe173f4f0f060a07

- GDP per head: $48,280 [16]
- Inflation: 2.0%[16]
- Budget balance (% GDP): -3.8 [16]

Approximately 10,000 years ago the sea water level had been 45m below the current Main Sea Level. Also four large rivers, Rhine, Thames, Meuse and Scheldt had been one large river that led into the North Sea. But after the last ice age, the water level had started to rise and had created the British Isles by the North Sea invading from the North to the South and from the south-west to north-east the sea had flooded the English Channel connecting with the North Sea. This way the Netherlands had come to boarder with the sea. [17]

The Netherlands geography is known all around the world. The fact that over half of the land is below sea level is very crucial especially with the rising sea level. The Dutch have created a series of dikes and dunes along the coasts and rivers to monitor the level of water entering and leaving the country. About 60% of the Dutch population lives directly behind these constructions and most of this land is below sea level. Thanks to the high income of water the deltaic plain has a high level of productivity and provides about 65% of the GDP. The airport is located 4.5meters below mean sea level. The threat of flooding is slowly growing due to climate change and the rising of the sea level. [18]

4.3. Weather conditions

The amount of days with precipitation has more or less become an average of 120 days per year. We can see this in figure 3, Annual average days with precipitation 1980-2010. This may be due to the shift in winds, currents and also amount of evaporation from the ocean or rivers. Higher precipitation in the Netherlands means that greater controls need to be made in certain areas to prevent the spill out of rivers especially on days with heavy rainfall.

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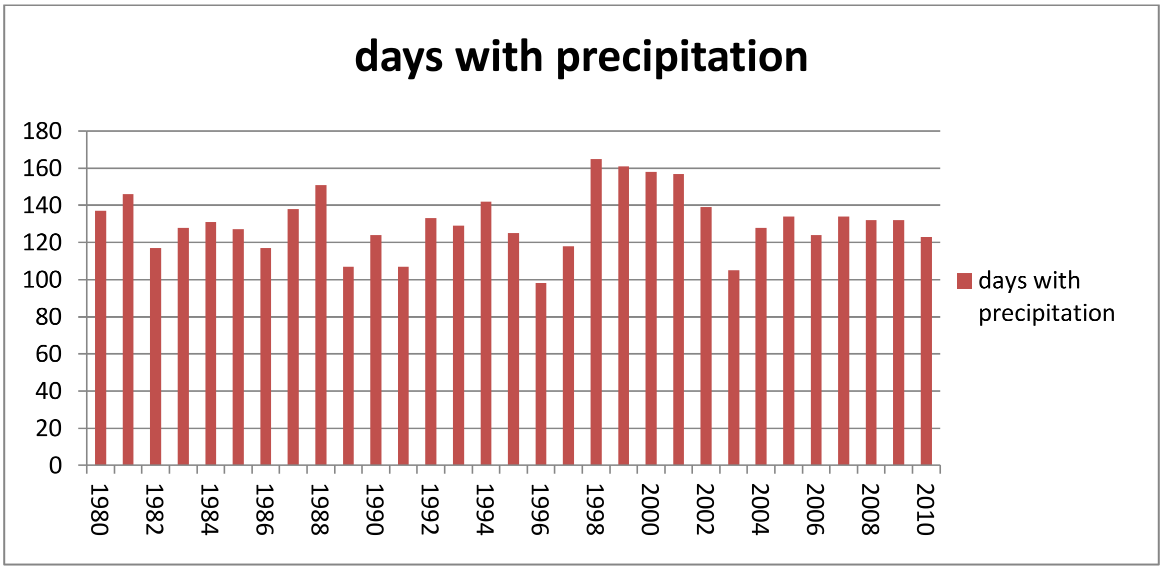
[17] SAEIJS, H., SMITS, T., OVERMARS, W., WILLEMS, D., Changing estuaries, changing views. Erasmus University, Rotterdam & Radboud University, Nijmegen; commissioned by the Worldwide Fund for Nature, The Netherlands. 2004

[18] STIVE, M., KONINGSVELD, M., MISDORP, R., The Netherlands: Challenges for the 21st century. Published: 31.12.2011.

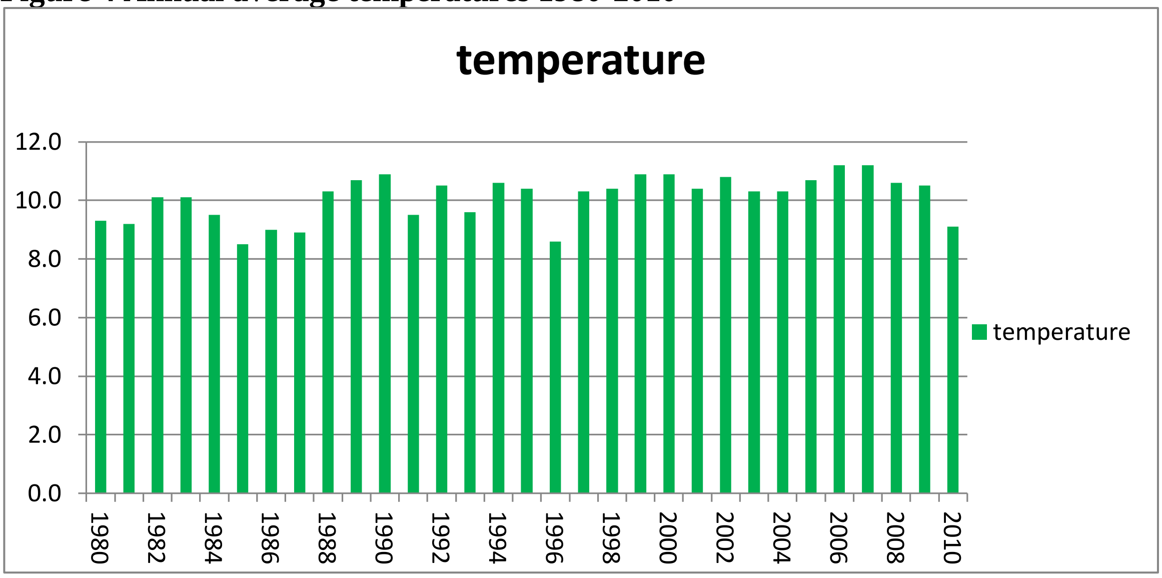
Figure 3: Annual average days with precipitation 1980-2010



Source: data collected from Statline – Centraal Bureau voor de Statistiek

In figure 4, Annual average temperature 1980-2010, we can see that over the past ten years the average temperature is steadily above 10’C which means that the climate has a slight change over the past years. This may also be an indicator that there are warmer winters and warmer summers. Of course there are slight fluctuations but none that are in the range of more than 2’C.

Figure 4 Annual average temperatures 1980-2010



Source: data collected from Statline – Centraal Bureau voor de Statistiek

4.4. Floods in the Netherlands

4.4.1. St. Elizabeth flood

In November 1404 a storm tide had invaded large areas of Flanders, Zeeland and Holland. This storm was named St. Elizabeth and the damages it caused were catastrophic. Polders that were built after previous floods had been pulled down by the strong tide and numerous small towns were flooded. [19]

In 1421, St. Elizabeth had attacked once more. This time it had caused severe damage to the area of North-Beveland. But this time the main cause was the water levels in rivers that rose rapidly due to a storm in the North Sea. This flood had caused 2,000 casualties and large damages. [19]

4.4.2. St. Felix flood

In November 1530, on Saint Felix Day, a severe storm flood hit the Zeeland once again. This flood had caused for many areas to be lost as they were washed away by water. The area known as Oost-Watering was made of eighteen villages and the city of Reimerswaal. The city was the only one to survive as it was situated on a small hill. It became an isolated island and the area around became to be known as "the drowned land of Zuid-Beveland". Today this area is an ideal locality for mussels due to the sand layer. Another area known as Nord-Beveland was also flooded but was able to be saved with the exception that it turned out to be a salt marsh area. [20]

4.4.3. All Saints Flood

Forty years later, the water had risen over 2.5m causing over 2,000 casualties. Even though there had been a warning, the effect of it was zero. Many dikes on the coast were torn down by the rage of water which allowed for water to keep entering the country. The water had reached all the way to Antwerp where it had covered four villages under layers of mud. More than five sixths of Holland were flooded and thousands of people have lost their homes and the large numbers of livestock and winter supplies were destroyed. [21]

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[19] St. Elizabeth floods, Deltawerken online, 2004. Ref. 10.12.2012. online: http://www.deltawerken.com/St.-Elizabeth-floods-(1404,-1421)/303.html

[20] St. Felix Floods, Deltawerken online, 2004. Ref. 10.12.2012. online: http://www.deltawerken.com/St.-Felixflood-(1530)/497.html

[21] All Saints Flood, Deltawerken online, 2004. Ref. 10.12.2012. online: http://www.deltawerken.com/All-Saints-flood-(1570)/304.html

4.4.4. Christmas flood

On Christmas 1717, a north-western storm had hit the coast of Netherlands, Germany and Scandinavia causing over 14,000 deaths. This was the worst flood for the past four centuries. Villages had been swept away as they were situated behind the dikes. The water had travelled to Amsterdam and Harlem but only causing material damages. [22]

4.4.5. Floods of 1953

On the night of 31st January 1953 a spring tide occurred in the North Sea which brought a huge wave towards the south and a rise of sea level by 2.5m above normal. On its way to the south, the way had broken dams and dikes which allowed the flooding of over 300km of land. The dikes were broken in more than 90 places, more than 130,000ha were flooded and 1836 casualties were recorded. In February 1953 a Delta Commission was appointed and after one year came with a recommendation to close all estuarine branches except the two main harbours Rotterdam and Antwerp. In Rotterdam, a movable barrier was built in the ship canal to link the sea with inner harbours. [17],[23]

The need for dikes had already been concluded before the Second World War, therefore in 1937 a plan was made to heighten the dikes but due to lack of money it was not possible. In spite of the high political stakes it took 25 years after the 53' floods to start with engineering works. The Minister of Transport and Water Management had brought together a Delta Commission who had the task to minimize the repetition of the 53' floods. They had come with two options: to raise all the dikes by 1 meter, which is 700-1000km of dikes or to shorten the coastline by large engineering works. The Committee had agreed on the second approach and its proposal was approved by the parliament in 1958. [17]

4.5. The Delta-works

Since the formation of the Delta Commission, several dikes and dams had been built along waterways either closing up deltas or dividing a large area of water into several

[22] Christmas flood, Deltawerken online, 2004. Ref. 10.12.2012. online: http://www.deltawerken.com/Christmas-flood-(1717)/305.html
[23] The Flood of 1953, Deltawerken online, 2004. Ref. 10.12.2012. online: http://www.deltawerken.com/The-flood-of-1953/89.html

compartments. This was all necessary as even the inhabitants were aware that something needed to be done to prevent a repetition of the 1953 floods. [24]

The first operational Deltawork was already in 1958 and it was the storm barrier in the river Hollandse Ijssel. This storm barrier was built to protect the densely populated area the Randstad. In 1961 the freshwater Lake of Veere was formed as two more mouths were closed. [24]

In the mouth of the Haringvliet a large number of sluices was built that would drain off excess water from the river Rhine. During cold winters these sluices are opened to prevent freezing of rivers and in emergency the salt water from the North Sea was allowed to enter to prevent freezing. These seventeen sixty-meter wide sluices were fully functioning by 1971.[24]

The Eastern Scheldt, one of the largest storm surge barriers, was officially opened in October 1986. The first idea of the Eastern Scheldt was that it would be closed and a large area of freshwater would form behind it. But many people had resisted as they wanted to keep the salt water environment which was also favourable for fishing. Therefore the government had agreed on building a barrier with many sluices that would close during strong storms and high water levels. There are sixty-two sluices and each forty meters wide which allow salt water to flow through.[24]

There are many benefits that have arisen with the Delta-works. There is the fact that freshwater supply has improved as the border with salt water has been moved further away and this was beneficial for agriculture. Another benefit is that some barriers had joined many islands together and therefore it became easier for cars to transfer between areas. We can say that the Delta-works have a double functioning: protection and easier transport.[24]

4.5.1. Barriers in the Netherlands

Barriers in the Netherlands were constructed for the protection of the country. These barriers are placed in rivers or estuaries in order to protect the ports or urbanized areas that lie behind. The barriers in the Netherlands were constructed after the flood of 1953. The big advantage of these constructions is that it does not affect the movement of ships in and out of ports. The barriers in the Netherlands are the:

[24] The Delta Works, Deltawerken online, 2004. Ref. 10.12.2012. online: http://www.deltawerken.com/Deltaworks/23.html

Hollandse Ijssel Storm Surge Barrier, Oostershelde Storm Surge Barrier (Eastern Scheldt barrier), Maesland Storm Surge Barrier, Europort Barrier and Hartel Barrier and the Venice Strom Surge Barrier. Altogether the cost of these barriers was over four billion euro. [25]

These barriers are not all the same and so it is necessary to know the different functioning of them. The Hollandse Ijssel and Oosterschlede Storm Surge Barrier and the Europort and Hartel Barrier are constructed as vertical lifting gates. Some of the advantages of this construction is that it has a wide gate span of up to 300feet, it takes up little space on land and the discharge of excess water is possible. Some of the disadvantages are that ships have a special lock in order to pass through and the height is not suitable for all, there is a slight stiffness during operations and the time to close may be up to one hour. [25]

The Maesland, Rotterdam Storm Surge Barrier, is a floating sector gate. This can be placed in a shallow dock which enables easy maintenance and separate sluice openings can be applied which controls the discharge of water flow. On the other hand, it is very sensitive to forceful waves and may have a problem to control the in-flow of water. [25]

The last barrier, the Ramspol Storm Surge Barrier, is a rubber dam. These are mainly used in river engineering, water control and creation of water reservoirs. But this barrier has the advantage that there is no limitation of span, it is not subjected to wind, it is invisible when it's not in use and there is little space required. On the other hand, there is a problem of ship collision, it is not suitable for deep water and maintenance is quite difficult. [25]

We can assume that these barriers were built according to proper decision making and will protect the Netherlands from the severe future floods.

4.5.2. Sand Nourishment

The Netherlands have dealt with many floods in the past and so they try to increase the safety of the country as much as possible. There are many areas that have been improved and rebuilt to maintain the functioning of the area. There are many areas

[25] DIRCKE, P. T. M., JONGELING, T. H. G., JANSEN, P. L. M., An Overview and Comparison of Navigable Storm Surge Barriers. Ref. 13.01.2013. Online: http://ussdams.com/proceedings/2012Proc/65.pdf

that need to be maintained or improved in order to protect the Dutch from severe floods. The cost of Delta-works exceeded 5billion euro. Even after the construction of these dikes, dunes, barriers, there still have to be annual costs that are used for maintenance. These costs go into hundreds of million euros along with the sand nourishment. [26]

One of the factors the Delta Committee has agreed on is to raise the height of dikes and dunes. But as years pass, they have realized that it is not possible to heighten the constructions for ever as the people living behind them would soon feel like living behind a large wall. This would probably cause the decline of preference to build in such an area and so this had brought the attempt of sand nourishment.[26]

Sand nourishment of the coast consists of extracting sand from the North Sea and applying it to the Dutch coast. At first it was used to replenish the erosion but now it used to mainly prolong the coast seawards and therefore enlarging the area of the Netherlands. It will also prevent severe damage in case of strong storm as the area before the dikes will be greater and so the power of waves will decline slightly causing smaller collisions and damage to the dikes and what lies behind it. [26]

4.6. Delta Programme

As already mentioned, the Netherlands are highly populated and especially along the coast, therefore the need for safety of these areas is required. The Delta Programme is aimed at maintaining the safeness and attractiveness of the Netherlands for the future. This is a national programme which consists of the government, provincial and municipal authorities, water boards and even civil organisations which together help come up with better solutions on problems. The Delta Programme works on scenarios which are generated by the Royal Netherlands Meteorological Institute. The scenarios so far show that the sea level has been rising and that the climate is becoming warmer and so the commission in charge need to take into account more frequent rainfall but also hotter and drier summers. The main project is now based on strengthening the dikes, protecting the coast from erosion but also making more room for rivers. Along with this project they are working on many sub-programmes

[26] HILLEN, R., ROELSE, P. Dynamic preservation of the coastline in the Netherlands. Journal of Coastal Conservation I: 17-28, 1995. Online: http://spicosa.databases.eucc-d.de/files/documents/00000414_C1.017-28.pdf

on what needs to be done for the future if they are to deal with wetter and drier seasons so that they are able to take action when necessary. [27]

4.7. Delta Fund

To be able to expand and invest into the construction and maintenance of dikes, dams, dunes, etc. a special fund was established especially for the Delta Programme. The money that goes into this fund is from the government and is to be used for any necessary measures, investigations and management. From 2020 the Delta Fund is to be fed a minimum of 1billion euro a year to maintain the persistence of the Delta Programme. The final decision on what is to be done with the money is made by the Minister of Infrastructure and the Environment. [28]

4.8. Delta Scenarios

The sub-programmes that the Delta Programme works on are all based on the changing climate and socio-economic developments. There are the four main scenarios:[29]

- BUSY: socio-economic growth/moderate climate change
    - 20million inhabitants in 2050 and 24million in 2100
    - Economic growth by 2% per year
    - Continuing urbanization
    - Decline in agricultural area by 2050 then rise
    - Environmental area strongly reduced by 2050
    - Winter precipitation increase by 3%
    - Summer precipitation by 3%
    - Increase in sea level of 35cm by 2100
- REST: socio-economic squeeze/moderate climate change
    - Population declines after 2050 to 12 million by 2100
    - Slight economic growth by 2050 then a slight squeeze
    - Decline in urbanization

[27] Delta Programme. Delta Programme Commissioner. Ref. 14.01.2013. online: http://www.deltacommissaris.nl/english/topics/delta_programme/
[28] Delta Fund. Delta Programme Commissioner. Ref. 14.01.2013. online: http://www.deltacommissaris.nl/english/topics/delta_fund/
[29] Delta Scenarios. Delta Programme Commissioner. Ref. 14.01.2013. online: http://www.deltacommissaris.nl/english/topics/delta_scanerios/

- No change in agricultural area
- Environmental area slightly increases
- Winter precipitation increase by 3%
- Summer precipitation by 3%
- Increase in sea level of 35cm by 2100

- STEAM: socio-economic growth/rapid climate change
    - 20million inhabitants in 2050 and 24million in 2100
    - Economic growth by 2% per year
    - Continuing urbanization
    - Decline in agricultural area by 2050 then rise
    - Environmental area strongly reduced by 2050
    - Winter precipitation increase from 14 to 18%
    - Summer precipitation decrease from -19% to -38%
    - Sea level rise by 85% in 2100
- WARM: socio-economic squeeze/rapid climate change
    - Population declines after 2050 to 12 million by 2100
    - Slight economic growth by 2050 then a slight squeeze
    - Decline in urbanization
    - No change in agricultural area
    - Environmental area slightly increases
    - Winter precipitation increase from 14 to 18%
    - Summer precipitation decrease from -19% to -38%
    - Sea level rise by 85% in 2100

29

4.9. Adaptive Measures

Along with these possible scenarios there are several adaptive measures the Committee has proposed for the future protection of the Netherlands from floods and any radical climatic changes.[18] These adaptive measures also take into account arguments that influence safety standards. The first standard consists of amount of storms, sea level rise, tide, wind and lowering of the land. The second standard has the quality of dams, dikes and sluices. The value of investments behind the dikes and expected loss of human life is in the third standard.[17]

One of the adaptive measures is to raise the level of lake Ijsselmeer. The plan is raise the water level by 1.5m by 2050. This would be done by increasing the enclosure height. The regulation of water that enters the lake is done by sluices which lead to the Wadden Sea. The raise of water level will also increase the amount of freshwater for the Netherlands and act as a reserve in case of droughts. Another measure is to reclaim coastal land from the sea. This will be done by continual sand nourishment off the coast of Zeeland, Holland and the Wadden Sea Islands. This could add 1000km2 to the country and expand the coastline by 4km. The only problem that may occur is that ecological and economic aspect as large amounts of sand would need to be retreated from the North Sea. The next measure is based on creating an open-closable water system at the mouth of rivers Rhine and Meuse known as Rijnmond. This system would be able to close in emergencies of flooding and offer a unrestricted shipping movement. This would be done by heightening the already built dams, dikes and dunes and adding four more barriers for protection of flooding.[18]

Another approach is the construction of artificial mounds. These artificial hills were used in the middle ages. The highest parts were used for cattle grazing and were flooded only during severe storms and the lower hills were made to withstand high tides. The worst that could happen during a severe storm was a shallow covering for only a few hours. But if a dike should break the level of water would be higher and would stay longer. Today, harbours and industrial estates are built on these mounds.[17]

4.10. Risk from constructions

When the risk calculations were made for the 1953 floods and for the year 2003, it had turned out that the probability of the disaster is lower but the effect will be greater as there would be greater casualties and larger damage. This is due to the fact that the water level would rise faster and quickly fill the polders as the land has sunk and dikes have been made taller. The constant factor is that every improvement is followed by more investments and larger populations: greater technical safety is cancelled out by the risk of greater numbers of deaths and damage. Before the 1953 flood the chances of a severe flood were 1/500 years. Now the Delta had computed it to be 1/4000 years. Every five to ten years the dikes and engineering works are checked on and improved if necessary. In the future we will end up living behind enormous dikes as the western area of the Netherlands is sinking the climate change fluctuations are on a monthly basis. The large height difference between the dikes and land would bring catastrophic damages; therefore new solutions need to be made as the rising of dikes cannot go on forever. [17]

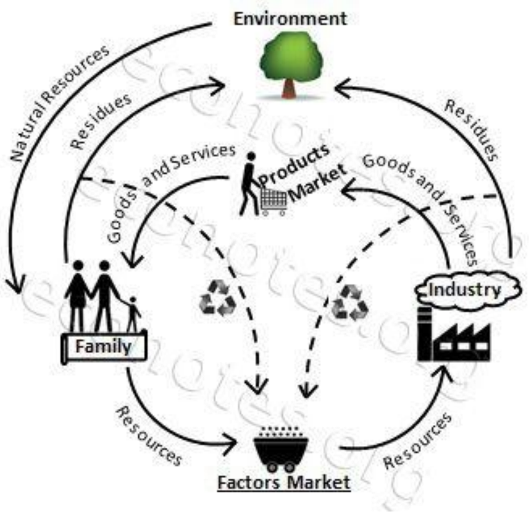
5. ENVIRONMENTAL ECONOMICS

"*An area of economics that studies the economic impact of environmental policies. Environment economists perform studies to determine the theoretical or empirical effects of environmental policies on the economy. This field of economics helps users design appropriate environmental policies and analyze the effects and merits of existing or proposed policies*."[30] But economics can not only concentrate on the needs and wants of humans in today's world. It is the importance of the influence of humans on the environment that had brought this area of economics to emerge. In every study of distribution, production and development there is a need to take into account the environmental aspect of such procedure.[31] Economists believe that the environment has essential functions that are economically valuable for humans. These include natural resources, life support systems, and certain natural goods. [32]

The connection between the environment and economics can be seen in the Material balance model, as shown in picture 3. We can see that the environment is a source of natural resources which has a value, monetary or non-monetary, but also the destination of residues. It is necessary to give value to the environment as the damages caused can have a great effect on the population. An example can be the deforestation of the tropical rainforests. The value of these forests is high as they are the habitats of many species but also they are called the "planets lungs". Therefore with the cut-down of trees, we increase the CO_2 concentration in the atmosphere.

[30] Definition of 'Environmental Economics', Investopedia US, A Division of ValueClick, Inc., 2013. Online: http://www.investopedia.com/terms/e/environmental-economics.asp#axzz2MrkxR0pS
[31] PAVITHRAN, K.V. *A textbook of environmental economics*. New Delhi: New Age International Publishers, 2008. ISBN 8122422802
[32] TURNER, R., PEARCE, D. W. and BATEMAN, I. *Environmental economics: an elementary introduction*. Baltimore: Johns Hopkins University Press, 1993, viii, 328 p. ISBN 08-018-4863-6.

Diagram 3: Material balance model



Source: Econotes, 2011 notes on environmental economics

5.1. Net Present Value

"Net present value is the total of present values of future investment cash flows including the invested amount."[33]

Net present value is calculated to show the profitability of a project or investment. Whenever an investor or company decides to invest into a project, they will need to have a calculation of the profitability. If the NPV turns out to be positive then the investor should take the project, but if the NPV value is below zero then there is probably no sign of profitability in the future.[34],[35]

Net present value is follows:

$$\sum_{t-1}^{T} \frac{C_t}{(1+r)^t} - C_o$$

-Co = Initial investment; C = Cash flow; r = Discount rate; t = time[34]

5.2. Internal Rate of Return

"Internal rate of return – the discount rate in cost-benefit analysis at which the present value of benefits equal the present value of costs."[3]

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[33] FIALOVÁ, H. a FIALA, J. *Ekonomický slovník s odborným výkladem česky a anglicky*. 2., dopl. a aktualiz. vyd. Praha: A plus, 2009, 312 s. ISBN 978-80-903804-4-8.

[34] Net Present Value, Investopedia, US, A Division of ValueClick, Inc., 2013. Ref: 10.2.2013. Online: http://www.investopedia.com/terms/n/npv.asp#axzz2N8ITAdyB

[35] Net Present Value, Finance Formulas. Ref: 10.2.2013. Online: http://www.financeformulas.net/Net_Present_Value.html

Internal rate of return is calculated to determine the percentage that will be returned from the project. It is usually higher than the actual return. On the other hand, the higher the internal rate turns out to be, the higher the actual return may turn out.[36]

[36] Internal Rate of Return. Investopedia, US, A Division of ValueClick, Inc., 2013. Ref: 10.2.2013. online: http://www.investopedia.com/terms/i/irr.asp#axzz2N8ITAdyB

6. SCENARIOS

The Royal Netherlands Meteorological Institute (KNMI) has developed scenarios for climate change in the Netherlands. The models that are used from projecting these scenarios are the General Circulation Models (GCMs). They are supported by Regional Climate Model (RCM) simulations and local statistical observations in the Netherlands. The scenarios are based on regional atmospheric circulation patterns and the temperature. This is, as already mentioned, due to the fact that the changes in the atmosphere are closely connected with changes in the oceans temperature. The main scenarios are: a strong change in circulation, which brings warmer and wetter winters and drier summers, and a weak change of circulation. These are underlined with a "+" which adds a strong change in circulation. These scenarios are presented for the global temperature change of +1'C and +2'C. The scenarios are shown in table 1.[37]

Table 1: KNMI scenario

Scenario	Global Temp. increase in 2050	Change of atmospheric circulation
G	+1°C	weak
G+	+1°C	strong
W	+2°C	weak
W+	+2°C	strong

Source: HURK, 2006

For sea level rise the KNMI has presented a different approach which is based only on two scenarios which are low and high scenarios. This is because the sea level rise in the North Sea is related to global air circulation rather than regional.

In table 2, KNMI future scenarios, we have the scenarios for 2050 relative to 1990. As we can see, the temperature in the Netherlands will rise in all four scenarios. We can clearly see that the winter temperatures will be warmer and bring with it larger amounts of rainfall, especially in the W+ scenarios. What is interesting is that the

[37] HURK, B. et al., KNMI Climate Change Scenarios 2006 for the Netherlands, published: 22.05.2006. ref: 5.1.2013. online: http://www.knmi.nl/knmi-library/knmipubWR/WR2006-01.pdf

precipitation in summertime during strong circulations of the two scenarios, there will be a big decline meaning that the Netherlands might suffer from droughts.

Table 2: KNMI future scenarios

Variable	G	G+	W	W+
	summertime			
mean temperature K	+0.9	+1.4	+1.7	+2.8
mean precipitation %	+2.8	-9.5	+5.5	-19.0
	wintertime			
mean temperature K	+0.9	+1.1	+1.8	+2.3
mean precipitation %	+3.6	+7.0	+7.3	+14.2

Sea level sensitivity	Low scenario		High scenario	
	2050 (+1°C)	2100 (+2°C)	2050 (+2°C)	2100 (+4°C)
Low	15	35	20	45
High	25	60	35	85

Source: HURK, 2006

If we look at scenarios generated from a new computer model where the Netherlands would be without barriers, dikes or other constructions and interactions then we get interesting results. The first scenario is with no dikes, open estuaries and no drainage. This scenario shows that the fishing sector would be greater in the south-western estuary and that the 1953 floods would probably not have occurred as there would be room for proper sedimentation and peat growth. This would match the rising water level and prevent it from spilling in such large amount onto land. Of course there would be some minor floods but none would cause such damage and the costs related to Delta-works would have been saved. The second scenario is with embanked islands, open estuaries and no drainage. This predicted that the Netherlands could have had a larger amount of land above sea level due to embankment but on the other hand this would also raise the river water levels enabling more floods to occur compared to the first scenario. [17]

It is clear from these scenarios that it is much better to have a natural delta than a static delta as it is able to adapt to changes in the environment and is more durable and robust. [17]

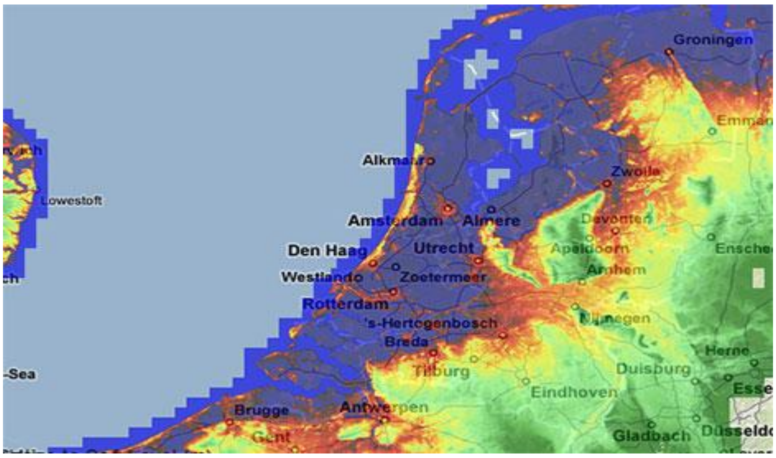
6.1. Scenario construction

To look at how the Netherlands are safe certain scenarios will be constructed based on the construction of dikes and barriers and the increasing sea level that is taken from the KNMI 2006 scenarios. The area of Friesland, Flevoland, North Holland and South Holland are approx. 95% below sea level with the remaining 5% being in the range of 0-1m above sea level. The province of Zeeland is mainly 0-1m above sea level with areas above 1m and small areas that are below sea level. The height of the barriers ranges around 4-7m above water level and the height of dunes is around 7m.

The total area of the Netherlands is 41,526km2 out of which approximately 60% is below sea level. In diagram 4, we can see the area of the Netherlands that is below sea level in order to help show the damage that could be caused. The dark blue shade shows the area below normal sea level and the light blue is area that is above 0m of the normal sea level.

For the calculation of the cost of damage, the average cost of 1km2 was taken, which makes it 4million euro per km2. The cost of land does not include the price for mortgaged land and so that is why the price is lower.

Diagram 4: Elevation of the Netherlands



Source: Science media centre, 2013

6.2. The Netherlands without barriers scenario

The storm surge barriers that are constructed enclose all estuaries and therefore limit the amount of water entering and leaving the rivers. If we consider that these barriers and dikes and dunes were not constructed, the Netherlands would have serious problems. The sea level rise of 35cm would flood the coastal provinces and large cities such as The Hague and Amsterdam. The region of the six coastal provinces makes an area of 14,443km2. If we calculate the damage that would be caused, only to the loss of land, it will be an enormous 57,772,000,000euro.

In 2100, when the sea level rises by 85cm, the damages would be much greater. The water level in rivers will rise, causing flooding in areas further inland and the flow would be stronger causing damage to the environment. Such rise would reach into the area of Utrecht, North Brabant, Gelderland and Overijssel. This makes the area of 14,626km2 which causes the damage to increase by an extra 58,504,000,000euro.

The provinces of Limburg and Drenthe with a population of about 1,5million people would be safe from flooding as they are further inland and are not situated below sea level.

6.3. The Netherlands and sea level rise scenarios

As already mentioned, the barriers are over 5m high and the dunes on the coasts reach to a height of 7m. These heights are big enough to prevent large amounts of water flowing into the country. The width of the beaches ranges from 100-

200metres. The scenarios constructed are based on the data from the KNMI 06' report.[37] For the scenarios, the scale of 1cm sea level rise = 1m inland for a 1°C global temperature increase.

6.3.1. First scenario

2050; +1°C; low sensitivity – 15cm rise

In this scenario, the sea level rises by 15cm which will flood the beaches by 15m. This will not be such a loss. The only effect that it may have is the fact that there will be less space in the summer when tourists visit.

6.3.2. Second scenario

2050; +1°C; high sensitivity – 25cm rise

This sea level rise may be registered on a larger scale as in some areas it may flood a quarter of the beaches.

6.3.3. Third scenario

2050; +2°C; low sensitivity – 20cm rise

Due to the increase in temperature by1°C, it will cause the increase of water temperature which leads to greater expansion. This will have an effect on the area flooded. For the 20cm rise, the water will flood 30metres inland, declining the width of the beaches. There will be no need for the barriers to be completely closed as the rise is only 3% of the height of some barriers. This is a very small percentage and can cause minimum damage to the barriers or even threaten from floods.

6.3.4. Fourth scenario

2050; +2°C; high sensitivity – 35cm rise

This scenario brings a greater increase in the amount of land reclaimed by the sea. In some areas the beaches will be half the size as the water will reach over 50m inland. This can have an effect on some species living in the area but also on the agriculture behind the dunes. The salt wind may not be favourable for all crops and the fact that the sea gets closer; the amount of salt particles in the atmosphere will be greater. But once again, no severe damage would be done to harm the population. The barriers would still serve their purpose of regulating the amount of water entering and leaving the rivers.

6.3.5. Fifth scenario

2100; +2°C; low sensitivity – 35cm rise

As the raise of the sea level and temperature is the same as in the previous scenario, the outcome will be the same. Except the time that it takes to occupy the beaches will be longer, therefore any changes in the landscape may occur, which may limit the area flooded.

6.3.6. Sixth scenario

2100; +2°C; high sensitivity – 60cm rise

The rise of 60cm may cause the sea water to spill over almost 90m inland. This will cause permanent changes to the Dutch coast. The sea will be noticeably closer to land. In some cases the water may be at the base of dunes and therefore slight undermining may occur which in turn may cause damage to the area behind it. The cost of protection would have to be greater.

6.3.7. Seventh scenario

2100; +4°C; low sensitivity – 45cm rise

It may seem a paradox that the land occupied by sea water will be around 90m as in the previous scenario even though the sea level rise is smaller, but it is the extra 2°C that allow this change to happen. The expansion of water when it is heated brings many changes to the behaviour and so the area will be greater even though the rise is smaller.

6.3.8. Eighth scenario

2100; +4°C; high sensitivity – 85cm rise

This is the greatest scenario that may bring the greatest effect to land. The water will reach 170m inland which in some cases may cause the disappearance of beaches and therefore forming a shallow sea right behind the dunes. This may probably cause greater damage to the area behind dunes as it is hard to predict the height of waves and the strength of tides.

6.4. Precipitation scenarios

Because the water levels are closely related to the amount of precipitation, it is necessary to state the effects that might occur with increased rainfall as is stated in the KNMI 06' scenario.[37] We can see the comparison of the G+ and W+ scenario in figure 5.

In January 2012, 100 residents had to be evacuated from a north province of the Netherlands and the authorities were also considering of moving cattle from farms. The cause of this action was due to heavy rainfall for a couple of days which met the amount of rainfall for the whole month. The need to evacuate was the threat of a dike leakage. The authorities speculated about the strength of this dike. If this dike would not have withstood the pressure of the water, a flood of 1,5m high would swallow the floodplain behind the dike.[38]

6.4.1. G+ scenario

The G+ scenario demonstrates a strong change in atmospheric circulation and the global temperature increase by 1°C in the year 2050. The mean precipitation for summer will decrease by 9,5%.[37] This may cause a slight decline in river water level as more water will be evaporated. It will also cause slight droughts which may have an effect on the agricultural yield in some areas. But on the other hand in winter the amount of precipitation will increase by 7%. This will definitely be seen on the river water. There may also be a slight problem of water pools on fields or other land as there will not be any room for it to soak into or to evaporate back into the atmosphere. This may farmers to think about some sort of protection for their winter crops.

6.4.2. W+ scenario

This scenario also consists of a strong change in atmospheric circulation but also an increase of 2°C in 2050.[37] This scenario brings with it the most radical changes in the atmosphere. The summertime mean precipitation will decrease by 19%. This decrease will cause great damage to yield of crops and probably most notably to horticulture. There definitely is no need to worry about floods in the summer, whereas in winter, the increase by 14,2% will be most notably seen. This can cause the spillage of many rivers and will also test the strength of dikes and barriers as in January 2012. It is necessary for the authorities to regulate the amount of water that

[38] Our Foreign Staff. The Telefigure. Posted 6.01.2012. ref. 1.2.2013. online: http://www.telefigure.co.uk/news/worldnews/europe/netherlands/8996761/Dutch-floods-threatening-dyke-forces-mass-evacuation.html

hurdles behind the barriers as the greater the amount gathered, the greater the damage will be.

In figure 5, we have a comparison of the two extreme scenarios. We can see that the W+ scenario has radical changes that may have an effect on the population and even on several sectors. The temperature change is almost 40°C between summer and winter.

Figure 5: Comparison of G+ and W+

Source: own input

6.5. Calculation of benefits and profitability

As seen in the scenario of the Netherlands without barriers, we can clearly state that the Netherlands definitely appreciate the monstrous constructions. But are these constructions of any benefit? In this scenario, the benefits are simplified and do not include the cost of mortality, health issues or damages to infrastructure. For the cost of 1km2 the price 4million euro was given as seen in table 3.

Table 3: Calculation of benefits from flooded land

Year	Sea level rise cm	Area km2	Price Euro/km2	Benefits Euro
2020	5	2,000	4,000,000	8,000,000,000
2050	25	10,000	4,000,000	40,000,000,000
2075	50	20,000	4,000,000	80,000,000,000
2100	85	34,000	4,000,000	136,000,000,000

Source: own input

In 2015, an investor pays 10billion for the investment in barrier and dike heightening and the heightening of dunes on the coasts as they also play a large role in the protection of land. The people living behind these constructions may protest as the heightening makes it unfavourable to live behind and so they want to know the benefits of these heightening. At first there is no visible benefit, but in 2020 the sea level rises by 5cm. This could have flooded an area of 2,000km2. And so the benefit from this is 8billion euro. This may seem quite low as 5cm isn't so high but when the water rises 25cm, the benefit is greater as the area flooded would be approximately 10,000km2. The benefit reaches to an enormous 10billion euro. In the next 25 years, the sea level rises by 50cm. This could cause great damage as the area flooded would reach behind the six coastal provinces and causing a damage of 80billion euro, but luckily this money is saved thanks to the barriers, dikes and dunes. The greatest benefit could be seen in 2100 when the rise of 85cm would flood all provinces below sea level and areas that are slightly above sea level. The benefit from the area saved would reach an enormous 136billion euro. The table with the values can be found in the appendices, database 1.

The net present value for the costs, with a rate of 5%, is 17,769,572,788euro. The net present value for the benefits is calculated to be 19,952,712,288euro. This is calculated only for the benefits from the sea level rise and does not include the net present value of costs which would be a negative benefit. The difference between the net present value of costs and benefits is over 2billion euro, which makes the investment very profitable as the benefits are greatly larger than the costs. The internal rate of return is 5.35%, which makes it a very promising project.

6.6. Results

From the scenarios where the Netherlands do not have any barriers, dikes or dunes, we can clearly see that the damages would be in the range of 100billion euro in 2100 with the rise of 85cm. The necessity to have barriers is very crucial for the country.

From the scenarios of the KNMI 06' on sea level rise, the Netherlands may have to be prepared for increased sea level rise in 2100 as the land reclaimed by the ocean could reach up to or even over 1km. This would cause the loss of coastal areas but also the loss of the total area of the Netherlands. In 2050 there is no threat to flooding, but the authorities would need to start taking some action in order to prevent such large reclamation.

Precipitation scenarios point out that there might be a need heighten the banks. The increased precipitation may cause a greater rise of water level in the rivers and also increase the flow of it. This is a greater threat than sea level rise because the rivers flow more inland and are partially regulated by the dikes and barriers. Also more cities and villages are situated right on the banks of rivers.

The future investment in barriers turns out to be very profitable. The net present value is above zero which proves the profitability and with the value of the difference between costs and benefits being 2,183,139,500euro, it is very appealing. The internal rate of return which is 5.35% makes it also favourable.

7. Conclusion

Global climate change has been around for centuries and will probably continue for next centuries. The everyday experience of changes is our proof. We can easily measure the changes by using satellites which scan the areas of ice cover and glaciers, measure the oceans temperature and depth and the ocean currents. The measurement of greenhouse gases is also crucial for prediction of future changes, especially temperature changes. For the future it is necessary to collect the data on the changes of the Arctic ice sheet to allow calculations of the global sea level rise as this is linked with increased rainfall and temperature exchange.

The Netherlands have half of the country below sea level. The average temperature has become warmer and the amount of precipitation has increased, thanks to climate change. The Dutch have constructed a series a storm surge barriers, dikes and dunes to protect the land from severe flooding that have happened in the past. They have established a committee which specializes on the functioning of the works and safeness of the population. Several adaptive measures have been considered to protect the land and population from damages.

If the Netherlands had not constructed these protective constructions, then the damages caused by the sea level rise would be enormous. The economy would have to function only on an area of approximately 10,000km2. But thanks to the heighting of the barriers, which range up to 7metres, the Netherlands do not need to feel threatened for the next 90years. The cost of land behind the barriers and dikes has become very fertile, thanks to the formed lakes, but also more housing has been built. Therefore the benefit reaches to over 19billion euro as the land is protected from being flooded and damaged, from the predicted scenario.

The Netherlands have made a very advantageous investment into the constructions. The benefits that it brings are great and the saved land becomes more prosperous which in turn allows the economy to grow.

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Appendices

Database 1: Benefits from construction

	Year	Costs	Benefits
investment in barrier construction and heightening in dunes	**2015**	10,000,000,000	-17,769,572,788
	2016	400,000,000	0
	2017	400,000,000	0
	2018	400,000,000	0
	2019	400,000,000	0
rise in sea level 5cm	**2020**	400,000,000	8,000,000,000
	2021	400,000,000	0
	2022	400,000,000	0
	2023	400,000,000	0
	2024	400,000,000	0
	2025	500,000,000	0
	2026	450,000,000	0
	2027	450,000,000	0
	2028	450,000,000	0
	2029	450,000,000	0
	2030	450,000,000	0
	2031	450,000,000	0
	2032	450,000,000	0
	2033	450,000,000	0
	2034	450,000,000	0
	2035	600,000,000	0
	2036	450,000,000	0
	2037	450,000,000	0
	2038	450,000,000	0
	2039	450,000,000	0
	2040	450,000,000	0
	2041	450,000,000	0
	2042	450,000,000	0
	2043	450,000,000	0
	2044	450,000,000	0
	2045	450,000,000	0
	2046	450,000,000	0
	2047	450,000,000	0
	2048	450,000,000	0
	2049	450,000,000	0
sea level rise 25cm	**2050**	350,000,000	40,000,000,000
	2051	500,000,000	0
	2052	500,000,000	0
	2053	500,000,000	0
	2054	500,000,000	0
	2055	500,000,000	0
	2056	500,000,000	0
	2057	500,000,000	0
	2058	500,000,000	0
	2059	500,000,000	0
	2060	500,000,000	0
	2061	500,000,000	0
	2062	500,000,000	0
	2063	500,000,000	0
	2064	500,000,000	0
	2065	500,000,000	0
	2066	500,000,000	0
	2067	500,000,000	0
	2068	500,000,000	0

	2069	500,000,000	0
	2070	500,000,000	0
	2071	500,000,000	0
	2072	500,000,000	0
	2073	500,000,000	0
	2074	500,000,000	0
sea level rise 50cm	**2075**	400,000,000	80,000,000,000
	2076	400,500,000	0
	2077	400,500,000	0
	2078	400,500,000	0
	2079	400,500,000	0
	2080	400,500,000	0
	2081	400,500,000	0
	2082	400,500,000	0
	2083	400,500,000	0
	2084	400,500,000	0
	2085	400,500,000	0
	2086	400,500,000	0
	2087	400,500,000	0
	2088	400,500,000	0
	2089	400,500,000	0
	2090	400,500,000	0
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	2093	400,500,000	0
	2094	400,500,000	0
	2095	400,500,000	0
	2096	400,500,000	0
	2097	400,500,000	0
	2098	400,500,000	0
	2099	400,500,000	0
sea level rise 85cm	**2100**	500,000,000	136,000,000,000