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Information and Communication Technology Solutions Role in Climate Change Adaptation, a Literature Review

With focus on present and future technology

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Abstract

Climate change is occurring and brings increased climatic problems for humans such as: torrential rainfall and flooding, droughts, glaciers melting, ocean acidification, and deforestation. Such climatic changes necessitate adaptation. *Information and Communication Technology* (ICT) offers opportunities to adapt to the consequences of climate change.

However, there is a need to have an overview of existing ICTs in use to cope with climate change as well as ICTs that could potentially be used in the future in adapting to the climate changes.

By using a 7-step method in doing a literature review of the existing literature, this report categorizes different ICTs and their use in climate change adaptation in regard to the specific climate changes listed above by categorizing them in a way in which they can be easily compared. The literature review resulted in the division of ICT technologies in two main categories: monitoring and data analysis/computation. An interesting finding was that oftentimes, the monitoring and analysis part already functions well but does not reach the end users.

Key words: adaptation, climate change, deforestation, droughts, flooding, glacial melting, ICT, ocean acidification, sea-level rising, SDG, and torrential rainfall.

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Introduction and background

Climate change[1] is a topic that has started to get more and more attention of people due to the visibility of the cumulative impact on the environment. The environment can be discussed in both natural and social aspects. In a direct way, climate change has led to the significant effects on nature and humans. The polar ice shields are melting and accelerating the rise of the sea level. There is a potential for the Arctic Ocean becoming essentially ice-free soon[2]. Meanwhile more frequent extreme weathers can be observed on this planet, resulting in various natural disasters and a more limited range of living habitat.

Human society is structured around the climate and natural resources. Therefore our social environment is sensitive to climate change[3]. At the most fundamental level, climate change can have a substantial impact on human welfare through extreme living conditions and devastating natural disasters. Moreover, an unstable climate, like increasing times of flooding and droughts, could significantly lower the living standard of humans. It also causes enormous damage to economic activities and cultural development.

Today climate change and how to cope and prevent it is a hot topic, and in 2015, the *United Nations* (UN) defined new global goals to replace the old Millennium Development Goals to take action against climate change and other negative aspects in the world. The new collection consists of 17 global goals, named the *Sustainable Development Goals* (SDG). The new goals cover many of today's challenges humanity face in social, economic and environmental sustainability. These areas include topics like poverty, world hunger, climate change and health. The SDGs are aimed to be reached in 2030 and apply to all countries. This study will focus mainly on aspects of goal number 13 which is defined as follows: "*Take urgent action to combat climate change and its impacts*"[4]. The goal will be examined in conjunction with solutions in *Information and Communication Technology* (ICT). However, several other SDGs are also indirectly touched upon such as number 14 "Life below water" and number 15 "Life on land" when dealing with technologies that help to improve the environment in those contexts. Also, since several technologies help human society in adapting to climate change, goals such as number 1 "No poverty" and number 3 "Good health and well-being" are also mentioned in the report.

Another clear indication that the ICT community is becoming more interested in climate change adaptation is that the *International Telecommunication Union* (ITU), a specialized unit within the UN that allocates global radio spectrum and define global ICT standards[5]. In 2007 ITU started a particular project investigating the relationship between ICTs and climate change adaptation. This paper continues this investigation by attempting to give an overview of different ICT solutions used in climate change adaptation.

Not only is climate change adaptation important to the UN, but several large global ICT and IT companies have also realised and accepted that climate change and its consequences, mentioned above is for real and that the trade and industry have much to gain from working towards the SDG's earlier mentioned and applying sustainable development such as reducing CO2 emission, which can lead to lower costs and higher profit[6]. ICT companies such as Apple, Samsung Electronics, Microsoft, IBM, Cisco, Ericsson, and others

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[1] "What is climate change adaptation? | Environment | The Guardian." 27 Feb. 2012, https://www.theguardian.com/environment/2012/feb/27/climate-change-adaptation. Accessed 23 Jan. 2018.

[2] "Climate Change: Vital Signs of the Planet: Effects - NASA Climate ...." https://climate.nasa.gov/effects. Accessed 26 Jan. 2018.

[3] "Climate Impacts on Society | Climate Change Impacts | US EPA." 22 Dec. 2016, https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-society. Accessed 26 Jan. 2018.

[4] "Goal 13: Climate Action | The Global Goals." http://www.globalgoals.org/global-goals/protect-the-planet/. Accessed 24 jan. 2018.

[5] About International Telecommunication Union (ITU) [Internet]. ITU. [cited 2018 Jan 25]. Available from: http://www.itu.int:80/en/about/Pages/default.aspx

[6] Karlsson, Mikael. Lecture. Kista, January 26, 2018.

have started taking action and used different strategies such as; reducing carbon dioxide emission by using e.g., video conversations instead of physical meeting, driven different initiatives for climate change adaptation. Microsoft developed "Fetch Climate" a database dedicated to climate data[7]. Cisco systems have several projects such as reducing the energy consumption in buildings with "clever" systems[8]. Ericsson is involved with research projects and for example, sponsor solar team Eindhoven[9].

Currently, there is a lack of overview on how current and future ICTs can be used in adapting to specific consequences of climate change.

Purpose and Goals

The purpose of the project is to provide an insight, of how current *Information and Communication Technology* (ICT) solutions can be used in future ICT development to adapt to climate change. By creating a better insight one could provide ICT companies with ideas of how to use new ICT solutions, as well as already existing ICT solutions in new ways, to help cope with climate change. It could also help politicians in deciding what ICTs might be used in their specific countries, regions, cities and so on. Then future ICT development can more efficiently help to reach the *United Nations* (UN) global sustainable developments goals.

This report aims to produce an overview of current and possible future ICT solutions used to cope with climate change adaptation.

Method

The literature review is the methodology to reach the goal of the project. Regarding 'The Writing Center' website, the definition of literature reviews is "*A literature review discusses published information in a particular subject area, and sometimes information in a particular subject area within a certain period.*[10]" The subject area that project focused on is climate change adaptation for *Information and Communication Technology* (ICT) fields. The broad overarching question of this report has been: *How is ICT used in coping with climate change adaptation currently and how might it be used in the future*? The review covers different aspects of climate change, from the point of varying phenomena caused by climate change. The conducted literature review followed seven steps listed below, inspired from different research techniques found in books such as *Essentials of Nursing Research: Appraising Evidence for Nursing Practice* by Polit and Beck and articles like this one by Cronin et al[11].

Step 1. Creating questions

- Where are the ICT solution geographically published?
- Where are the ICT solution geographically applied?

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[7] "FetchClimate." *Microsoft Research* (blog). Accessed January 26, 2018. https://www.microsoft.com/en-us/research/project/fetchclimate/.

[8] "Adaptation Private Sector Initiative - Showcasing Best Practice." Accessed January 26, 2018. http://unfccc.int/adaptation/workstreams/nairobi_work_programme/items/4748.php#siemens.

[9] "Battling Climate Change with Smart Solar Solutions - Technology For Good Blog." Accessed January 26, 2018.https://www.ericsson.com/thecompany/sustainability_corporateresponsibility/technology-for-good-blog/2017/10/27/battling-climate-change-with-smart-solar-solutions/.

[10] "Literature Reviews - The Writing Center". 2018. The Writing Center. https://writingcenter.unc.edu/tips-and-tools/literature-reviews/.

[11] Cronin, Patricia, Frances Ryan, and Michael Coughlan. 2008. "Undertaking A Literature Review: A Step-By-Step Approach". British Journal Of Nursing 17 (1): 38-43. doi:10.12968/bjon.2008.17.1.28059..

- What type of ICT technology exists?
- Is the ICT technology applied presently or planned for future use?
- What type of adaptation and opportunities are there within a certain area

Step 2. Choosing databases

The choice of databases: *Scopus, ScienceDirect, IEEE Xplore, Web of science core collection* was to be selected due to their focus on ICT. Thus to minimize and reduce non-related material not connected to our categories. Three databases were used, to provide a more extensive domain for where relevant articles could be found. Scopus was later discarded, due to access problems. Both IEEE and Web of science core collection generally gave similar findings. ScienceDirect was only used for the area about deforestation.

Step 3. Defining search words

Identifying search words by reading a given article[12] that laid the foundation for brainstorming and using terms that are relevant to ICT and climate change adaptation. The result was: *ICT, ICT 4 adaptation, ICT 4 development, ICT Ecosystem, Climate change adaptation, ICT4D, E-resilience, ICT Solutions, Sustainability, Sustainability development, Opportunity, Innovation, Model, Resource monitoring, Resource management, Green ICT, Green IoT,* Adaptation, Resilience, Ecosystem, Vulnerability, Complexity, *Climate change adaptation programs, Ecology, Economic, Future, Identifying, Geographical, Rainfall, Torrential, Flooding, Drought, Heat waves, Glacial melting, Sea-level, Sea-level rising, Flaura, Fauna, Warning systems, Disaster recovery, Sensors networks, Analyzing, Accessibility and provision.* See table 1-5 in Appendix C for this reports used search words, databases, limitations and number of found articles.

Step 4. Defining limitations

Climate change is complicated, and there are a lot of different possible scenarios where adaptation with ICT can be used. In conjunction with what's needed to be done with regarding to the nine planetary boundaries[13] we limited the literature within the climate change boundary to these five categories, based on a list from the article "ICT 4 Climate Change Adaptation".[14] : *Torrential rainfall & flooding, droughts, glacial melting & sea-level rising, ocean acidification and deforestation.*

Other limitations:

- Material: Limiting was not performed entirely, thus not enough articles were found.
- Publication date limit: no particular limitations for when the articles were published.

Step 5. Dividing and selecting material between analytics

Articles, by analyst judged irrelevant, were discarded and not analyzed. Only one analyst reviewed found materials for the respective area (Torrential rainfall & flooding, roughts, Glacial melting & sea-level rising Ocean acidification or Deforestation).

Step 6. Analyze

All analyzers noted, in separate tables, their results, see tables 1-5 under result section. The table structure was constructed by all analytics to give a broad knowledge of what the primary focus in the analyze is, to summarize ICT technologies, their future and

[12] Shabajee, Paul, Malcolm Fairbrother, John-David Dewsbury, and Chris Preist. "ICT 4 Climate Change Adaptation: Systemic and Generative Perspectives & Tools." Atlantis Press, 2014. https://doi.org/10.2991/ict4s-14.2014.30.

[13] "The Nine Planetary Boundaries - Stockholm Resilience Centre." Text, September 17, 2009. http://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html.

[14] Paul aShabajee et al., "ICT 4 Climate Change Adaptation," 2014.

present possibilities to adapt to climate change. Thus, information such as; author and year, title, location/country (where it was conducted/applied), type of ICT solution, future or present technology, the method used and general conclusion.

Step 7. Discuss results

To secure that this overwhelming and multi-fielded literature review has followed similar types of articles regarding content, legibility, trustworthiness,etc. The discussion also gave a chance to discuss irregularities or ambiguous results.

Results

This section starts with categorizing climate changes, and the ICTs used to adapt to them, according to geography. Then, the results of the literature review for each climate change issue is presented afterwards. The literature review was divided into five individual studies to cover the earlier mentioned climate change categories: *Torrential rainfall & flooding, roughts, Glacial melting & sea-level rising, Ocean acidification* and *Deforestation.* The results are presented in separate sections in the same order as the mentioned categorization with an introduction to the area.

Geography

The literature review covers 18 countries where Information and Communication Technologys (ICT) coping with climate change have been deployed. The countries covered are: Antarctica, Australia, Brazil, Czech Republic, India, Indonesia, Japan, Malaysia, Netherlands, Norway, Nigeria, Pakistan, Portugal, South African, Sweden , United Arab Emirates, United Kingdom and United States. Some countries occurred about 1-4 times. Figure 1 represents a world map where green colored countries represents the countries from the literature review. The percentage for each country; Antarctica 3,3%, Australia 12%, Brazil 6,7%, Czech Republic 3,3%, India 13,3%, Indonesia 6,7%, Japan 6,7%, Malaysia 3,3%, Netherlands 6,7%, Norway 3,3%, Nigeria 3,3%, Pakistan, 3,3%, Portugal 3,3%, South africa 3,3%, Sweden 13,3 %, United arab emirates 3,3 %, United kingdom, 6,7% United states 3,3%, see figure 2. Some ICT solutions have not been concluded in either figure 1 or 2, which are based upon the same data, from column location in table 1-5 (see Appendix A), for separate table used (see Appendix B).

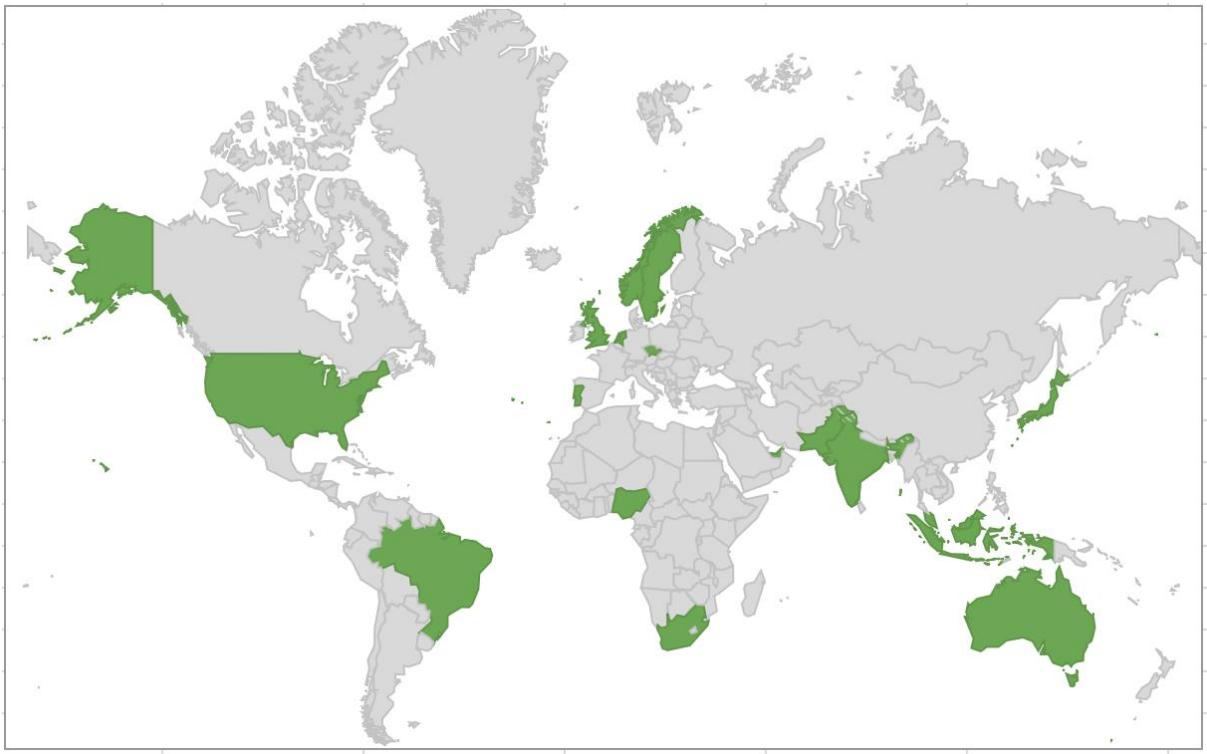

Figure 1. World map showing primarily, where a certain ICT was deployed or review material published (colored green) except Antarctica, that is not included in the map.

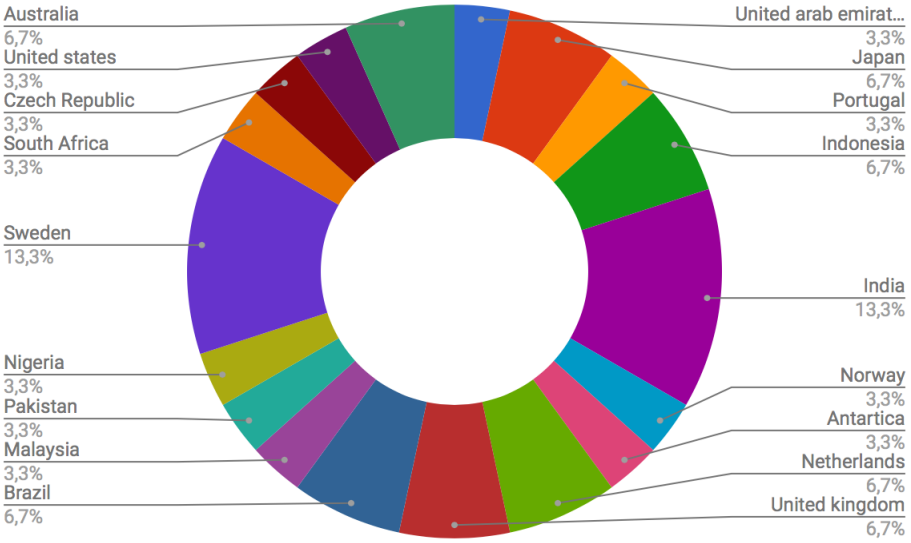

Figure 2. Pie chart showing the number of articles connected with a certain country, primarily in regards to where a certain ICT was deployed

Technology

The result that the researchers collected about "type of ICT technology" was categorized into five categories which are *computation, clean energy, information sharing, education and monitoring*, see figure 3 that shows the sum and distribution regarding all five literature review areas. The sum is presented in percentage, monitoring 47,5%, computation 20,0%, education 17,5%, information sharing 10%, clean energy 5,0%.

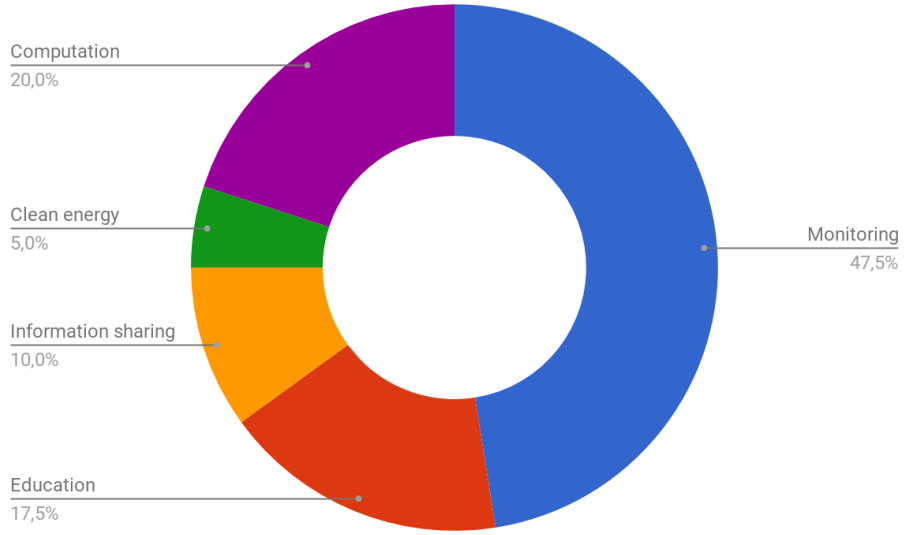

Figure 3. Pie chart showing the distribution of categorized ICT solutions from the result of the literature review.

Torrential Rainfall & Flooding

In near years, torrential rainfall has become heavier and more frequent. One reason is that climate change leads to the warmer natural condition which has increased evaporation and transpiration by vegetation, and thus the water vapor concentration in the atmosphere tends to be higher[15]. An accompanying consequence of the downpour is the flooding. Flooding can be defined as "any high flow, overflow, or inundation by water that causes or threatens damage"[16]. This is a more general phenomenon including both weather and human related factors[17]. It usually causes the direct damage on environment and human society. As shown in the presented result of literature study in Table 1 under Appendix A, the current proposed ICT solutions for adaptation within this field mainly focus on the predicting and warning of disaster situation, together with emergency decision making.

Droughts

Agriculture is foundational to society, but it is also vulnerable to different natural disasters. One of them is drought. If it could be possible to foresee heat waves coming, resulting in drought, great benefits would be gained for society in being able to reduce the loss of crops due to drought. Prediction of droughts is one possible role of adaptation that *Information and Communication Technology (*ICT) can take when dealing with drought, another is the role of analyzing what happens to society when drought occurs and take measures to prepare early on with suitable adaptation strategies.[18] Moreover, it is important that the people who are affected by drought and other natural disasters will be informed in a timely manner so that they may prepare accordingly.[1920]

Glaciers Melt

The main cause of glaciers melt is due to enhanced greenhouse effect [21]. Greenhouse effects effect is an layer of greenhouse gases that necessary to keep the earth in a suitable temperature for animal to live. If the greenhouse gases in the atmosphere over the standard earth can process, enhanced greenhouse effect will happen [22].

The number 13 of *United Nations* (UN) Sustainable Development Goals mentioned that to prevent climate change and enhanced global warming, the development of the world should be sustainable and the energy that used should be clean[23]. This goal have strong connection with *Information and Communication Technology* (ICT) industry and can be reached by various ICT solutions. By reaching this goal, the glaciers melting situation should be slower down and eventually stopped. Table 3 in Appendix A categorizes the ICT solutions that can improve the glaciers melting situation and reach the 13th UN sustainable development goal.

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15 "Are recent heavy rain events due to climate change? | Cornell Climate ...." http://climatechange.cornell.edu/are-recent-heavy-rain-events-due-to-climate-change/. Accessed 23 Feb. 2018.

16 NOAA, 2013: United States Flood Loss Report - Water Year 2011. 10 pp, National Oceanic and Atmospheric Administration, National Weather Service

17 "Extreme Weather - National Climate Assessment - GlobalChange.gov." https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather. Accessed 23 Feb. 2018.

18 M. Hussain et al., "Emerging Geo-Information Technologies (GIT) for Natural Disaster Management in Pakistan: An Overview," in *Proceedings of 2nd International Conference on Recent Advances in Space Technologies, 2005. RAST 2005.*, 2005, 487–93, https://doi.org/10.1109/RAST.2005.1512618. 491.

19 O. Eguaroje, A. Atijosan, and S. Mohammed, "Geospatial and Information Communication Technology Convergence (Geo-ICT): Enabling Sustainable Environmental Management in Nigeria," in *2012 8th International Conference on Information Science and Digital Content Technology (ICIDT2012)*, vol. 2, 2012, 313–18.

20 D. Singh et al., "ICT Platform for Climate Change Adaptation in Agriculture," in *2015 7th International Conference on Communication Systems and Networks (COMSNETS)*, 2015, 1–6, https://doi.org/10.1109/COMSNETS.2015.7098723.

21 Photograph Paul Nicklen, National Geographic Creative. 2018. "Global Climate Change, Melting Glaciers". Nationalgeographic.Com. https://www.nationalgeographic.com/environment/global-warming/big-thaw/.

22 "What Is The Enhanced Greenhouse Effect?". 2018. What's Your Impact. https://whatsyourimpact.org/enhanced-greenhouse-effect.

23 "Climate Change - United Nations Sustainable Development". 2018. United Nations Sustainable Development. http://www.un.org/sustainabledevelopment/climate-change-2/.

These ICT solutions are mainly focusing on preventing and detecting enhanced greenhouse effect, detection of glacier melting and increase the efficiency and usage of clean energy.

Ocean Acidification

This section is a summary of the literature review, see table 4 in Appendix A. Oceans stands for about 70%[24] of the earth's surface and is getting acidified. *Ocean acidification* (OA) is one of the *nine planetary boundaries*. Boundaries created to guide humans to stay within the Holocene, rather than the antropocen that some scientific researcher claims us to be in now. Holocene and anthropocene, two geological time epokes, where antropocen means that the human now determines natural events more than earth it self[25]. Holocene epoch claimed to be the crib and main reason for human life as we know it today with seasons, agriculture and our climate. Humans emits *Carbon dioxide* (CO2) in different processes e.g. driving a car. As much as a quarter of the emitted CO2 is ending up in our oceans[26]. The consequences with acidified oceans mentioned by Rockström is:

- Reduction of important matter for formation of shell and skeleton for marine species.
- Some species e.g corals, shellfish and plankton will have harder time to grow and survive.
- When some species have hard time surviving that might affect the amount of fish overall decreasing the fish stock[27].

Education by using *Information and Communication Technology* (ICT) about OA. There are different current ICT solutions that aid students at all different school levels. Fauville and other researchers have looked at how ICT can be used to increase awareness about ocean acidification. Either by using online platforms that allows students to have direct contact with experts within the field, in this case marine expert[28], or by letting them interact with a virtual laboratory that can increase the awareness by inquiry to insight[29]. Tough ICT solutions and online platforms is a good way, enhancements seem to be needed within methodologies for *Environmental education* (EE)[30].

Fish stock, ICT seem to be able to provide computational knowledge, that could be provided by an application for smartphones, that can be used by fisher's to estimate how much fish they can caught without endangering the fish stock. According to A. F. P. Oviedo and M. Bursztyn monitoring fish stock can be better, with the use of community based knowledge (from fishers) with ICT technology[31]. According to another article by Saville Ramadhona et al. they write that managing fish with ICT can lead to fishers stopping before there scheduled stop, due to the amount of fished fish [32]. Already on big scale, ICT is used for monitoring

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[24] "Hav - Uppslagsverk - NE.Se." Accessed February 17, 2018. https://www.ne.se/uppslagsverk/encyklopedi/l%C3%A5ng/hav.

[25] TED. *Johan Rockstrom: Let the Environment Guide Our Development*. Accessed January 31, 2018. https://www.youtube.com/watch?v=RgqtrlixYR4.

[26] "The Nine Planetary Boundaries - Stockholm Resilience Centre." Text, September 17, 2009. http://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html.

[27] Ibid.

[28] Fauville, Geraldine. "Questions as Indicators of Ocean Literacy: Students' Online Asynchronous Discussion with a Marine Scientist." *INTERNATIONAL JOURNAL OF SCIENCE EDUCATION* 39, no. 16 (2017): 2151–70. https://doi.org/10.1080/09500693.2017.1365184.

[29] Fauville, Geraldine, Jason Hodin, Sam Dupont, Pam Miller, Julie Haws, Michael Thorndyke, and David Epel. "Virtual Ocean Acidification Laboratory as an Efficient Educational Tool to Address Climate Change Issues." In *ECONOMIC, SOCIAL AND POLITICAL ELEMENTS OF CLIMATE CHANGE*, edited by Filho, WL, 825–36. Climate Change Management. HEIDELBERGER PLATZ 3, D-14197 BERLIN, GERMANY: SPRINGER-VERLAG BERLIN, 2011. https://doi.org/10.1007/978-3-642-14776-0_49.

[30] Fauville, G., A. Lantz-Andersson, and R. Saljo. "ICT Tools in Environmental Education: Reviewing Two Newcomers to Schools." *ENVIRONMENTAL EDUCATION RESEARCH* 20, no. 2 (March 4, 2014): 248–83. https://doi.org/10.1080/13504622.2013.775220.

[31] Oviedo, A. F. P., and M. Bursztyn. "Community-Based Monitoring of Small-Scale Fisheries with Digital Devices in Brazilian Amazon." *FISHERIES MANAGEMENT AND ECOLOGY* 24, no. 4 (August 2017): 320–29. https://doi.org/10.1111/fme.12231.

[32] Saville, Ramadhona, Katsumori Hatanaka, Minoru Sano, and Masaaki Wada. "Application of Information and Communication Technology and Data Sharing Management Scheme for the Coastal Fishery Using Real-Time Fishery Information." *OCEAN & COASTAL MANAGEMENT* 106 (March 2015): 77–86. https://doi.org/10.1016/j.ocecoaman.2015.01.019.

systems, such as *Vessel Monitoring System* used by the *European Union* (EU) to track vessels, with the aid of satellites and communication tools on vessels [33]. Still for eg. in Indonesia a country with a large production and distribution of fish the observations can be improved, with the use of ICT in the hole chain from hatching to delivering the product according to Wada M et al[34] . The same goes for India where a study of a smartphone application can help local monitoring, and according to Sanjay Kimbahune et al. 2013 reduce the use of diesel fuel, when improving fishing spot localisationing[35]

Coral reefs can of course also be educated about by a ICT technology such as entertainment-based education that's what Kopek-Putala Wioleta et al, writes in their conference paper[36] still education is always good other areas where ICT can contribute is when doing computations. According Kiyoki, Yaushi et al. they are trying to calculate several factors such as coral areas [37]. Noel, Conruyt on the other hand wrote in his conference paper that, as mentioned earlier the value of digital platforms, with focus on changing social behaviors into "eco-citizens" via platforms that can be used for managing coral reefs[38]. Some articles about ICT and coral reefs are about *Autonomous underwater vehicles* (AUV's). ICT and *Information technology* (IT) plays an important role for communication, since these AUV usually collect video-materials, for analyze or remoting, and regarding the remoting can be tricky to navigate, sometime via cables directly to the AUV. Still AUV can help and are used for monitoring the earth's coral reefs, but are in need of further development and are still expensive[3940].

Deforestation

Deforestation is defined by Cambridge dictionary as "*the cutting down of trees in a large area, or the destruction of forest by people*"[41]. It occurs for several reasons amongst others are to build on the land, land to be used for livestock and plantation but also to get raw materials for products like timber and palm oil. Even though it has positive effects for food resources and products, deforestation has a very negative impact on the environment. The world forests, especially the rainforest help to absorb greenhouse gases, produce water vapor and reduce water pollution but is also home for many different species on the planet. By

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[33] Anonymous. "Vessel Monitoring System (VMS)." Text. Fisheries - European Commission, September 16, 2016. https://ec.europa.eu/fisheries/cfp/control/technologies/vms_en.

[34] Wada, M., K. Hatanaka, R. Saville, I. N. Radiarta, K. Sugama, and Ieee. "Marine Observation Framework Using Ict for Mariculture in Indonesia." [In English]. 2013 Oceans - San Diego (2013): 6.

[35] S. Kimbahune, V. V. Singh, A. Pande, D. Singh and P. A. Chandel**,** "ICT for fisheries — Environment friendly way: Pilot experience in Raigadh," *2013 Annual IEEE India Conference (INDICON)*, Mumbai, 2013, pp. 1-8. doi: 10.1109/INDCON.2013.6725968

[36] Kopek-Putala, Wioleta, and Martin Bilek. "The Interdisciplinary Educational Project about the Coral Reef as an Element of Entertainment Based-Education." In *PROJEKTOVE VYUCOVANI V PRIRODOVEDNYCH PREDMETECH XIV*, edited by Rusek, M and Starkova, D and Metelkova, IB, 147–53. FAC EDUC, OVOCNY TRH 5, PRAHA 1, 116 36, CZECH REPUBLIC: CHARLES UNIV PRAGUE, 2017.

[37] Kiyoki, Yasushi, Xing Chen, Anneli Heimburger, Petchporn Chawakitchareon, and Virach Sornlertlamvanich. "Cross-Cultural and Environmental Data Analysis in Data Mining Processes for a Global Resilient Society." In *INFORMATION MODELLING AND KNOWLEDGE BASES XXVII*, edited by Welzer, T and Jaakkola, H and Thalheim, B and Kiyoki, Y and Yoshida, N, 280:281–98. Frontiers in Artificial Intelligence and Applications. NIEUWE HEMWEG 6B, 1013 BG AMSTERDAM, NETHERLANDS: IOS PRESS, 2016. https://doi.org/10.3233/978-1-61499-611-8-281.

[38] Conruyt, Noel. "E-Co-Innovation for Making e-Services Living Labs as a Human-Centered Digital Ecosystem for Education with ICT." In *2013 7TH IEEE INTERNATIONAL CONFERENCE ON DIGITAL ECOSYSTEMS AND TECHNOLOGIES (DEST)*, 25–30. IEEE International Conference on Digital Ecosystems and Technologies. 345 E 47TH ST, NEW YORK, NY 10017 USA: IEEE, 2013.

[39] M. Dunbabin, J. Roberts, K. Usher, G. Winstanley and P. Corke, "A Hybrid AUV Design for Shallow Water Reef Navigation," *Proceedings of the 2005 IEEE International Conference on Robotics and Automation*, 2005, pp. 2105-2110. doi: 10.1109/ROBOT.2005.1570424

[40] M. D. Dunbabin and S. S. Allen, "Large-Scale Habitat Mapping Using Vision-Based AUVs: Experiences, Challenges & Vehicle Design," *OCEANS 2007 - Europe*, Aberdeen, 2007, pp. 1-6. doi: 10.1109/OCEANSE.2007.4302309

[41] Dictionary, deforestation. 2018. "Deforestation Meaning In The Cambridge English Dictionary". *Dictionary.Cambridge.Org*. https://dictionary.cambridge.org/dictionary/english/deforestation.

cutting down these forests it drives climate change by indirect increasing greenhouse gases in the atmosphere and decreasing biodiversity.

To counteract deforestation Bradford proposes actions like reforestation but also to educate and create awareness of the situation and consequences of deforestation.[42] Articles was found that reflects Bradfords proposition and could be divided into two categories, monitoring and education.

The found articles on monitoring forest areas presented different approaches in relation to the purpose of the solution. Prabhakar et. al proposes an approach to use vibrating sensors to monitor trees and detect irregular activities to prevent criminal deforestation in commercial plantations.[43] Another approach proposed by Reiche et. al is to combine multiple observations from image satellites with observations from Synthetic Aperture Radar (SAR) satellites to improve near real-time monitoring on deforestation in tropical areas where cloud cover is normal.[44] The solution showed better results in comparison with usage of only observations from one type of sensor and decreased the time period of which deforestation was indeed detected.

Also a few newer approaches was found, one to combine object-based and pixel-based classification approaches to be applied on remote sensing data[45] and another to use *Unmanned Aerial Vehicles* (UAV) to monitor and manage plant conservations[46]. This last mentioned solution brings up a great deal of issues with both current technology regards to sensors, battery and image resolutions and also insurance, regulations and bureaucracy. But the authors believe that the future generation UAVs will be able to manage and monitor plant conversations better and more efficient.

In many of the articles found and read the term Landstat was found which is a joint NASA/USGS program which is a collection of satellites which monitors Earth to provide data to be used to manage the earth's resources and monitor the environment.[47] This seem to be one common source of data which many of the solutions was built on. Yusoff et. al. presents an teaching aid that could be used by using Landstat images to develop games to increase awareness of environmental issues in students.[48] Another education tool found in the literature study was to create mobile applications with the purpose to introduce environmental issues to younger kids which had been conducted in Malaysia with promising results.[49] In table 6 in Appendix A all the found articles are presented.

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42 Bradford, Alina. 2015. "Deforestation: Facts, Causes & Effects". *Livescience*. https://www.livescience.com/27692-deforestation.html

43 Prabhakar, Prakhar, Vishwateja Mudiam Reddy, Naresh Vinay, and Nagarjun Rao U. 2017. "Multi-Node Wireless Surveillance System For Commercial Plantations". In *IEEE International Conference On Technological Innovations In ICT For Agriculture And Rural Development(TIAR 2017)*, 223-227. IEEE.

44 Reiche, Johannes, Eliakim Hamunyela, Jan Verbesselt, Dirk Hoekman, and Martin Herold. 2018. "Improving Near-Real Time Deforestation Monitoring In Tropical Dry Forests By Combining Dense Sentinel-1 Time Series With Landstat And ALOS-2 PALSAR-2". *Remote Sensing Of Environment* 204: 147-161.

45 Grecchi, Rosana Christina, René Beuchle, Yosio Edemir Shimabukuro, Luiz E.O.C Aragao, Egidio Arai, Dario Simonetti, and Frédéric Achard. 2017. "An Integrated Remote Sensing And GIS Approach For Monitoring Areas Affected By Selective Logging: A Case Study In Northern Mato Grosso, Brazilian Amazon". *International Journal Of Applied Earth Observation And Geoinformation* 61: 70-80.

46 Baena, Susana, Doreen S. Boyd, and Justin Moat. 2017. "Uavs In Pursuit Of Plant Conservation - Real World Experiences". *Ecological Informatics*.

47 "Landsat Science". 2018. *Landsat.Gsfc.Nasa.Gov*. https://landsat.gsfc.nasa.gov/.

48 Yusoff, Amri, Shahrizuan Shafiril, Che Zalina Zulkifli, Gary Wills, Lester Gilbert, and Richard Crowder. 2016. "The Application Of Environmental Data From Real-Time Forest Monitoring System To Develop Games As An Engineering Course Teaching Aid". In *2016 IEEE 8Th International Conference On Engineering And Education (ICEED)*. IEEE.

49 Savita, K.S, Manoranjitham Muniandy, Z Nur' Ain, and Mazlina Mehat. 2017. "A Mobile Based Environmental Education For Primary Schoolchildren In Malaysia". In *2017 International Conference On Research And Innovation In Information Systems (ICRIIS)*. IEEE.

Discussion and Conclusion

The results were a bit unexpected, the choice of databases gave sometimes similar objects, the amount of found articles varied much with the choice of search words, which can be seen in Appendix "Search words". The included objects where not only articles but also conference papers in many cases. This might give a more overviewing result and is something that goes well with the main problem formulation or question. Even so, most of the articles focused mostly on present state solutions, not cutting edge technologies. Still, with the similarities of all scientific papers they contained a future work to be done, in many cases.

The articles were read and studied with the intention to find specific *Information and Communication Technology* (ICT)s that could potentially be used in climate change adaptation. However, it was sometimes difficult to find papers that talked in-depth about specific technologies. Many of the papers we found were more generally written in regards to what technologies were used. They, for instance, mentioned certain technologies they used but did not go into depth in exactly how those technologies were used or the limitations of those technologies. Despite this, there were still some very interesting articles that did provide specific technological findings. On a general level, the ICTs found could be divided into monitoring technologies and computational/analytical technologies. Monitoring technologies were for example: *Remote Sensing* (RS), *Global Positioning System* (GPS), *Wireless Sensor Networks* (WSNs), *Autonomous underwater vehicle* (AUV) and *Unmanned Aerial Vehicle* (UAV). These technologies are all dependant on well-functioning network infrastructure. One interesting finding was that oftentimes information gathering and analysis is already being done on a satisfactory level by different research institutes, but the results do not reach the end users, such as farmers. The reason for this miscommunication could be based either on lacking the right technology solutions or lacking the right communication structures.

One other unexpected result of this study was that many of the found ICT solutions was actually used to prevent climate change instead of being restricted to just cope with it. Since these areas are strongly interconnected it was hard to find articles that focused on the later one and it was decided to include some of the articles that brought up solutions to prevent climate change.

A common proposed area that this study found was that ICT could help in was education. By using ICT in teaching aids it could increase the awareness of environmental issues in younger children and adults. This could have a positive effect on how the future generations chose to live their lives as well as drive innovation for sustainable development.

The geographic locations where the research was performed and implemented was spread all over the world. However, some countries like India was represented more than other countries. This is probably due to the fact that they deal with many different climate changes such droughts, torrential rainfalls and flooding. Furthermore, since India is densely populated, the climate changes appearing there will affect a lot of people, thus increasing the incentives of doing research on how ICTs may cope with the climate changes.

Climate change should be countered by preventing unsustainable human activities and spreading the knowledge of the connection between human activities and climate change. However, we also need to prepare for climate change to continue to happen and then we need to be prepared for them. ICT solutions that may be used in countering climate change, as well as coping with it, can be divided into the following categories: Computation, clean energy, information sharing, monitoring and education. As figure 3 showed in the result section, around 20 percent of ICT solutions are focused on computation and 47,5 percent are focused on monitoring. Monitoring and computation almost always go hand in hand, since the data

collected from monitoring needs to be analyzed in order to be used in a meaningful way. These two solutions can be used to detect what human actions are causing climate change but also help people adapt to climate change since monitoring systems can detect if any extreme weather such as torrential rainfalls or droughts are on their way. Around 17.5 percent of ICT technology in our review focus on educating people about which human activities can cause climate change. There are five percent of ICT solutions that focus on replacing the energy source of non-sustainable technology with sustainable solutions and 10 percent of ICT solutions that focus on sharing the information and communicate it in a better way to the end users. This is very important since it does not matter how much good information you collect if it does not reach the people that need it, such as farmers.

Torrential Rainfall & Flooding

Weather is one of the factors which is hard to control in the natural context. Indirect impact from climate change leads to the torrential rainfall followed by flooding. Based on the study of causal chain[50], the primary climate change impact is the indirect result from globaling warming. There is no straight and technical way of adaptation in this stage. The physical consequence of primary impact is the natural phenomenon caused by increased evaporation and transpiration. This leads to the human and ecosystem impacts which can be observed as the torrential rainfall and flooding. This climate change issue becomes a significant problem against 13th *Sustainable Development Goals* (SDG) which aims for "Climate action"[51]. The potential interventions of *Information and Communication Technology* (ICT) in these stages so far are limited. According to the results of literature review presented in the last section, the sufficient ICT adaptations in field of torrential rainfall and flooding mainly focus on monitoring. The monitoring systems proposed currently can be divided into predictive monitoring and real time monitoring. The predictive system is often designed upon the evaluation of the potential for activity of certain natural phenomenons from the weather forecast model outputs[52]. Meanwhile real time system is using the existed technology which is "a wireless Local Area Network (LAN) that has been established using innovative geo-ICT tools"[53].

Based on the monitoring technology, another type of ICT adaptation is also introduced in some scientific literatures. When the stage comes to consequences for humans and ecosystems, some other dimensions of sustainable developments are effected. The adaptation used to reduce the damage on human lifes and economy is emphasized in order to avoid the slowing down of the SDG including "No poverty", "Zero hunger" and "Life on land". Through the smart computing, ICT system can play a significant role in emergent decision making.

One common feature observed from the ICT technologies mentioned in literature studies is the shared goal of achieving data visualizable. Since the ICT adaptation is aimed to be generalized to people from various areas and different backgrounds. Either monitoring or computing solution are developing in a way to deliver the data and message in a more visual and understandable way. On the other hand, a limitation shown in many current researches on this climate change issue can be that they tend to scaled the global issue down to the local field study. Therefore the current proposed ICT technology is mainly oriented towards the specific geographical environment. In order to generalize the ICT solution to adapt the global climate change context, specifically the torrential rainfall and flooding issue, further scalable

[50]Shabajee, Paul, Malcolm Fairbrother, John-David Dewsbury, and Chris Preist. “ICT 4 Climate Change Adaptation: Systemic and Generative Perspectives & Tools.” Atlantis Press, 2014. https://doi.org/10.2991/ict4s-14.2014.30.

[51] “The Global Goals,” The Global Goals, accessed March 7, 2018, https://www.globalgoals.org/.

[52] Fiori et al.,"Implementation and performance analysis of the lightning potential index as a forecasting tool", Estoril, Portugal, 2016.

[53]Fukui, H., P. Limlahapun, and T. Kameoka. "Real Time Monitoring for Imja Glacial Lake in Himalaya — Global Warming Front Monitoring System." SICE Annual Conference, 2008, 2008, 2578-581.

implementations and tests based on different geographical configuration or atmospheric processes is required.

After the study of ICT solutions within the torrential rainfall and flooding area, the conclusion can be drawn. The current trend of ICT technologies used to adapt the torrential rainfall and flooding mainly focus on monitoring and intelligent computing. The procedure includes collecting real time data and processing the predictive pattern in order to make the emergent decision during the disaster. In the future, data visualization is one direction to develop the ICT solutions furtherly meanwhile the generalization through different geographical and natural conditions should be emphasized.

Droughts

Since droughts in populated areas will affect the lives of people, the adaptation to droughts is strongly connected to *Sustainable Development Goal* (SDG) number 1 "No poverty" and number 3 "Good health and well-being"[54] in that *Information and Communication Technology* (ICT) could provide a way for society to better deal with these climate changes and prevent people from lacking in food and water due to drought and the consequences thereof.

There are several ICT technologies that may be used to detect the upcoming of droughts, as well as mitigating the consequences of drought. The mitigating does not have to do so much with stopping the drought of happening but rather prepare society in such a way that it can deal with droughts[55]. In predicting and monitoring potential droughts, we see the use of Remote Sensing (RS), which is usually satellite or aircraft based, and detects changes from a distance through "optical, acoustical or microwave"[56] signals. The Global Positioning System (GPS) is also used as well as Wireless Sensor-based Networks (WSNs). RS, GPS and WSNs could all possibly benefit from further improvements in network technologies such as 5G because of potentially shorter latency and greater bandwidth, making it easier to provide greater amounts of data for analysis.

Although certain specific ICT techniques have been found during the literature review, many of the techniques named under the category "Type of ICT technique" did not have to do so much with a very specialized high performance ICT technique, but rather the use of existing technologies in new ways, or make better use of already existing technologies. Examples of this is the discussion on how farmers in India could benefit from the great research that is already being done by agricultural institutes but that never reach the end users - the farmers[57]. The same problem is also seen in Nigeria where the author makes the case that ICT needs to be implemented on a larger scale to actually communicate important findings to local farmers[58]. The ICT techniques of interest in these cases are basically web applications and phone applications.

Glaciers Melt

One of the main cause of glaciers melting is global warming. The *Information and Communication Technology* (ICT) solution can provide active help to slow down the global warming process and help *United Nations* (UN) to reach their 13th SDGs(Sustainable Development Goal). These help include:

1. Using renewable and sustainable energy instead of coal and gasoline.

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54 "The Global Goals," The Global Goals, accessed March 7, 2018, https://www.globalgoals.org/.

55 Hussain et al., "Emerging Geo-Information Technologies…", 491.

56 Robert A. Schowengerdt, *Remote Sensing: Models and Methods for Image Processing* (Elsevier, 2006). 2.

57 Singh et al., "ICT Platform for Climate Change Adaptation in Agriculture," 1.

58 O. Eguaroje, A. Atijosan, and S. Mohammed, "Geospatial and Information Communication Technology Convergence (Geo-ICT): Enabling Sustainable Environmental Management in Nigeria," in *2012 8th International Conference on Information Science and Digital Content Technology (ICIDT2012)*, vol. 2, 2012, 313–18. 1.

2. Monitoring the effect of global warming
3. Computing and analyze the data that collect from the monitoring
4. Smart city solution to make sure the energy resource and after-effect to the environment from human activity is properly managed
5. Smart workspace solution to make sure the production do not cost more than it required

The categorization of the ICT solution to slow down global warming process is based on the human activity and the after-effect from the activity. The categorization start from the tool of human used to maintain proper living in modern society. The tools need a energy source to be able to work as human required. If the energy used, there must be emission from the energy. Therefore the first category limit the energy that produce from the tools must be renewable and clean so that the emission should not harm the environment or cause cumulative impact.

The second category is focus on control human activity in a broader view. Since the clean energy technology is not perfectlized yet, the efficiency from the clean energy will be low. Due to the clean energy has low efficiency the clean energy is more expensive than traditional coal and gasoline. In this way, human has to monitor its own after-effect properly and know the damage level of the human activity. With the data collect from monitoring solution, ICT solutions are capable to compute and analyze the data and provide a suggestion about the method to decrease the after effect of human activity. Not all the monitoring solution is meant for ICT computation solution. Some data do not need to be analyze or is visualizable. Those data are self-explained in the RAW data state. That is the reason they are in two different category.

By using the the help of monitoring and computing from ICT solution, the smart city solution is made possible. Smart City solution mean the city is self-maintained and the input and output of production is well managed by city itself. Smart city solution is also helping UN to reach number 11- sustainable city and communication and 12 - responsible consumption and production. goal self-maintaining are done by monitoring and computing in ICT solutions. With the data analyzed, the smart city solution aware which threshold has been reached and make certain decision to prevent the threshold been certain excess. For example, the smart city solution can decide which car allow to drive for each day base on the car plate number or the emission from each car or which street light allow to turn on at what intensity base on the sunlight intensity and time of the day.

People discuss about economy efficiency in business,but in sustainability the energy efficiency is discussed instead of money. Same concept as smart city is implemented in workspace but the focus of the smart workspace is to control the energy efficiency for each production cycle. Smart workspace self-manage or provide feedback to the user with the amount of energy has been used to each department and equipment to make sure the energy output is maintain efficient.

Ocean Acidification

Ocean acidification (OA), most concerning the *Sustainable development goal* (SDG) number 14 “Life below water” and also number 12 “Responsible consumption and production”. From a social aspect OA mainly concern food, and that could be compared with SDG number 2 “Zero hunger”. The result, catched some technologies, that could easily be categorized into, education and monitoring. Still the result also gave insight in how simple applications can help the monitoring on local level, such with small scale fishing in e.g. India or Indonesia. High technological solutions as *Autonomous Underwater Vehicle* (AUV)

performing odometry over coral reefs in the coast of Australia, a bit more high technological with sensors and automatisation. Still the found objects in this review haven't mentioned adaptation, more than something like “we have a great challenge to meet..” where the fact that climate change is ongoing and are to create these affects mentioned, mainly the risk of the fish stock to decrease regarding OA. I see adaptation in more efficient fishing, with new and present *Information and Communication Technology* (ICT) solutions. Still as for all ICT there is a conflict with e-waste, energy use, production of minerals used for ICT technologies. Conflict minerals might be the case in producing a smartphone for a fisherman. These subjects, personally haven’t been touched upon enough in the found reviews. Still there is complexity in the result, advanced algorithms and systems calculating where the fish is, or guiding a underwater vehicle through a labyrinth of corals. Is the profit of more efficient localisation of fish, with the save of fuel consumption better that the mining effects for the smartphone used? There are also regulatory questions to be answered, some problems with overfishing is also a policy and regulation problem, mentioned earlier how ICT is used by the European union to monitor vessels. Still for some countries the fishing industry means money, and are perhaps depending on that money for welfare.

Conclusion drawn by the research on ICT and climate change with focus on OA, there are current and possible solutions, as mentioned in the background *International Telecommunication Union* (ITU) are creating standards for monitoring, by satellite and etc. Thus the result is that possible present and future ICT technology aids in educating, monitoring and collecting data, both on global and local scale. There are specific solutions, such as AUV’s that can automatically monitor changes in coral reefs. And still there is more research and quiet few articles talking about ICT and OA and adaptation, with respect to ICT’s potential.

Deforestation

Deforestation is one of today's environmental challenges. It drives climate change in different ways and is strongly related to the earlier mentioned *Sustainable Development Goals*. In more detail deforestation affects following goals “12: Responsible consumption and production”, “13 climate action” and “15 life on land”. By creating awareness of the environmental impact of deforestation one could get the market to care more about their consumption which impacts companies production to be more responsible and sustainable. The problem on how to influence people to be more consumption aware is an actual problem today when people tend to be more driven economical and also that consequences of deforestation are hard to grasp if not located in that area. Both goals number 13 and 15 is in direct relation to the environment and goal number 15 has specified target to promote a sustainable implementation of managing forests and increase afforestation and reforestation on a global level.[59]

When it comes to deforestation in combination with *Information and Communication Technology* (ICT)this study found many solutions that proposes distance monitoring on forest areas. This in fact seems the most common solution to both cope and prevent deforestation and it seem reasonable since many forest areas that are affected by deforestation is often hard to reach and might have limited resources for power, infrastructure and people. The proposed solutions that this study examined when it comes to monitoring systems all proposes different solutions. The different approaches on how to monitoring forest seemed to vary depending on the purpose of the solution. One solution proposed to use *Unmanned Aerial Vehicles* (UAVs) to monitoring plant conservations[60] as the drone-technique is getting cheaper and more

[59] "Forests, Desertification And Biodiversity - United Nations Sustainable Development". 2018. *United Nations Sustainable Development*. http://www.un.org/sustainabledevelopment/biodiversity/.

[60] Baena et. al "Uavs In Pursuit Of Plant Conservation - Real World Experiences"

available but proposed challenges when it comes to insurance and regulations as well as drawbacks of today's technique when it comes to sensors and image resolutions on drones. This solution would probably not work to monitor the global deforestation due to technical restrictions of today's technique and then solutions based on satellite images would be more useful and economical favorable. The drawbacks that were presented with the UAV solution is one solution that could benefit from the development of 5G.

This study also examined if ICT is used in educational tools for deforestation.There was some articles found that used ICT to educate about deforestation but these solutions was not restricted to deforestation but instead proposed an application that could be used for other environmental problems as well. Either way the approach of using ICT solutions as teaching aids can surely be beneficial to early teach future generations of human impact on the environment and could also boost innovation concerning sustainable development.

When analyzing the result of this study it is clear when talking about deforestation and ICT it is hard to or even impossible to draw a line between solutions that are strictly used to cope with deforestation respectively to prevent it. Since they are strongly interconnected we can see where the problem lies. Even though not many solutions were found that strictly are used to cope with deforestation the result can still be used to draw conclusions from as well as expand on.

The conclusion of this study on deforestation was that there are some different approaches used today to cope but also prevent deforestation by using ICT. The solutions found could be categorized in to two groups, one for monitoring to prevent deforestation and help reforestation and one to educate people about deforestation and other environmental issues.

General conclusion

The overview that has been presented is by no means extensive, but it provides a starting point for further literature review into this important area. A problem of making such a review is that the area of study is very large and relatively new and undiscovered (meaning the adaptation to climate change). At least this study have started to clarify some areas where ICTs tend to or can be used. Some of them such as monitoring and computation were expected findings but other areas such as education and information sharing was not as expected. The latter two are more indirectly connected to cope with climate change but are also very important as has been discussed earlier; without the information reaching the end user, there are no benefits of it. Education provides a more indirect way of coping with and also preventing climate change. Hopefully, this report can act as a starting point for someone else to continue delving even deeper into this very important area of study.

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Appendix

A. ICT Solution For Each Climate Change

Table 1. ICT solutions for torrential rainfalls and flooding

Database	Author and year	Title	Location	Type of ICT technique	Type of adaptation	Present or future	Method used	General conclusion
IEEE	H.Mohammad et.al 16-18 Dec. 2013	A Critical Evaluation of the Rational Need for an IT Management System for Flash Flood Events in Jeddah, Saudi Arabia	Abu Dhabi, United Arab Emirates	Computing (computer based emergency response training system)	low-, medium-, and high-intensity flooding events	Future	Field study, analysis on primary data from local responders in Jeddah	This IT system could help decision makers calibrate the right response criteria in the event of scalable flash flooding across Jeddah.
IEEE	F.Hiromichi et.al. 20-22 Aug. 2008	Real time monitoring for Imja Glacial Lake in Himalaya — global warming front monitoring system	Tokyo, Japan	Monitoring ("the Digital Earth", real time monitoring and early warning system)	Flooding due to rainfall	Present	Scale down the global issue to local level, practical experiment to collect raw data	The system is found to be useful to predict the critical situation due to its dynamic approaching and capturing images from the camera from the field server.
IEEE	F.Elisabetta et.al 25-30 Sept. 2016	Implementation and performance analysis of the lightning potential index as a forecasting tool	Estoril, Portugal	Monitoring and Computing (forecasting tool based on lightning potential index(LPI))	Downpour and flash floods	Future	model definition and implementation, case studies	LPI model can be valid for lightning activity forecasting system. However the effectiveness of LPI needs to be further tested based on different geographical configuration or atmospheric processes.
IEEE	P.Azfina et.al. 20-21 July 2016	Dam water level prediction system utilizing Artificial Neural Network Back Propagation: Case study: Ciliwung watershed, Katulampa Dam	Surabaya, Indonesia	Monitoring and Computing (long term warning system based on predictive model and data visualization)	Flooding	Future	previous work study, model design and system implementation	The system could reduce risk probability and material loss of evacuation. Prediction result was better than the conventional one. Elevated prediction shows higher similarity with actual real data than the previous work. The system would perform better using direct API (web service) from current telemetric sensors. Automatic data transfer would allow more room for periodical prediction model update and system development.

Table 2. ICT solutions for droughts

Data base	Author and year	Title	Location	Type of ICT technique	Type of adaptation	Present or future	Method used	General conclusion
IEEE	Hussain, M et al. 2005.	Emerging geo-information technologies (GIT) for natural disaster management in Pakistan: an overview	Pakistan	Geo-Information Technologies: Remote Sensing (RS), Geographical Information Systems (GIS), GPS, Information and Communication Technology (ICT)	Drought, and other natural disasters	Present	Review	Geo-Information Technologies are vital to mitigate, monitor and to cope with natural disasters as well as organizing rescue operations caused by natural disasters.
IEEE	O. Eguaroje, et al. 2012	Geospatial and information communication technology convergence (Geo-ICT): Enabling sustainable environmental management in Nigeria	Nigeria	Convergence of Remote sensing (RS), Geospatial data, Information Communication Technology (ICT)	Drought, and other natural disasters	Present	N/A	Geo-spatial technologies need to be converged with other technologies such as ICT to better reach end consumers.
IEEE	D. Singh et al. 2015.	ICT platform for Climate Change Adaptation in agriculture	India	Web based platforms, mobile apps, Interactive Voice Response(IVR)	Drought, primarily	Present	N/A	The beneficial research of agricultural institutes providing new cropping patterns and cultivation practices oftentimes does not reach the end users - the farmers, on time. ICT can play a crucial role in connecting farmers with adequate research findings.
IEEE	K. Elevant et al. 2011.	Improving Weather and Climatic Information Quality with User-Generated Observations	Sweden	Sharing of weather data among the public	Many climatic events where drought can be included	Present	Quantitative	The general idea is to let the normal citizen contribute with weather data input instead of expanding on National Meteorological and Hydrological Services (NMHSs). In general, people with more spare time like pensioners and children are more likely to contribute weather data.
IEEE	M. Masinde. 2014	IoT applications that work for the African continent: Innovation or adoption?	South Africa	Drought early warning systems - sensor-based	Drought	Present	N/A	Instead of creating a homogenous weather forecasting system, create a heterogenous forecasting system consisting of cell phones, RFID's, conventional weather stations and WSN's.

Table 3. ICT solutions for glacial melting

Database	Author and year	Title	Location	Type of ICT technique	Type of adaptation	Present or future	Method used	General conclusion
World Economic Forum ("The World'S First Solar Airport Takes Off" 2018)[61]	10 Nov 2015 K. Rajendran	The world's first solar airport takes off	India	Renewable/Sustainable Energy	Renewable Energy to power the airport	Present	Official Press News	Cochin International Airport in southern India's Kerala state may be best known as the gateway to the tourist beaches and houseboats of the region's famous backwaters. Now it has a new claim to fame: world's first solar airport.
LEDs Magazine("City Of Oslo Slashes Energy Use With LONWORKS Network For Street Lighting" 2018)[62]	September 29, 2014 Echelon Corporation	City of Oslo slashes energy use with LONWORKS network for street lighting	Oslo,Norway	Smart City Monitoring	Smart ICT solution to control the light level of the street light	Present		Oslo chose an Echelon intelligent street lighting system based on LONWORKS technology, an open, extensible architecture that lets control devices from multiple manufacturers interact with each other. The project—the first large-scale implementation of a LONWORKS-based control network in a street lighting application—includes replacing older, inefficient mechanical ballasts in the city's 55,000 streetlights with electronic ballasts from SELC Ireland Ltd. that communicate over existing power lines using Echelon's power line technology.
Telenor Group ("Smarter ICT Solutions Can Help Prevent Global Warming, According To New Report" 2018)[63]	Apr 2013 Jan Kristensen, Director Climate Change, Group CR, Telenor Group	Smarter ICT solutions can help prevent global warming, according to new report	World wide initiative	Smart City Smart Workspace Monitoring computing	Smart ICT solution in commen work and living enviorment	Future	Company Blog	Telenor takes part in new ICT industry report, SMARTer 2020, providing analysis of how communications technology can help reduce carbon emissions and prevent climate change.
Ericsson Group ("Ericsson Demonstrates Solutions To Climate Challenges At COP22" 2018)[64]	Nov 10, 2016 Ericsson Corporate Communications	Ericsson demonstrates solutions to climate challenges at COP22	World wide intiative	Renewable/Sustainable Energy Monitoring Computing	Solar Powered electricity car LED lightting with connectivity IoT Network and utility Public Safety & Security Transport	Future/ Now	Company Blog	Stella Lux, a solar-powered electric car developed by Solar Team Eindhoven. Ericsson Zero Site, developed in partnership with Philips, is a multi-application pole solution that combines LED lighting with connectivity. Five Zero Sites are installed in Marrakech. IoT: Connected mangroves; connected water; connected vineyards Network & OBS: Cellular for massive IoT + 5G videos; HDS Command Centre; Apcera Hybrid Cloud; ECM (VNF Lifecycle, Orchestration); Ericsson Expert Analytics Energy & Utility: Smart metering; IoT Accelerator; Smart City; Show IT 2.0, Google Glass for Grid control; Ericsson Expert Analytics Public Safety & Security: Disaster and emergency management; private LTE networks for disasters and public safety Transport: Smart parking; traffic management

61 "The World'S First Solar Airport Takes Off". 2018. *World Economic Forum*. https://www.weforum.org/agenda/2015/11/the-worlds-first-solar-airport-takes-off/.

62 "City Of Oslo Slashes Energy Use With LONWORKS Network For Street Lighting". 2018. *Ledsmagazine.Com*. http://www.ledsmagazine.com/ugc/iif/2014/09/29/oslo-street-lighting-system-slashes-energy-usewith-lonworks-network.html.

63 "Smarter ICT Solutions Can Help Prevent Global Warming, According To New Report". 2018. *Telenor Group*.https://www.telenor.com/smarter-ict-solutions-can-help-prevent-global-warming-according-to-new-report/.

64 "Ericsson Demonstrates Solutions To Climate Challenges At COP22". 2018. *Ericsson.Com*. https://www.ericsson.com/en/news/2016/11/ericsson-demonstrates-solutions-to-climate-challenges-at-cop22.

International Telecommunication Union (""Icts: Environment And Climate Change"" 2018)[65]	International Telecommunication Union (ITU)	ICTs: Environment and Climate Change	World wide intiative	Smart monitoring Smart Computing	Conducting and managing studies on remote-sensing Providing key climate data via radio-based applications Satellite monitoring	Present	Presentation	Monitor the Climate change with the help of Stellite and ICT. This solution can be used for various climate change monitoring include glaciera melting and global warming.
QUARTZ (Schlanger 2018)[66]	Zoë Schlanger February 22, 2018	New cutting-edge science confirms that Antartica is losing ice faster every year	Antartica	Smart Monitoring	An cutting edge technology that confirm the glaciers on Antartica is melting	Present	Official Press News	In a cutting-edge survey of satellite data published Feb. 13 in the journal Cryosphere, researchers from NASA and other institutions shows that ice loss from the critical region of Antarctica is happening at an increasingly fast pace.

65 ""Icts: Environment And Climate Change"". 2018. *Itu.Int*. https://www.itu.int/dms_pub/itu-t/oth/06/47/T06470000020006PDFE.pdf.

66 Schlanger, Zoë. 2018. "New Cutting-Edge Science Confirms That Antartica Is Losing Ice Faster Every Year". Quartz. https://qz.com/1213702/a-new-nasa-image-confirms-that-antartica-is-losing-ice-faster-every-year/.

Table 4. ICT solutions for ocean acidification

Database	Author and year	Title	Location	Type of ICT technique	Type of adaptation	Present or future	Method used	General conclusion
WOSCC	Fauville, G. et al., 2014	ICT tools in environmental education: reviewing two newcomers to schools	Sweden	Education / online platform "voice thread"	Ocean acidification	Present	Review	More research is needed.
WOSCC	Fauville, G, 2017	Questions as indicators of ocean literacy: students' online asynchronous discussion with a marine scientist	Sweden	Education /virtual laboratory	Ocean acidification	Present	Analyse, focus group, interviews & online questionnaire	Can give more of a touch for scientific knowledge
WOSCC	Fauville, G. et al., 2011	Virtual Ocean Acidification Laboratory as an Efficient Educational Tool to Address Climate Change Issues	Sweden	Education / virtual animation laboratory	Ocean acidification	Present	Develop, implement and test	Inquiri to insight (I2I) about ocean acidification (OA) increases.
WOSCC	Oviedo, A. F. P. et al. 2017	Community-based monitoring of small-scale fisheries with digital devices in Brazilian Amazon	Brazil	Smartphones for community monitoring	Ocean acidification	Present	Field experiments	Volountars can contribute with data reducing cost compared to government agencies.
WOSCC	Saville, R et al., 2015	Application of information and communication technology and data sharing management scheme for the coastal fishery using real-time fishery information	Japan	Automatic computation and data sharing	Ocean acidification	Present/Future	Field experiments	Grid size can easier be faster evaluated, thus current automatization works fine.
WOSCC	Kopek-Putala, W. et al. 2017	The Interdisciplinary Educational Project about the Coral Reef as an Element of Entertainment Based-Education	Czech Republic	Education	Ocean acidification	Present	NA	NA
WOSCC	Kiyoki, Y. et al. 2016	Cross-cultural and Environmental Data Analysis in Data Mining Processes for a Global Resilient Society	Netherlands	Computing e.g. coral areas	Ocean acidification	Present	NA	NA
WOSCC	Conruyt, N 2013	E-co-innovation for making e-services Living Labs as a human-centered digital ecosystem for education with ICT	USA	Education by Semiotic web	Ocean acidification	Present	NA	NA
WOSCC	Wada, M. et al 2013	Marine Observation Framework Using Ict for Mariculture in Indonesia.	Indonesia	Monitoring	Ocean acidification	Present/future	NA	Indonesia is a large producer and exporter of fish, something that's needed to be monitored to support a sustainable or stable production and distribution for the future.
IEEE	Sanjay K. et al. 2013	ICT for fisheries — Environment friendly way: Pilot experience in Raigadh	India	Smartphone app. for community monitoring and locating fish.	Ocean acidification	Future	Field experiments	ICT and mKRISHI®-Fisheries' can reduce the use of fuel for fishing and increase the amount of catched fish.
IEEE	M. Dunbabin et al. 2005	A Hybrid AUV Design for Shallow Water Reef Navigation	Australia	Autonomous underwater vehicle (Starbug)	Ocean acidification	Present/future	Field experiments	There are AUV's that can function and manouvre pretty well nowadays, in the future more research is needed for sensor network distribution under water and the collection of data. Also automatisation the docking to a boat.
IEEE	M. D. Dunbabin et al. 2007	Large-Scale Habitat Mapping Using Vision-Based AUVs: Experiences, Challenges & Vehicle Design	Australia	Autonomous underwater vehicle (Starbug)	Ocean acidification	Present/future	Field experiments	The AUV's get more automated, with better sensors and less error's. Still AUV's are expensive, but a good way to do obometry of coral reefs.

Table 5. ICT solutions for deforestation

Database	Author and year	Title	Location	Type of ICT technique	Type of adaption	Present or future	Method used	General conclusion
IEEE	P.Prakhabakat et. al 2017	Multi-node wireless surveillance system for commercial plantations	India	Vibration sensors	Deforestation	Future	Literature study	By using trial-and error methods using electric components and communication concepts that can be used as a benchmark that can be used by various corporations, plantation owners and governments to have efficient economic methods of surveillance over large stretches of forests and tree plantations and preventing the problem of criminal activities and deforestation along the way.
ScienceDirect	J.Reiche et. al 2017	Improving near-real time deforestation monitoring in tropical dry forest by combining dense Sentinel-1 time series with Landstat and ALOS-2 PALSAR-2	Netherlands	Satellite based monitoring systems (optical + radar)	Deforestation	Present and future	Tree steps: collect time series data from individual components, pre processing of this data and then a probabilistic approach for multi-sensor NRT deforestation detection.	"Combining multiple SAR and optical time series can guarantee regular and temporally dense observations at medium spatial resolution independent of wheather, season and spatial location, which can improve NRT deforestation monitoring in the 'tropics."
ScienceDirect	S.Baena et. al 2017	UAVs in pursuit of plant conservation - Real world experiences	United Kingdom	Unmanned Aerial Vehicles (UAVs)	Deforestation/ reforestation	Present and future		"The next generation of UAVs offer enormous potential for plant conservation, but will require to have adequate and flexible legislation in place".
ScienceDirect	R.C. Grecchi et. al 2017	An integrated remote sensing and GIS approach for monitoring areas affected by selective logging: A case study in northern Mato Grosso, Brazilian Amazon	Brazil	Combination of object-based and pixel-based classification approaches	Deforestation	Present and future	3-step method: 1. mapping forest, non-forest and new deforested areas. 2. Extracting logging evidence. 3. assessing logging intensity and dynamics over time.	"Our method provides a feasible means of assessing forest disturbances consistently over time using medium resolution Landstat satellite images, and allows to assess deforestation and forest disturbances due to selective logging."
IEEE	K.S. Savita et. al 2017	A mobile based environmental education for primary schoolchildren in Malaysia	Malaysia	Mobile based application for environmental education	Education	Present and future	4-step method: 1 Requirement planning 2. User design 3. Construction 4.Cutover	The usage of the application to influence younger for green practice was very promising.
IEEE	A.Yusoff et. al 2016	The application of environmental data from real-time forest monitoring system to develop games as an engineering course teachning aid		Monitoring device/ games	Deforestation /education	Future		The implementation of the system that has been developed to monitor environmental data not only can be used as a prototype but can also contribute into developing the serious game as a teaching aid for students to increase their awareness towards environmental issues

B. Data Used to Create the Geographical Map

Table 1. Table with the data used to create the geographical maps.

Location
United arab emirates
Japan
Portugal
Indonesia
India
Norway
Antarctica
India
Netherlands
United kingdom
Brazil
Malaysia
United kingdom
Pakistan
Nigeria
India
Sweden
South Africa
Sweden
Sweden
Sweden
Brazil
Japan
Czech Republic
Netherlands
United states
Indonesia
India
Australia
Australia

C. Search Word

Table 1: Search words for ocean acidification study

Database	Searchwords	Limitations	Number of found objects
IEEE	ICT 4 adaptation	None	210
IEEE	"ICT" AND "adaptation"	None	376
IEEE	"ICT" & "adaptation"	None	98
IEEE	"ICT" & "ocean acidification"	None	5322
IEEE	ICT 4 adaptation AND ocean acidification	None	541
IEEE	Ocean acidification	None	48
IEEE	Ocean acidification AND ICT	None	62,346
IEEE	ICT AND Fish stock	None	34,704
IEEE	"ICT" & "Fish stock"	None	5322
IEEE	ICT AND Climate change AND Fish	None	1
IEEE	ICT AND corals	None	7
IEEE	"ICT" & "corals"	None	5329
IEEE	ICT AND Marine species	None	1
IEEE	"ICT" & "Marine species"	None	5328
WOSCC	ICT 4 adaptation	None	17
WOSCC	ICT 4 adaptation AND ocean acidification	None	0
WOSCC	Ocean acidification	None	5456
WOSCC	Ocean acidification AND ICT	None	3
WOSCC	ICT AND Fish stock	None	2

WOSCC	ICT AND Climate change AND Fish	None	1
WOSCC	ICT AND corals	None	3
WOSCC	ICT AND Marine species	None	4

Table 2: Search words for torrential rainfall and flooding study

Database	Search words	Limitation	Number of found objects
IEEE	ICT AND flooding	None	88
IEEE	ICT AND (torrential rainfall OR downpour)	None	38
IEEE	ICT AND rainfall AND flooding	None	3
IEEE	ICT 4 adaptation AND flooding	None	2

Table 3: Search words for deforestation study

Database	Search words	Limitation	Number of found objects
IEEE	ICT deforestation	None	2
IEEE	deforestation detection	None	118
IEEE	reforestation monitoring	None	16
ScienceDirect	deforestation ICT	None	130
ScienceDirect	reforestation sensor	None	735
ScienceDirect	deforestation drones	None	41
ScienceDirect	Ecosynth	None	4
Scopus	deforestation AND education	None	380
Scopus	deforestation AND education AND application	None	34

Table 4: Search words for drought study

Database	Search words	Limitation	Number of found objects
IEEE Xplorer	drought AND ict	None	211
IEEE Xplorer	heat AND ict AND climate	None	984
IEEE Xplorer	drought AND climate change	None	2725
IEEE Xplorer	drought AND climate change adaptation	None	446

Table 5: Search words for glaciers melting

Database	Search words	Limitation	Number of found objects
World Economic Forum	ICT, greenhouse effect,ICT solution	None	3
LEDs Magazine	None	Redirection from world economic forum	1
Telenor Group	Smart office, sustainable, greenhouse effect	None	6
Ericsson Group	Greenhouse effect, MWC, ICT solution	None	6286
International Telecommunication Union	ICT impact, climate change	None	4970
QUARTZ	Antartica melting, ict	None	3