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Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences

The Transformative Role of Information and Knowledge Governance on Climate Change Adaptation in the Information Age: a Systematic Review

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submitted by: Yanhua Shi

(Family name, first name)

1st Examiner (Supervisor): Prof. Dr. Eisenack Klaus

(Academic degree, family name, first name)

Division or Institution Division of Resource Economics

2nd Examiner: Dr. Philipp Grundmann

(Academic degree, family name, first name)

Division or Institution Division of Resource Economics

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Yanhua Shi

International Master of Rural Development

Abstract: Climate change adaptation has emerged in the last few decades as a hot topic not only in scientific research, but also in the political decisions and planning from local to international level, in the media, and in public awareness. The academia has emphasized the importance of recognizing knowledge and endeavor from various groups while tackling the issue. The entering of the Information Age in the 21st century, especially with the development of Information and Communication Technologies (ICTs), has significantly transformed the patterns of information and knowledge flows and the platforms for stakeholders' interaction. Against this background, the analytical concepts of information and knowledge governance have thus arisen in the environmental governance literature to depict the induced societal changes. Hoverer, there is a lack of research evidence using the terms explicitly in the context of climate change adaptation. The purpose of this study is thus to identify the transformational role of the two relatively new concepts of information and knowledge governance on climate change adaptation by synthesising existing literature using a formal systematic review approach. A total of 77 articles were selected and reviewed under the framework of three types of institutional rules regarding information, namely *information rules, platform rules and stakeholder rules*, developed in this work. The major findings are: (i) the developed analytical framework is useful in analysing the literature and fit with the assumption of the external environment, especially the changing role of non-state actors and non-scientific knowledge claims with the development of ICTs in the Information Age; (ii) there are in total three types of information rules, five types of platform rules and three types of stakeholder rules identified in this study, yet the distribution of selected articles and sectors is not well balanced among various types of rules; (iii) More explicit definition have been made in my research to clarify the use of these interlinked terms of data, information and knowledge.

Keywords: climate change adaptation; Information Age; information governance; knowledge governance.

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1.Introduction

In 1973, design theorists Horst Rittel and Melvin M. Webber firstly used the term “wicked problems” for situations that are contested, difficult to define and inherently unsolvable. Climate change is one of the typical examples that many scientists have referred to as a “wicked”, or even “super wicked problem” (Bekkers et al., 2018; Ison et al., 2013; Levin et al., 2012).

Unlike social system designed by humans, climate, as a nature system, is more complicated and challenging to understand. Adaptation to climate change is not only a technical issue, but a matter of governance, involving communication and coordination both horizontally and vertically between diverse governance groups (Aoki and Rothwell, 2012). There is an increasing scientific effort to investigate climate change adaptation as governance challenges, especially considering its complexity and uncertainty of the impacts and the monitoring and evaluation process of climate change (Berrang-Ford et al., 2013). Based on the previous findings, Vink et al. (2013; p.1) identified the challenges of the adaptation of climate change as follows: (i) inherent uncertainties, given the long-term character of the policy issue; (ii) involvement of different stakeholders with their own ambitions, preferences, responsibilities, problem framings and resources; (iii) the lack of a well-organized policy domain for enhancing and monitoring climate adaptation in the policy agenda.

The governance of climate change adaptation requires intensive knowledge and endeavor from multiple groups to understand the social-ecological systems in their full complexity so as to respond to feedback from the system across both spatial and temporal scale. The importance of incorporating all kinds of knowledge from different disciplines and stakeholders, such as local and scientific knowledge, basic and policy-relevant knowledge, social and natural scientific knowledge (Birkmann and von Teichman, 2010), to inform decision-making of the commons management has been well recognized by more and more researchers (Hess and Ostrom, 2007). It is further pointed out that adaptation does not involve one-shot decisions, but rather a continuous social learning process (Hofmann et al., 2011).

The literature has not only recognized the importance of knowledge in climate change policies and plans from all levels around the world, but also of data and information, which are closely interlinked concepts with each other. Dating back to the Paris

Agreement on climate change (UNFCCC, 2015), the significance of climate change information management was officially addressed by setting out guidance in Article 7.7 for parties to develop, share, manage and deliver climate change knowledge, information and data. Pahl-Wostl et al. (2013) further differentiated climate change adaptation planning into three processes regarding the inter-relations between data, information and knowledge, referred to as the Information and Knowledge Management (IKM): (i) utilizing data to determine climate change projections and impacts; (ii) generating information on future climate related risks by applying data to undertake vulnerability assessments; and (iii) utilizing risk information to develop and evaluate adaptation options and plans.

The entering of humanity into Information Age since the invention of the World Wide Web in 1992, characterised with the unprecedented processes of information creation and ownership, has displayed a significant influence on the complexity of knowledge and information flows and their relationship with the stakeholders (Soma et al., 2016). New challenges are emerging in terms of digital divide and unequal positions and powers of organizations and nation states (van Deursen and van Dijk, 2014; Mol, 2006; Mol, 2008).

At the same time, with the growing significance of information due to the rise of distributed and digital information, society has been profoundly altered around the world with people and information becoming ever more connected (Buys et al., 2009). Considering the widespread use of social media nowadays, Muller et al. (2015) pointed out that people are no longer simply consumers of data and information, they can also be producers. The conventional hierarchy governance approach with the state as the central actor governing public interests within a country is no longer suitable. Instead, it is evolving and diversifying into newer modes such as private governance, co-governance and self-governance (Kooiman, 2003).

The transformation of information and knowledge flows and their relationships with the stakeholders have already attracted the attention of scholars in the field of environmental governance. Mol (2006) firstly introduced the concept of informational governance to depict such societal transformation that information is not only a source for environmental governance arrangements, but also a contribution to the transformation of environmental governance institutions. As a relatively new analytical concept, informational governance has been used to analyze how new societal development could affect various environmental issues, such as biodiversity loss (Routledge, 2011), marine governance

(Toonen and Lindeboom, 2015; Lamers et al., 2016), landscape governance (Opdam et al., 2016), agri-food sector (Ge and Brewster, 2016), fishery governance (Holm and Soma, 2016). The work was mainly carried out by a research team in Wageningen University with a theme issue on "sustainability governance and transformation: information governance and environmental sustainability" to capture the new challenges of environmental governance in the Information Age (Wageningen University Research, 2016).

Inspired by their work, I intend to narrow the research scope from general environmental sustainability issues to the specific domain of climate change adaptation. Based on the findings of the above related literature, an analytical framework, embedded with three types of rules, namely information rules, platform rules and stakeholder rules, was designed to capture the emerging societal changes arisen from the Information Age in the context of climate change adaptation. Specifically, rules in this study are seen as the institutional solutions and settings that are developed to address the problems related to the three key elements of information, stakeholder and platform in the information and knowledge governance. The information rules center on the information itself, clarifying the rules that define the quantity, quality, standards and usability of information and knowledge. The platform rules focus on the rules that facilitate the channels of the information and knowledge flows among various stakeholders. Last but not the least, the focal point of the stakeholder rules is the rules that related to the responsibility, obligation and power of each stakeholder, especially in the aspect of whom is in charge of what. More detailed explanation can be found in the following section.

Nevertheless, the existing literature on the use of the two newly developed analytical concepts is rare and fragmented with various terminology[1]. A clearer conceptualisation of the new forms of information and knowledge governance in the Information Age plays a pivotal role in understanding and evaluating the climate change adaptation process, policies and measures. Generally speaking, this study aims to fill this gap by applying the above mentioned analytical framework to evaluate the current state of the concepts of

[1] Searched in Scopus (at 11:03 pm, 04-05-2019) with the combination of "informational governance" AND "Climate change adaptation" OR "Climate adaptation" OR "Climate change adaptation governance" OR "CCAG", we found no results; while in search with "knowledge governance" AND "Climate change adaptation" OR "Climate adaptation" OR "Climate change adaptation governance" OR "CCAG", I only found four results with two of them from book resource and the other two from environmental science.

information and knowledge governance in the adaptation literature. A formal systematic review method will be used to enable the methodological transparency and rigor in synthesizing and tracking adaptation research. The research objectives of this study are: (i) to assess the current state of the interconnection between the emerging information and knowledge technologies, flows and networks within the platforms that facilitate the stakeholder interaction; (ii) to identify specific types of rules regarding information, platform and knowledge in the existing literature; (iii) to identify crucial knowledge gaps for future research. Specifically, this work intends to examine the following four research questions, related to two major aspects of terms and rules:

- How the three interlinked terms of data, information and knowledge have been defined, conceptualised and used in the literature?
- What are the rules that define the content, quantity, quality and standards of information and knowledge in the context of climate change adaptation?
- What are the rules that facilitate the information and knowledge flows among the stakeholders, especially in the Information Age?
- What are the rules that address the involvement, responsibility, obligation and power of the involved stakeholders in the process of climate change adaptation?

After applying the analytical framework through the systematic review, several specific examples for the information rules, platform rules and stakeholder rules were identified in this study correspondingly. The analytical framework developed in this study is found useful in analyzing the literature and fits well with the assumptions of the external environment, especially the changing role of non-state actors and non-scientific knowledge with the development of ICTs in the Information Age. It is indicated that ICTs and other digitalisation technologies have brought up new patterns and structures of information and knowledge governance in the context of climate change adaptation. The involved stakeholders and institutions thus shall gain more insights to understand the new relationships in the information and knowledge construction, dissemination and exchange processes, especially the arising roles of public and local communities and their knowledge claims. The structure of this article is as follows: Chapter 2 explains the design of the theoretical framework and research questions of this work. Chapter 3 describes the method of systematic review used to collect the database in the study. Chapter 4 presents the main results of the study systematically. At last, this article will conclude with core findings, limitations and suggestions for future research in Chapter 5 and Chapter 6.

2.Analytical framework

This section will explain the logic of the analytical framework applied in this work, divided into two major parts. The first major part is the review of the concepts and the related terms, starting from the general question of what we know about knowledge, to the relationship between data, information and knowledge, knowledge governance and information governance. While the second major part is the detailed elaboration of the developed analytical framework based on the above-mentioned concepts.

2.1 What do we know about knowledge?

To comprehensively understand the role of data, information and knowledge in climate change adaptation, I would firstly like to proceed with the question: what do we know about knowledge conceptually?

The Oxford English Dictionary interprets the word “Knowledge” as “Facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject” (Lexico, 2019). The verbs used in the definition express how knowledge is a result of a varied set of dynamic process, constantly changing through experience and learning (Mclnerney, 2002).

The study of knowledge has been influenced by a variety of disciplines, including philosophy, social science, information science, law science, economics and others. Every discipline can have its claim on knowledge. For example, philosophers take it as an epistemology issue. Plato firstly defined knowledge as “justified true belief” in his *Meno, Phaedo and Theaetetus*, and this concept has been actively debated by others (e.g., Aristotle, Descartes, Kant, Polanyi) over the centuries (Parikh and Renero, 2017). The latin expression *“ipsa scientia potestas est”*, written in Francis Bacon’s *Meditationes Sacrae* in 1597, was known today as “knowledge is power”.

From the view of law literature, knowledge is identified as a broad set of intellectual property rights and cultural resources that encompass the various cultural, intellectual, scientific, and social resources that we inherit, use, experience, interact with, change, and pass on to future generations (Frischmann et al., 2014). At the same time, there has been a wide range of scholars, artists and activists taking information/knowledge as a commons, such as the law scholars (Frischmann et al., 2014), political scientists and neoclassical institutional economists (Ostrom and Hess, 2007).

The authors argue that there are two different ways to understand *commons*, either as a resource or resource system or a property-rights regime. On the one hand, shared resource is also called *common-pool resources,* which is one of the four broad classes of goods with difficult exclusion and high subtractability attributes (Hess and Ostrom, 2007). For the latter, property-rights regime is rather a legal view, talking about the ownership issue. One related example can be the common property, which indicates a jointly owned legal set of rights. For the purpose of our study, we would rather follow the first definition domain. Generally, the term *commons* is applied to assess how a resource may be best managed, involving the rules, decisions, and behaviors people make in groups in relation to their shared resource (Hess and ostrom, 2007). In other words, knowledge is viewed as a resource shared by a group of people that is subjected to social dilemmas (Hess and Ostrom, 2007).

Based on the definition of knowledge from different disciplines, knowledge can be further classified into different forms based on different criteria. Michael Polanyi, a physical chemist, economist and philosopher, is one of the earliest theorists to identify knowledge as either the tacit or explicit (1962). Tacit knowledge is unspoken and hidden, which means that the expertise and assumptions, that individuals develop over the years, may never be recorded or documented. On the contrary, explicit knowledge is explained, recorded or documented.

On the other hand, following the perspective of knowledge commons, Hess and Ostrom (2003) further identified knowledge into the threefold nonhuman and human materials: facilities, artifacts, and ideas. The classification further helped argue why knowledge is non-rivalrous commons, especially with the rise of distributed digital information.

For the purpose of this study, the most important knowledge classification is to be related to environmental and climate change adaptation, thus two types of classification are included. Friedrich Hayek firstly started the classic analysis of the two types of knowledge in 1945. He argued that while we are used to respecting scientific knowledge gathered by experts, the knowledge will only take on the real value in combination with local knowledge. Afterwards, a wide range of scholars especially from resource management further assured the importance of indigenous knowledge under the increasing global challenges of ecosystem degradation and climate change (Mistry and Berardi, 2016).

The relationship between the two types of knowledge is further explored, stemming from two types of exchanges between science-based researchers and indigenous people (Davidson-Hunt and Michael O'Flaherty, 2007). One type of exchange refers to scientists, who carry the technological packages (technologies, methodologies and processes), would improve the welfare of the indigenous society.

Another relationship type considers that researchers extract knowledge from indigenous societies through documentation and its conversion into a form useful for generating profits within commercial markets. They further proposed the necessity of creating a dialogic network that engage researchers and indigenous people as collaborators in the process of knowledge co-production regarding natural resource management, especially considering knowledge as a dynamic process by being formed, validated and adapted to changing circumstances (Davidson-Hunt and Michael O'Flaherty, 2007).

More specifically, when it comes to climate change adaptation, Vink et al. (2013) classified the related knowledge into organized and unorganized forms. On the one hand, organized knowledge usually comes with written or modeled form, such as the IPCC reports that combine climate scenarios with socioeconomic scenarios. On the other hand, unorganized knowledge may be manifested in the forms of learning, sharing knowledge, making sense, framing, or deliberating over the nature of the problem. To be noted, organized knowledge is essentially temporal that can be altered by unorganized forms of knowledge such as learning.

2.2 The relationship among data, information and knowledge

Data, information and knowledge are three terms that closely interlinked with each other, whose relationship has been explored widely by the academia, especially from the information science and knowledge management. Boehlje (1994) differentiates these three terms in the following way that knowledge is a set of the broad-based concepts, theories, principles and models that are necessary to understand a particular phenomenon. Data is more specific than knowledge, which takes form of individual numbers and observations, or individual ideas and concepts. Compared to knowledge and data, information is more context specific and decision focused.

The *data-information-knowledge-wisdom hierarchy* (DIKW) developed by Davenport and Prusak (1998) is one of the most prominent theories, in which they identify and describe the processes involved in the transformation of an entity at a lower level in the hierarchy to an entity at a higher level in the hierarchy (Rowley, 2007). Data was identified as “a set of discrete, objective facts about events” (Davenport and Prusak, 1998; p.2), which are not structured and thus do not convey any meaning. While information is taken as data put in context, which can only be achieved through interpretation and analysis. Furthermore, knowledge is neither data or information. They suggested that knowledge derives from information as information derives from data. As we have mentioned before, knowledge involves the process of action. Therefore, Davenport and Prusak (1998) argued that knowledge is more valuable than data or information because it is closer to action or decision making, which is usually undertaken as a result of available knowledge.

2.3 Knowledge governance

Regarding on knowledge-based process, what is known more often is knowledge management. It refers to the day-to-day actions of using, sharing and managing information, and is shaped by knowledge governance management (Gerritisen et al., 2013). More specifically, it answers questions such as: who sets research questions? whether it is shared and with whom? what are the systems for access? what are the expectations around how decisions or actions should be justified? (Clark et al., 2016; van Kerkhoff and Pilbeam, 2017).

While the term knowledge governance is a relatively new analytical concept, defined as “the formal and informal rules and conventions that shape the ways we conduct or engage in knowledge processes, such as creating new knowledge, sharing or protecting knowledge, accessing it and applying or using it” (van Kerkhoff and Pilbeam 2017; p.30). As explained by van Kerkhoff and Pilbeam (2017, p.32), when stakeholders recognize the structures that shape the knowledge-based process within the cultural and socio-political conditions, it will be easier for them to develop effective knowledge management strategies that enable transformative adaptation.

A further explanation of the knowledge governance framework as a three-layer model is shown in the work of Múnera and van Kerkhoff (2019), including the civic epistemology and knowledge systems. The main knowledge input in the framework is scientific knowledge and its role towards decision-making, also called science-policy interface, while other forms of knowledge as taken as feedback role.

Several challenges have been identified for the knowledge governance in the context of climate change adaptation. To start with, the scientific knowledge on climate change impacts, adaptation, and vulnerability is fragmented, making it difficult to take stock of what is known on climate change impacts, adaptation, and vulnerability as well as to access the knowledge for informing adaptation decision-making and further adaptation research (Hofmann et al., 2011). Currently, some larger scale attempts have been made to synthesize this research-based knowledge, such as the IPCC report, the Millennium Ecosystem Assessment, the reports of the European Environmental Agency (EEA) on climate change impacts, adaptation, and vulnerability in Europe.

But still, these narratives have their limitations. Firstly, they do not give a systematic and quantitative account of what is known about climate change impacts, adaptation, and vulnerability for a specific sector or region. Secondly, a lot of evidence is provided, but not related sufficiently. Third, for a given sector or region, the knowledge presented is often not specific enough. Fourth, the above-mentioned conceptual confusion around the central concepts has not been addressed sufficiently (Hofmann et al., 2011).

Since most adaptation processes were implemented at a local scale, there is a strong need to improve downscaled climate data. By conducting a systematic quantitative meta-analysis of published peer-reviewed documents reporting local indicators of climate change, Reyes-García et al. (2016) found out that if local observations of climate change are reported more frequently, the more useful knowledge regarding impacts on biophysical systems could provide better insights to our understanding of climate change at local scale.

Another challenge that scholars have emphasized is that in some cases, the local municipalities get information from agencies using different values, standards or climate models, which further hinders straightforward communication, collaboration and joint programming due to different types of knowledge, data and work applied by scientists and practitioners. It is thus of great importance to design the basic indicators, standards and knowledge in certain areas such as data of local climate effects, seasonal weather forecasts and trends of extreme weather events (Birkmann and Teichman, 2010).

Furthermore, some important information, such as social and economic census data of dynamic areas with high fluctuations of people and economic instability, which would be essential in order to assess changing vulnerabilities and develop appropriate adaptation strategies, is not available at all. This data has not been sufficiently developed mainly due to lack of costs and appropriate methodologies to forecast societal development at various scales (Birkmann and Teichman, 2010).

Therefore, knowledge or information on these observations and respective findings shall be better shared among all stakeholders, including scientists, practitioners as well as the affected people. A balanced combination of scientific and local knowledge as well as of natural and social scientific data is required. The knowledge exchange must take place, particularly for the community that lacks research support mainly in developing countries and localities (Rosenzweig and Wilbanks, 2010). A central and accessible knowledge management platform can be developed at the international and national level for various state and non-state actors.

Finally, a very important aspect of knowledge is the awareness of the limits of our knowledge. Therefore, it is necessary to take decisions under uncertain conditions and possible surprise, yet possible ways of dealing with the limits of knowledge are not sufficiently discussed between both communities (Birkmann and Teichman, 2010).

2.4 Informational governance

The concept of information governance has been used to govern the information flows among actors for better informed decision-making for the environmental governance issues. The related literature can be traced back to the 1960s, when George Stigler recognized the economics of information and argued that “one should hardly have to tell the academicians that information is a valuable resource: knowledge is power. And yet it occupies a slum dwelling in the town of economics” (p.213).

Afterwards, Castells (1996, p.21) further differentiated between the term information economy and informational economy in the first volume of his trilogy. Information economy indicates the role that information plays in economic processes. Information, in its broadest sense of communication of knowledge, has always been critical in all economies. The collection and generation of information and knowledge, and the communication and exchange of information played an important role in organising markets and economic processes of production and consumption. Informational economy, in contrast, refers to a specific form of social organisation in which information generation, processing, and transmission become the fundamental sources of productivity and power. This notion points at a fundamental transition of the economic order.

Based on Castells' work, Mol (2006, p.501) firstly drew the concept of informational governance in the context of environmental policy and sustainability issues, as "information (and informational processes, technologies, institutions, and resources linked to it) is fundamentally restructuring processes, institutions, and practices of environmental governance, in a way which is essentially different from that of conventional modes of environmental governance".

Inspired by Mol (2006), more scholars recognized the fundamental role of information on governing environmental issues, especially in the Information Age when information shows the centrality in the society. From the work of Soma et al (2016), they further separated the influence of informational governance on environmental governance into two interrelated processes: (i) new form of governing through information; (ii) transformative changes in governance institutions due to the new information flows. Such social transformation refers to how the rise of information technology, flows and networks leads to a fundamental restructuring of governance processes, structures, practices and power relations, enabling multilevel networks with a diversity of independent actors.

However, this transformative role of information is both inspiring and challenging. On the one hand, the increasing information is supposed to inform better decision making through, for example, the hyper-connectivity across the globe, which opens up enormous possibilities for information exchange, knowledge creation, feedback, debate, learning and innovation (Soma et al, 2016). Further, successful information governance shows the transformative capacities for institutional changes due to information flows (Mol, 2006).

On the other hand, scholars showed concern about the massive and messy flows of information and its negative influence. Castells (1996) and Paehlke (2003) both argued about the informational (electronic) capitalism with the growing centrality of information that capital and information collapsed into one each other and became the same thing. Some other studies explored the attribute of uncertainty. Urry (2004) firstly illustrated it as regressive uncertainty so that the more we know, the more uncertainty grows. Mol (2006) further argued that the increasing role of information is not only a cause, but rather a consequence of the growing uncertainties. Ge & Brewster (2016) used the term "meta-ignorance". It usually arises due to questions about the legitimacy and credibility of meta-information, which can be understood as information of information. Together, Ge & Brewster (2016) concluded it into three types of information problems: (i) technical problem with overloaded information; (ii) semantic problem relates to meaning and truth of information; (iii) governance problem relates to the impact of information on human behavior.

Therefore, in order to make the informational institution function well to govern the information flows among actors for better informed decision-making of environmental issues, Ostrom and Basurto (2011) conceptualized information rules as the level of information available to actors about actions and the links between actions and outcomes. It authorized channels of information flow among actors, assign the obligation, permission, or prohibition to communicate to actors in positions at particular decision nodes, and the language and form in which communication will take place.

2.5 The analytical framework

Inspired by the above literature on knowledge governance (van Kerkhoff and Pilbeam 2017), information governance (Mol, 2006; Soma et al., 2016) and information rules (Ostrom and Basurto, 2011), this analytical framework further divides information and knowledge governance into three types of institutional rules regarding information, referred to as *information rules, platform rules* and s*takeholder rules,* shown in Figure1.

With the increasing advances in Information Age, society has been profoundly altered around the world with people and information becoming ever more connected through the development of Information and Communication Technologies (Buys et al., 2009). The traditional role of both science and state actors as the authority has been changed, especially when ordinary people became not only the information receivers, but also the producers (Muller et al., 2015). It further influenced the complexity of knowledge and information flows and their relationship with the stakeholders (Soma et al., 2016), which is further depicted through the development of three types of rules of information/knowledge governance in this framework below.

According to the concept of information rules identified by Ostrom and Basurto (2011), information, stakeholders and their connecting platform are the three key elements interlinked with each other in the information governance. Information without its carrier, the stakeholder, has no practical meaning. In other words, one cannot talk about information without mentioning stakeholders. For each element, there are certain rules that could define its function. Rules are defined in this study as institutional solutions and settings that are developed to address the problems related to the three key elements of information, stakeholder and platform. I further differentiate such rules related to the three key elements into three types, namely *information rules*, *platform rules* and *stakeholder rules*. The information rules focus on the information itself by clarifying the rules that define the quantity, quality, standards and usability of information and knowledge. The focal point of the platform rules underlies the rules that facilitate the channels of the information and knowledge flows among various stakeholders. Last but not the least, stakeholder rules underly the rules that related to the responsibility, obligation and power of each stakeholder,

Based on this framework, I try to identify the type of rules that has been the major focus of each article selected for the systematic review in this study. The major assumption is that information is an inherent attribute of the stakeholder. For example, $S_{1(i1)}$ is referred as stakeholder 1 (S_1) with its inherent information 1 (i1).

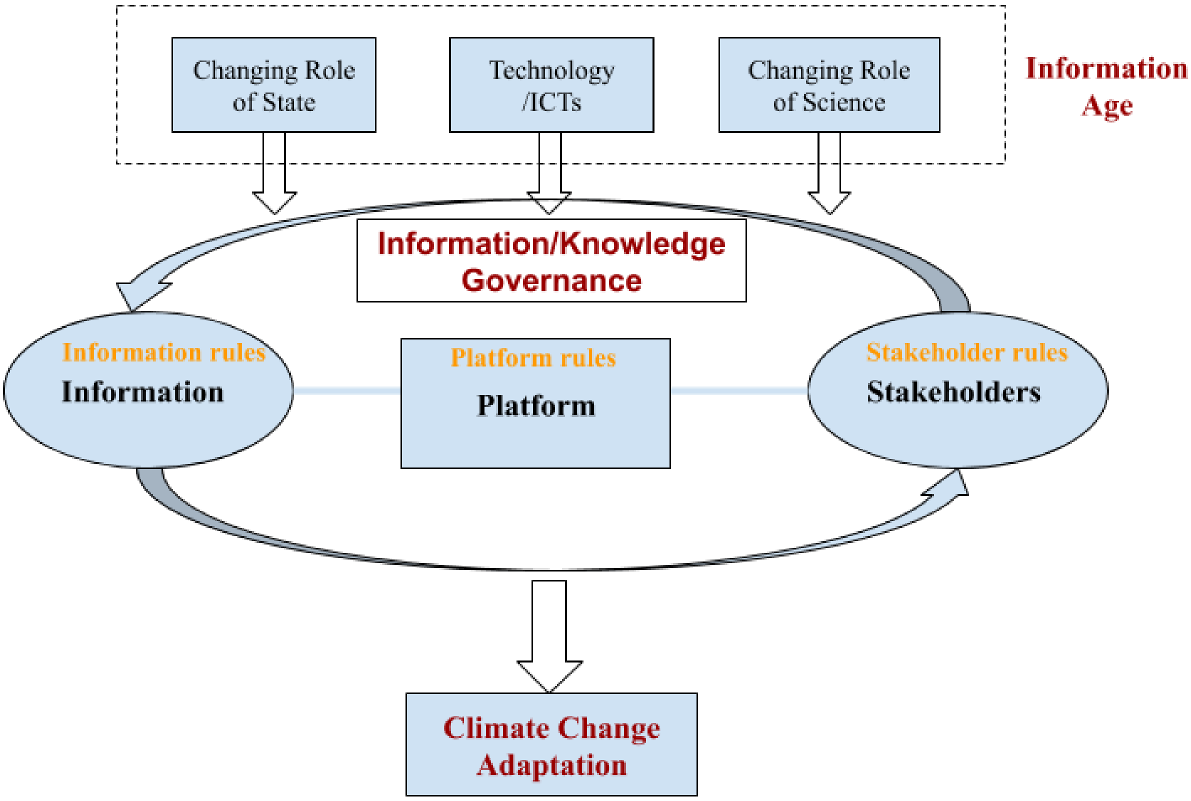

Figure 1: The analytical framework of the information/knowledge governance and climate change adaptation in the Information Age (adapted from the framework developed in the work of Soma et al., 2016)

The following Figures (2, 3, 4) zoom in on the Figure 1 explaining each type of rules correspondingly. For instance, Figure 2 shows the information rules. The center of this type of rule is the information itself, covering articles that would address the questions what the rules regarding the standards, quality, usability, quantity of the information.

While the stakeholder, as a provider of information, remains the same in this case and there is no stakeholder interaction.

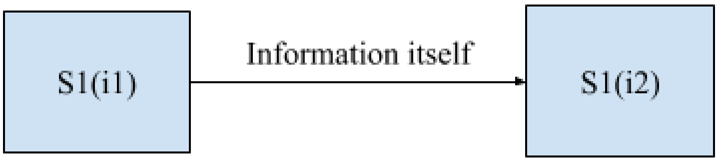

Figure 2: Information rules

Furthermore, Figure 3 shows the platform rules that facilitate the stakeholder interaction, through which the information can be exchanged, disseminated, accessed and integrated. To be noted, during the process, there is no new information being generated through the interaction.

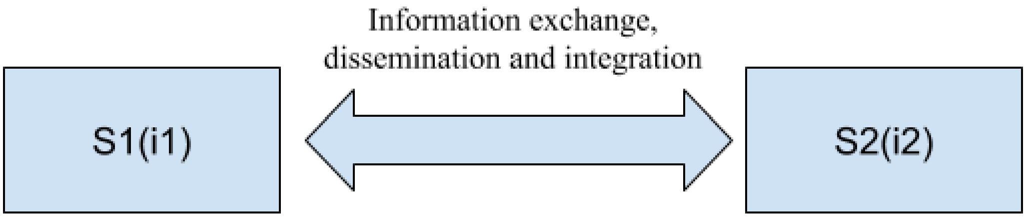

Figure 3: platform rules

Finally, Figure 4 shows the stakeholder rules, whose focal point is the involved stakeholders. It aims to address the question of who is in charge of what, such as who provides information, who collects the information, who disseminates the information, who uses the information. The stakeholder interaction is sometimes inevitable. When it comes to information co-production, we categorize under stakeholder rules since the co-produced information will become the new inherent attribute of the involved stakeholders. Shown in Figure 4, the co-produced new information ($i_{(new)}$) turns into the common information owned by both stakeholders Stakeholder 1 (S_1) and Stakeholder 2 (S_2).

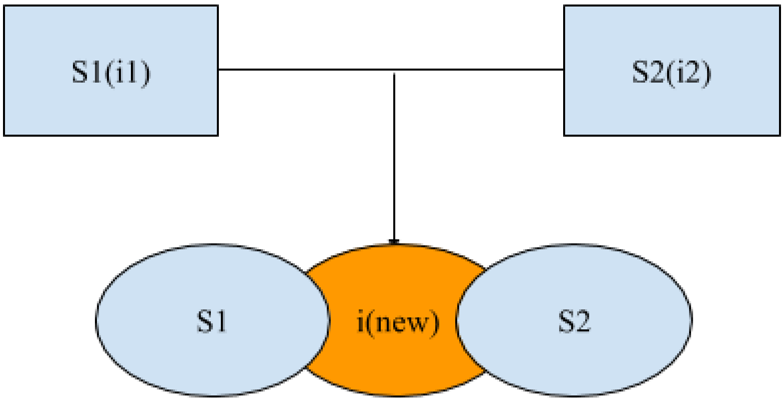

Figure 4: stakeholder rules

3.Methods

Narrative reviews are the most often used type of literature reviews in the studies. However, authors of narrative literature reviews often use informal, subjective methods to collect and interpret studies and tend to be selective in citing reports that reinforce their preconceived ideas or promote their own views on a topic (Akobeng, 2005). Thus, narrative reviews are often criticized as they do not provide a detailed description of the process that led to the review and cannot replicate and verify the results and conclusions of the reviews by the readers. While systematic reviews can overcome such limitations of narrative reviews by providing detailed information of the scientific research process to reduce bias and to allow replication by others (Jadad et al., 1998).

3.1 What are systematic literature reviews?

Conceptually, systematic reviews are a form of research, to synthesize existing knowledge of what is known from the research literature using explicit and accountable methods (Gough et al., 2012). The history of systematic reviews is relatively recent, dominated by the development and application of statistical meta-analysis of controlled trials to synthesize the evidence on the effectiveness of health and social interventions (Berrang-Ford et al., 2015). Such logic of systematic methods for reviewing the literature can be applied to all research scope with the variation of systematic reviews, and the variation occurs in both the method of review and the type of primary studies that they consider (Gough et al., 2012).

Systematic reviews serve for various purposes, including: (i) to aggregate data from controlled trials statistically (Dixon-Woods et al., 2006); (ii) to emphasize the central role of theory in synthesizing existing knowledge (Dixon-Woods et al., 2006); (iii) to address the complexity of interventions (Shepperd et al., 2009); (iv) to highlight the social and paradigmatic context of the research (Greenhalgh et al., 2005).

To clarify the main conceptual distinction and to assist the selection of methods for reviewing, Gough et al. (2012) further proposed three major types of dimensions to identify different dimensions of the variations, including: (i) the aims and approaches of reviews; (ii) the structure and component of reviews; (iii) the breadth, depth, and extent of the work done by a review in engaging with a research issue. Once these aspects are clear, more specific methodological issues can be considered, such as searching, identifying, coding, appraising and synthesizing evidence.

- The aims and approaches of review: Aggregative and configurative reviews are two types of review logics and their distinction was firstly identified by Voils et al. (2008). Aggregative logic means reviews that collect empirical data to describe and test predefined concepts, which are used to make empirical statements to inform decision making. While configurative reviews aim to interpret and understand the world through interpreting and arranging information and developing concepts, which are often applied to develop concepts and enlightenment (Weiss, 1979). More distinctions can be checked from the work of Gough et al. (2012).
- The structure and component of reviews: Three main types of structure are discussed by Gough et al. (2012), including systematic map, mixed methods review and mixed knowledge reviews. To start with, systematic map is the analysis of map that begins with a broad initial review question and follows with a subset of studies in different areas of a map. Scoping review is used to describe maps that examine the nature of the literature on a specific topic area. While mixed methods reviews are designed to apply sub-reviews that ask questions about different aspects of the issue and are more likely to consider different primary research (Thomas et al., 2004). One example is the realist synthesis implemented by Pawson (2006) that examine the usefulness of mid-level policy interventions across different areas of social policy by unpacking the implicit models of change.

In addition, the mixed knowledge reviews use a similar approach but combine data from previous research with other forms of data.

- The breadth, depth, and extent of the work: A research study usually addresses a macro research issue and a specific sub-issue, which is explored by the specific data and analysis. The need for a broader review is raised by complex questions. Strategies to achieve breadth can be through multi-component reviews, such as a broad map and mixed methods review, mega reviews (Smiss and Glass, 1977) or multivariate analysis (Thompson and Sharp, 1999). In addition to the breadth of the review, its depth also worth attention. Considering the time and other resource constraints, a rapid review may be applied, even though the review will be limited regarding the selected sources, coded data, quality and relevance assurance measures and depth of analysis (Abrami et al., 2010).

3.2 The formal systematic review applied in this study

Based on the research for systematic reviews, methods that only apply for quantitative analysis of quantitative data are not suitable, therefore, the methods of meta-analysis, best-evidence synthesis, quantitative comparative analysis are excluded. Considering the research questions of this study, I used the method of formal systematic review.

A formal systematic review is a review in which there is a comprehensive search for relevant studies on a specific topic, and those identified are afterwards appraised and synthesized according to a predetermined and explicit method (Klassen et al., 1998; Cook et al., 1995). Compared to other methods, it has the advantage of its high degree of formal standardization. Except for summarizing existing knowledge and evidence rigorously, this method can identify gaps and new directions for future research and differ from generic literature reviews as well (Ford and Pearce, 2010).

The following are the guidelines for implementing a formal systematic review, mainly based on the work of Jadad et al. (1998) and Klassen et al. (1998):

- Ideally, a formal systematic review involves all the available and relevant trials. Three sources are identified by Klassen et al. (1998), including (i) to scan all records in available bibliographic databases; (ii) to hand search all journals, theses, proceedings, and textbooks that are not indexed in any of the database; (iii) to obtain grey literature that is relevant but unpublished from investigators and/or organizations. However, in practice, due to time and other constraints, reviewers must try the most to identify the maximum number of eligible trails as a representative sample.

- The detailed information of two aspects of the literature search should be covered, including the source being searched and the method used to search them. In order to allow the readers to judge the breadth of the search, the following aspects need to be mentioned as well: the number and names of sources, the date on which they were searched, the period covered by the search. Furthermore, in order to allow the readers to judge the depth of the search, strategies need to be identified to search each source, such as terms related to the condition, or/and terms related to the intervention, or/and terms related to the method of the trials. The Boolean operators, such as AND (to narrow a search) or OR (to broaden the search), can be used to link these terms. On the other hand, for the hand search, it should include a description of the number and background of the searchers. If the review involves the contact with investigators, the method used to contact them and their identities should be provided as well.

In regards of the evaluation of the trial quality, Jadad et al. (1998) and Klassen et al. (1998) pointed out that the final assessment of the comprehensiveness of a literature search is subjective, yet, reviews that include only one source are not likely to be complete. Therefore, in order to retrieve all relevant studies on a topic, several different sources should be included, and the search strategy should not be limited to the English language. Jadad et al. (1998) further suggest that a review with a comprehensive search should use at least three sources and provide a description of efforts to identify unpublished trails. The assessment of the quality of the trial could provide valuable information to reviewers while conducting the systematic reviews and to readers who make their decisions based on the systematic reviews.

To conclude, several rules need to be addressed while using a qualified systematic review, including: (i) to describe the definition of quality clearly; (ii) to discuss the tools, circumstances and methods that are used to obtain the assessments in the review; (iii) to provide enough information to allow the readers to re-evaluate the effect estimates using different approaches (jaded et al., 1998). Ford et al. (2015) further summarize the process of carrying out a systematic review into the following methodological steps:

(1) Define the research question and scope of the study
(2) Select the document based on the inclusion and exclusion criteria

(3) Analyze and synthesize evidence, quantitative and/or qualitative
(4) Present results.

3.3 Database search

The review of key concepts and terms that are relevant for this study has indicated that both knowledge governance and informational governance have the transformative capacities for dealing with environmental issues. However, the term knowledge and information in that context is not well differentiated, but very often used interchangeably. As clarified in the introduction section, I found out that the concepts of information governance and knowledge governance is hardly used together with CCAG in the literature, yet, social, environmental and economic sciences have contributed to the study of this area in their own way with their related terms. Therefore, synonyms and replacement words were identified. Particularly, I referred to the literature that addresses climate change adaptation contexts and explored the links between the new emerging information flows, different forms of knowledge and how these lead to change within and across existing institutions and stakeholders. Accordingly, in this study I systematically explore literature within environmental governance domain to gain more insights into ways by which the Information Age impacts climate change adaptation.

To do so, I identified three main categories of keywords as selection criteria for searching articles in Scopus (more detailed information of the keywords can be found in Appendix 2):

- Environmental studies and climate change adaptation: There has been studies showing interest in exploring informational and knowledge governance in the context of environmental studies generally. For our paper, I would also focus more on climate change adaptation, while still in the scope of environmental studies such as environmental governance, sustainability, water, soil, river, etc. Through the search in SCOPUS, the number of articles exclusively talking about climate change is still limited, most of them are still more generally related to environment and sustainability issues.

- Informational and knowledge governance: While searching for literature with specific terms of “informational governance” and “knowledge governance” in the context of climate change adaptation, not many papers are being selected. It shows that the two specific concepts are not yet widely used. Instead, I found out that many authors have been discussing this topic while using other terms. Furthermore, based on the analysis in the introduction part, I separated the search terms into three sub-categories:

- terms related to informational and knowledge governance
- terms related to the quantity, quality, standards, usability and reliability of data, information and knowledge
- terms related to the production, exchange, dissemination, accessibility, equality of data, information and knowledge

- Information Age: the inclusion of this category is to set up the institutional environment, targeting on the time period when information plays an important role and becomes the centrality of the society.

A systematic database search of peer-reviewed articles was conducted using the electronic Scopus. At the time of 15:48 in 2019-05-11, I searched in Scopus using the search query string with the above keywords and selected in total 466 documents. Beforewards, other trials have been implemented. Considering the concept of information governance was first proposed in 2006, thus I limited the publish year from 2007 to forwards. Furthermore, after excluding (i) the irrelevant subjects such as chemistry, nursing, chemical engineering, physics and astronomy, medicine, computer science; (ii) document type except paper and review; (iii) publication stage that the ones are not yet in press; (iv) languages that are not English, I collected 210 documents of papers and reviews. The search query string of both times can be checked in Appendix 2

For the 210 articles, two times of reading were implemented: (i) I read the title-keywords-abstract in the first time and selected 131 articles that fit more with the topic; (ii) For the second time, I accessed and read the whole script of the 131 ones. It turned out that 11 of them were not accessible and 15 of them do not fit within the research scope, either the topic is non-climate-related, but tourism, urban planning, health librarians, airline, regulatory laws; or the topic is climate-related, but without mentioning data/information/knowledge. Therefore, 105 articles were chosen after discarding the irrelevant papers through the full script reading process.

Among the 105 articles, the first trial of coding was implemented. The literature was categorized into two groups that 77 of them are merely related to climate adaptation and 28 of them are generally related to environmental sustainability topics. Considering the aim of this work is to gain insights on information and knowledge governance for further climate change adaptation, I focused my analysis on the 77 selected articles and used the 28 ones for introduction and comparison material later. The table for coding analysis with the selected articles is attached in Appendix B. To conclude, the several steps involved in the process of data collection are shown in Figure 5 below.

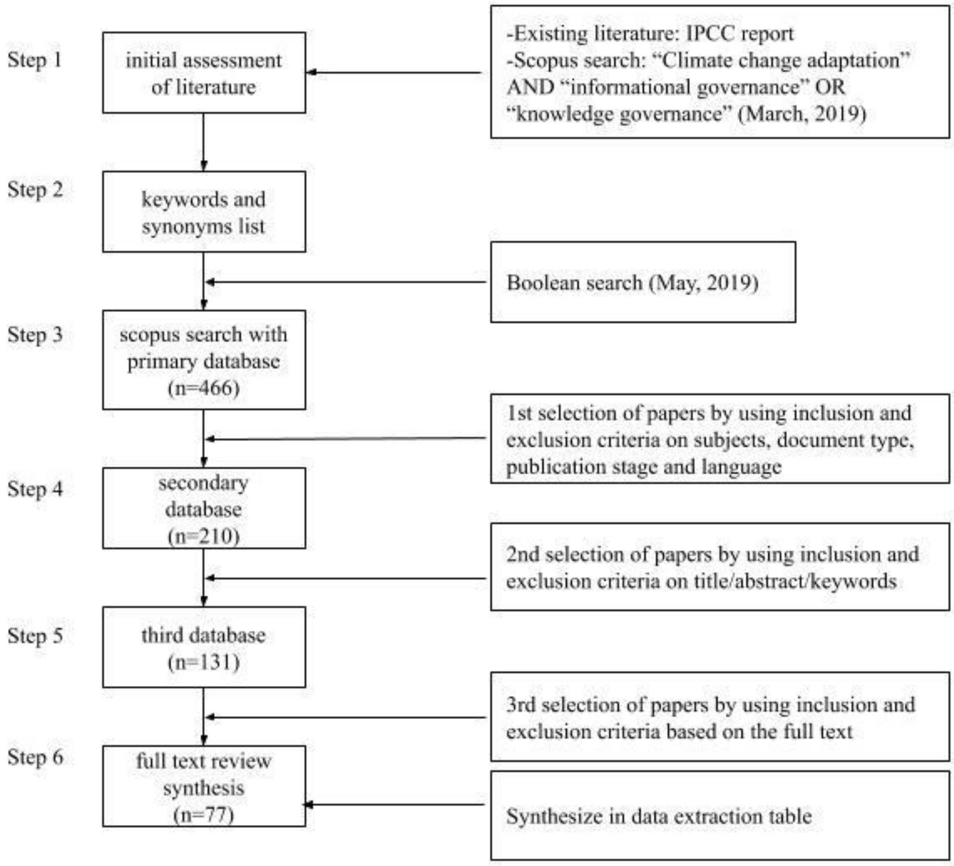

Figure 5: Schematic representation of the systematic review process

4.Results

In this section I present the results of my analysis. First, the use of terms of data, information and knowledge is reviewed, which is followed by the general analysis of selected articles categorised into the three types of rules identified in the analytical framework, namely, the information rules, platform rules and stakeholder rules. Finally, I show the general view of articles in each sector based on the three types of rules.

4.1 The use of data, information and knowledge in the selected literature

Despite the commonly accepted viewpoint of the importance of data, information and knowledge in the context of climate change adaptation, the three terms have been used in the literature rather mixed and interchangeably in different research scope. Considering the ambiguous definitions that were presented in the reviewed articles, I tried to identify how each term has been applied in the selected literature and come up with definitions that I use in this study.

To begin with, data was mainly used in the scope of *information rules*, associated with the development of climate model. However, in many articles no specific concept definition has been provided. The focal point in this literature regarding the data in the climate change adaptation is the improvement of data quality for climate and crop models. Many authors argue that as the main input of climate model, there is a growing need to develop a tool for data digitisation and visualisation in order to understand the hidden pattern of the massive and non-standardised data produced by the ICTs (Tumbo et al., 2018; Liu et al., 2017; Kipling et al., 2016; Rosenzweig et al., 2013).

In addition, the terms of ‘data poverty’ and ‘digital divide’ have been discussed together with ‘information poverty’ in the work of Leidig et al. (2016), yet in their definition they have put data and information in the equal level. Digital divide is generally defined as the gap between those who have good access to computers, digital data and information and those who do not (Van Dijk, 2016). Similarly, information poverty is referred to as the lack of effective and reliable data and information (Baban et al., 2014).

Information and knowledge are the two most mentioned terms in the selected articles, yet not much has discussed the concept of information compared to knowledge. The discussion for the concept of knowledge involves several perspectives. From an epistemological viewpoint, scholars criticize the paradigm of taking knowledge as object, but as an emergent, relational dynamic of social interactions (Rydin 2007; Ison et al., 2007).

From the moral, political and practical perspectives, different knowledge claims are gaining increasing acknowledgement. Back in the 1970s, Lasswell underlined the importance of scientific knowledge for policymaking regarding on complex societal problem, which was perceived as objective and context free (Martin and Richards, 1995). However, its production was limited by qualified official spaces such as universities, with a clear distinction between the knowledge created by the public.

Insights from the sociology of scientific knowledge have challenged such viewpoint that knowledge can be contributed by multiple actors across multiple sites (Soares and Dessai, 2016). In addition to scientific knowledge, other alternative truth claims were proposed to be incorporated, including: (i) the common knowledge, or known as laymen's knowledge, created by citizens (Lievrouw, 2011); (ii) the local and traditional knowledge as an invaluable resource and cultural capital that can play a major role in addressing climate change concerns (Beckford, 2018); (iii) the political argument presented by a responsible politician who represents the will of the people in the democratic society (Bekkers et al., 2018).

Scholars studying the information governance are one of the few scientists that have explicitly addressed the difference between information and knowledge and their interrelations (Mol, 2006; Mol, 2014; Holm and Soma, 2016). Information is understood as encompassing data and knowledge and points to meaningful flow of signs among targeted audiences (Mol, 2008). While Knowledge is seen as the final product of information exchange where analyses allow conclusions to be drawn (Mol, 2014). The literature on non-scientific information flows in the fisheries usually refers to knowledge instead of information, however, Holm and Soma (2016) preferred to use the term "information" in their work. They argued that the focus should be on the transfer of such knowledge to the governance of marine resources, and not on the final product of information exchange.

More explicit definition has been made in my research to clarify the use of these interlinked terms. Following the logic of the *data-information-knowledge-wisdom hierarchy* (DIKW) developed by Davenport and Prusak (1998), the three terms are positioned in the different levels of the hierarchy (Rowley, 2007). Starting with the lowest level of data, it is viewed as "a set of discrete, objective facts about events" (Davenport and Prusak, 1998; p.2), which are not structured and thus do not convey any meaning, thus it does not contribute to the decision making directly. In the context of climate change adaptation, it is suggested to be used in the literature addressing information rules related to climate model. Higher than the level of data, information is taken as data put in context with further interpretation and analysis. The transfer of the information flows among stakeholders is recommended to be the focus when it comes to the use of the term information in the literature of climate change adaptation. Finally, positioned at the highest level, knowledge is closest to the action and decision making, which is usually understood as the result of information exchange. Therefore, unlike the term information applied in the transfer of information to the governance structure, the term knowledge shall be used if the focus of the study is the final decision-making or actions.

Figure 6 below shows the general distribution of the three terms in the selected literature. Both information and knowledge were used more frequently than data, taking up to more than one third of the selected articles. Specifically, the numbers of articles devoted to the term of data, information and knowledge are 8, 28 and 28 for each out of 77 articles in total. The rest 13 ones covered more than one term at least for each.

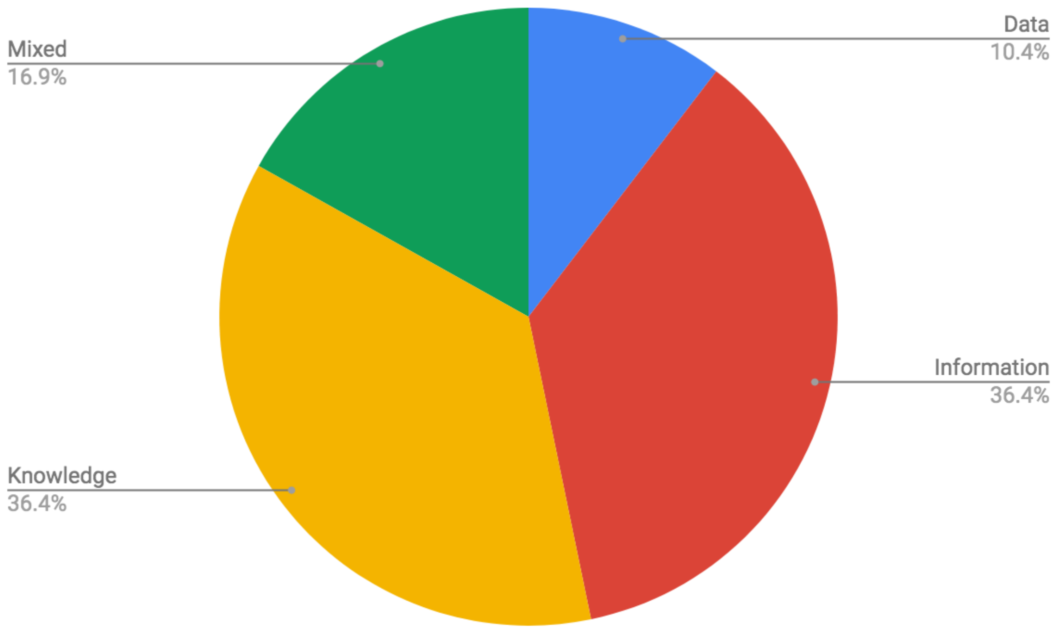

Figure 6: the use of terms related to data, information and knowledge

4.2 The analysis of selected articles based on the three types of rules

Figure 7 below shows the distribution of articles based on the three types of rules, namely information rules, platform rules and stakeholder rules, I identified in the framework. According to the previous definition in the framework, the information rules emphasize on the information itself, clarifying the rules that define the quantity, quality, standards and usability of information and knowledge. The platform rules focus on the rules that facilitate the channels of the information and knowledge flows among various stakeholders. Last but not the least, the focal point of the stakeholder rules is the rules that related to the responsibility, obligation and power of each stakeholder, especially in the aspect of whom is in charge of what.

it is also found out that the distribution is not well balanced among the three types of rules that more than half of the articles fall into stakeholder rules, followed by platform rules and information rules. From the perspective of the number of articles, there are 15, 20 and 42 articles devoted to information rules, platform rules and stakeholder rules respectively. The rest of this section will investigate more into each type of rule, focusing on the examples of the rules that can be identified from the selected literature.

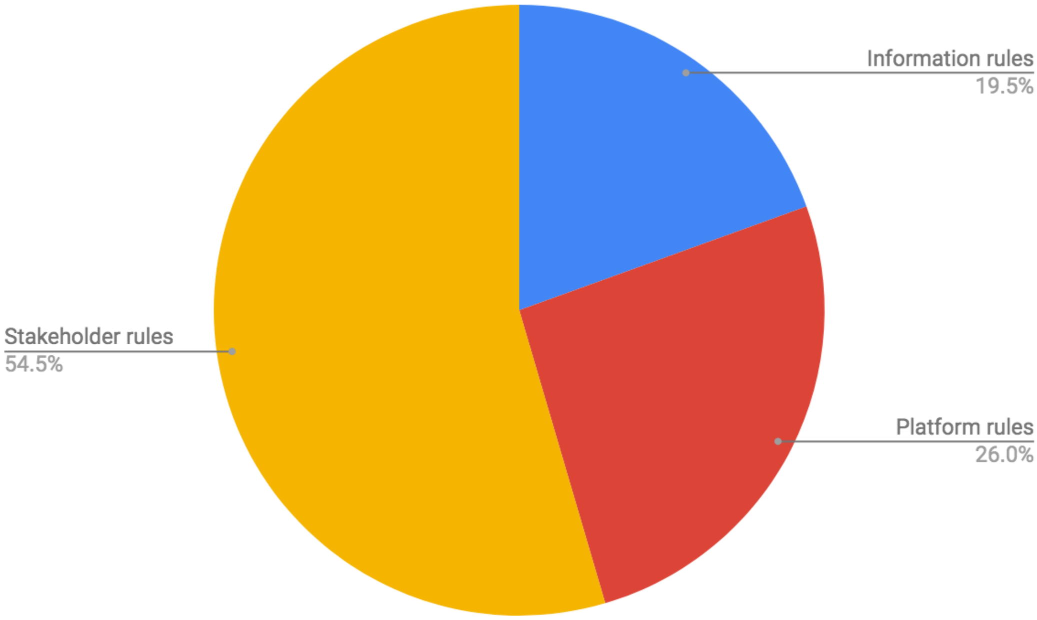

Figure 7: the distribution of selected articles based on three types of rules

4.2.1 Information rules

As presented in the previous section, the information rules underly the information itself, clarifying the rules that define the quantity, quality, standards and usability of information and knowledge. There are three types of information rules identified in this subsection, which will be explained in detail in the following part respectively.

Information rule I: To standardise the lack, quality and format of specific data for climate models.

The first type of information rule is aimed to address the lack and quality of specific data, differences in measurements and data inequality, mainly in the scope of climate modelling in the agriculture sector (Tumbo et al., 2018; Liu et al., 2017; Widener et al., 2017; Kipling et al., 2016; Smith et al., 2015; Ding et al., 2014; Kiem and Verdon-Kidd, 2011) and one article in the land use sector (Brown et al., 2018).

In light of the challenges that climate change has induced, climate models in the agriculture sector have advanced markedly over the past two decades. It can provide valuable insights towards the prediction of both the crop performance under a range of climate conditions and short-term weather and longer-term climate patterns at specific sites with a certain degree of confidence (IPCC, 2007). However, studies have pointed out the incompatibility of climate data and models could hinder the further interdisciplinary collaboration between various nations and research groups (Rötter et al., 2011; Rosenzweig et al.,2013; Kipling et al., 2016; Brown et al., 2018).

A study carried out by Rosenzweig et al. (2013) has identified two types of barriers regarding data for modeling corporation that: (i) in the regions with large spatial heterogeneity the data in general tends to be more sparse, which then leads to unequal representation of the diversity in the datasets among regions; (ii) there is a low adoption rate of shared format through standards and shared language. On the other hand, in the case of European grassland modeling, Kipling et al. (2016) further addresses the data issues that constrained the collaboration among climate modelling communities and experiment workers. For example, (i) there is the lack of information about previous management in relation to data on soil carbon and carbon sequestration, which requires new experimental work to be implemented in the future; (ii) the quality and consistency of existing agricultural datasets for use in crop models needs to be evaluated; (iii) the difference in the way that variables are measured and the way that terminology is used in different research groups; (iv) the data inequality in different regions.

Therefore, there is a growing need for scientific modelling community to develop shared resources of data, models and approaches that are accessible for stakeholders to stimulate the new research (Kipling et al., 2016). Such model development requires the engagement of stakeholders to focus on the gaps in knowledge and opportunities for collaborations. Considering the massive and over-flown amount of data nowadays in the Information Age, there is a growing need to create the high resolution and standardised dataset through ICTs tools such as data digitisation and visualisation so that the scientific community can better communicate with each other (Tumbo et al., 2018; Liu et al., 2017; Kipling et al., 2016; Rosenzweig et al., 2013).

In the case of land use sector, Brown et al. (2018) pointed out that the knowledge diffusion between land managers was to a great extent influenced by information technology. The rapid development of mass communication, digital resources and social media has fundamentally altered communication processes. Generating such knowledge requires the complement statistical data analysis, which, however, is constrained by the lack of relevant data covering long time periods and at high spatial resolution. Thus the authors further addressed the need for the high-resolution remote sensing data, records of public funding to land managers and social survey outcomes (Brown et al., 2018).

Information rule II: To inform better decision-making by relaxing stationary climate model assumption to climate-informed and regionally specific scenarios

Scholars in sectors of disaster management (Mackay et al., 2019; Ding et al., 2014), forest (Bettinger et al., 2013) and water management (Jeffrey et al., 2017; Difrancesco and Tullos, 2014; Kiem and Verdon-Kidd, 2011) have addressed the second type of information rule, focusing on the improvement of climate models to inform better decision-making, by relaxing the simple stationary climate model assumptions.

In the sector of disaster management, Mackay et al. (2019) first pointed out the challenging process of transforming data to information and knowledge for decision-making in climate change adaptation. It starts from the climate projection data, to useful risk-based information, to generate adaptation options and knowledge, especially in the context of different methodologies used in different disciplines at multiple geographic scales.

In regards of disaster simulation model, Ding et al. (2014) introduced an integrated virtual geographic environmental simulation framework, which is capable of automated collecting and imparting of additional raw sensor data into the corresponding simulation model at runtime, in order to overcome the limitations of the passive static data driven simulation model. Studies have shown the improvement of data, model and simulation of disaster management. At the same time, the rising concern in the digitalisation period of the 21st century is the "access challenge" due to the intellectual property rights that make information fragmented and not always accessible (Ding et al., 2014).

In the case of water sector, Jeffrey et al. (2017) proposed to digitize the data applied by each municipal water manager so that researchers can further visualize, join, and represent disparate data to form new interpretations. From the work of Difrancesco and Tullos (2014), they discussed what kind of information system is required to increase the flexibility of water resource adaptation to climate change.

When it comes to decision making, water resource managers have gradually turned to climate models for direction on what to plan for, realizing the necessity of planning for climate change. Despite the wide-spread recognition of the climate model, Kiem and Verdon-Kidd (2011) criticized its limitations and further application in the water resource management practice in the case of Murray-Darling Basin. For example, the climate model is based on the stationary climate assumption that the chance of an extreme event occurring is the same from one year to the next, ignoring the complex physical mechanisms. Also, the most critical factors that drive the extremes are not well simulated by the climate models. Even with sophisticated downscaling or bias correction techniques, the applicability of the models remains to be a serious issue.

Therefore, a further recommendation for future research in the water sector was to focus on the development of climate-informed instead of climate model–reliant, regionally specific, practically useful scenarios that incorporate impacts associated with both natural climate variability and anthropogenic climate change, along with robustly quantified uncertainty estimates (Kiem and Verdon-Kidd, 2011).

Similarly, given advances in technology, software, and data management processes and the increasing demand for an improved quantification of the multiple ecosystem services, the more comprehensive forest models are needed for the decision making. By incorporating natural disturbance regimes and the impacts of invasive species with the traditional forest concerns, Bettinger et al. (2013) suggested the use of simulation models rather than the more popular deterministic mathematical programming models that are often used in forest planning currenyly (i.e. linear programming).

Information rule III: Integrating knowledge from local/indigenous communities with climate science to gain a more complete and accurate information

The third type of information rule pointed out the importance of integrating both local traditional knowledge and scientific knowledge. It has emphasized several perspectives, including the weather forecasting system in the agriculture sector (Loboguerrero et al., 2018; Nyadzi et al., 2018; Loboguerrero et al., 2018; Plotz et al., 2017; Kraaijvange et al., 2016; Soares and Dessai, 2016; Jiri et al., 2015), the disaster management sector in the vulnerable regions such as Carribean communities and The Alliance of Small Island States (AOSIS) (Canevari-Luzardo et al., 2017; Beckford., 2018; McGregor et al., 2018) and the land use sector (Chiang et al., 2014).

In a case from Taiwan, Chiang et al. (2014) found out the land use policy was greatly influenced by the role of culture, which was indicated by the local knowledge of the locals (the Hakka people) and their societal response to environmental change. Similarly, in regard to the weather forecasting system, both traditional and contemporary forecast systems have its pros and cons. For the indigenous system, studies have indicated that the use of Indigenous Knowledge System (IKS) in local communities is an effective way of predicting weather and climate patterns (Jiri et al., 2015). However, a case study in Zimbabwe (Jiri et al., 2015) indicated that although IKS has been used in local farming communities as an effective way to build coping and adaptation strategies, indigenous knowledge is being eroded and is becoming less accurate in seasonal weather prediction. Plotz et al. (2017) further summarized it into two underlying parts: (i) the loss of knowledge due to rapid urbanization with emphasis on western science; (ii) the loss of traditional indicators within the process of changing environment (Plotz et al., 2017).

On the other hand, climate science has advanced markedly over the past decades that it is now possible to predict both short-term weather and longer-term climate patterns at specific sites with a certain degree of confidence (Loboguerrero et al., 2018). The National Meteorological Services (NMSs) from most countries either generate their own seasonal climate forecasts or have access to forecasts produced by other agencies for them, yet, the forecasts often take the form of numerical outputs of percentage chance of above or below normal rainfall or temperature (Plotz et al., 2017). Besides, the contemporary forecast system is usually available at the subnational level and the uptake by local community is rather limited (Loboguerrero et al., 2018). Therefore, there is a growing urgency to integrate both scientific and local traditional knowledge, in order to gain a more complete and accurate information taken up by the local communities.

The following Table 1 below summarises the three examples of information rules in the above context.

Examples of information rules	**Description**	**Reference**
Information rule I (i.e. sector of agriculture and land use)	To standardise the lack, quality and format of specific data for climate models.	Brown et al. (2018) Bosomworth et al. (2017) Kipling et al. (2016) Rosenzweig et al. (2013) Rötter et al. (2011)
Information rule II (i.e. sector of disaster management, agriculture and water)	To inform better decision-making by relaxing stationary climate model assumption to climate-informed and regionally specific scenarios	Mackay et al. (2019) Jeffrey et al. (2017) Ding et al. (2014) Difrancesco and Tullos (2014) Kiem and Verdon-Kidd, 2011
Information rule III (i.e. the sector of disaster management, agriculture and land use)	Integrating knowledge from local/indigenous communities with climate science to gain a more complete and accurate information	Loboguerrero et al. (2018) Nyadzi et al. (2018) Beckford. (2018) McGregor et al. (2018) Canevari-Luzardo et al. (2017) Plotz et al. (2017) Kraaijvange et al. (2016) Soares and Dessai. (2016) Jiri et al. (2015) Chiang et al. (2014)

Table 1: Summary of information rules identified in the literature

Considering the distribution of sectors in the type of information rules, the sector of agriculture, disaster management and water take up the three highest proportions of selected articles among all the six involved sectors, shown in Figure 8 below. On the other hand, both the sector of land use and sea-level rise contributed the lowest proportions, one article out of 15 ones in total for each.

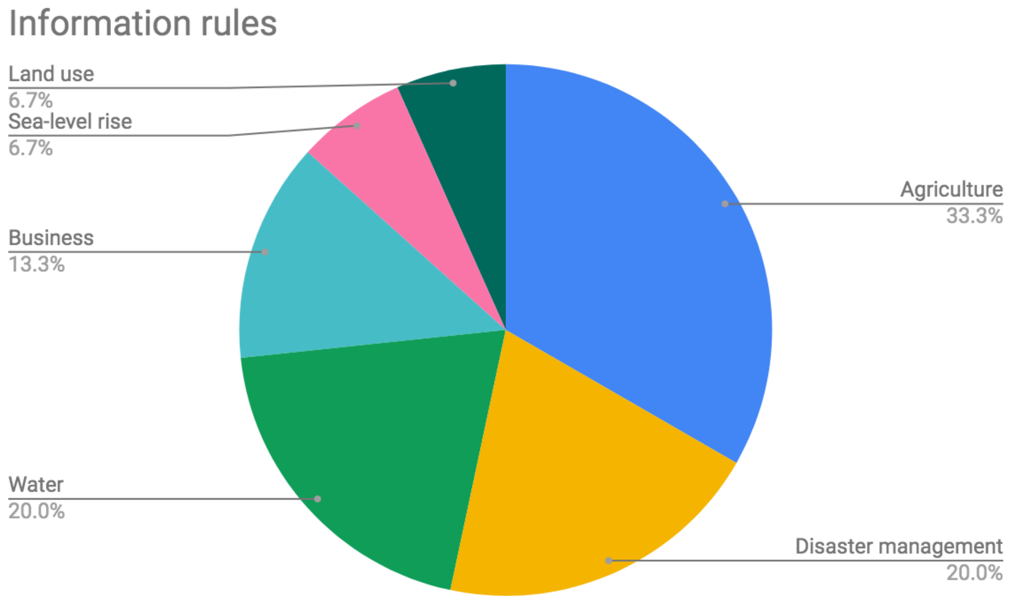

Figure 8: the distribution of sectors for information rules

4.2.2 Platform rules

According to the definition mentioned in the beginning of the sector, the platform rules are understood as rules that facilitate the channels of the information and knowledge flows among various stakeholders. Five types of platform rules in total were identified based on the selected literature.

Platform rule I: to create focused networks in order to facilitate interdisciplinary collaboration between various research groups from local to international levels

This type of platform rule was identified to address the interdisciplinary collaboration between various nations and research groups, mainly in the sector of agriculture. Currently, the good examples for modellers to collaborate, create and enhance the community resources are AgMIP and the Global Research Alliance (Rosenzweig et al., 2013). With the development of ICTs, new approaches have been proposed to facilitate a more joined-up and focused networks among climate modelling communities to communicate and share resources across the organizations and nations worldwide. One Platform such as FLUXNET was developed to share open access data that provide examples of how standardised data collection, processing and delivery can be developed and shared (Baldocchi et al, 2001). Meanwhile, there are online resources or sites being created to share meta-data among researchers for soil at European and global levels

(Kipling et al., 2016). At the same time, a tool for digitalisation and data visualisation is developed to create the high resolution and transparent dataset that can integrate climate and weather data covering a long time period (Tumbo et al., 2018).

Platform rule II: Developing ICTs-based information system with up-to-date and high-quality information to address the accessibility and inclusiveness barrier for broader community

Articles from the sector of agriculture (Loboguerrero et al., 2019; Bernard et al., 2018; Haworth et al., 2018; Mwalukasa et al., 2018; Liu et al, 2017), business (Hasan and Ionescu, 2017) and mountain development (Khezri et al., 2018a; Khezri et al., 2018b) have focused on the second type of platform rule, regarding the transformation of ways that farmers, companies or local communities have access to information.

In the sector of agriculture, it was found out that ICTs has greatly transformed the way that small-holders and family farmers get access to the climate-related information. The traditional top-down agricultural and extension services no longer meet with farmers' information needs (Benard et al., 2018) and the inclusiveness remains an issue since women and other socially and economically marginalised groups usually got excluded from the services (Loboguerrero et al., 2019). Therefore, a series of ICTs-supported platforms have been developed, especially through mobile-based agricultural advisory services, such as Climate Information Services (CIS) (Loboguerrero et al., 2019), Agricultural Geographic Information (AGI) initiative (Haworth et al., 2018), Web-based farmers' advisory information system, mobile-based farmers' advisory information system and agricultural value-added services (Mwalukasa et al., 2018).

Similarly, the selected two articles of the mountain development sector both discussed the information system that can be used by the mountain community for climate change adaptation in Nepal. Both studies aimed to explore the barriers of the Community-based Adaptation Programs (CAP) (Khezri et al., 2018a; Khezri et al., 2018b). They argued that the lack of supportive information on land and climate at the local level is the key constraint, especially when CAPs are usually developed at the national level (Khezri et al., 2018a). In order to facilitate the successful information dissemination, a web-based visualized information system that collected data from data providers and integrated with near real time climate and weather datasets was developed (Khezri et al., 2018b). Such interface provides more up-to-date information than previous ones.

For small business companies, although they are not required to report their GHG emissions like the large businesses, there is a concern among them that it may happen in the future. With the development of ICTs, tools have been developed to collect data that can be further processed into information for monitoring and predicting emissions, which are usually freely available such as Carbon Calculator. In the work of Hasan and Ionescu (2017), considering it is the activities instead of things/products that matter for the environmental footprint, a new information system tool that is low cost and easy to use was developed.

In other words, not only the ICTs platform can provide better information access to farmers or community, it can also integrate data from various providers with near real-time datasets to provide more up-to-date information compared to before (Khezri et al., 2018a).

Despite the rapid application of ITCs on the information access to the end-users, several issues attract our attention. First of all, to improve the use of mobile phones to access information, developers of such mobile-based agricultural advisory services need to consider the socio-demographic characteristics of farmers when developing mobile phone applications (Mwalukasa et al., 2018). Secondly, the research from Baird and Hartter (2017) pointed out that mobile technologies are more often used to support existing farming activities rather than transforming them. Thirdly, by examining 27 AGI initiatives, Haworth et al. (2017) found out that only a small percentage of targeted users of AGI initiatives are using and acting on the information provided, while the majority usually does not have the financial capacity to undertake meaningful change. Last but not the least, the bulk amount of data produced through ITCs has made it more difficult for stakeholders to make well-informed decisions.

Efforts have been made to deal with the above-mentioned issues, such as to create a tool for data visualisation in order to understand the hidden pattern of massive data (Tumbo et al., 2018), or to create a high-resolution dataset to integrate water and climate data that can be further used for agronomic applications in terms of data resolution, quality and continuity (Liu et al., 2017).

Platform rule III: Integrating public e-participation in decision-making through information disclosure and dissemination from social media and other online portals

The platform rule III addressed the role of civil society especially in the sector of disaster management (Albris, 2018; Wehn et al., 2018; Yang et al., 2018; Nahayo et al., 2017), policy making (Geldin, 2019; He et al., 2017) and urban adaptation (Sharman, 2014).

With the development of ICTs, online environment such as online portals and social media have been suggested to be the alternative mechanisms for e-participation (Wehn et al., 2018). Compared to expensive and hardly-understood peer-reviewed journals, social media such as blogs, news media generally have much lower entry barriers, which gives them a unique position as a mediator of public disclosure to disseminate information, raise awareness of and engage the public on climate change adaptation through so-called e-participation (Geldin, 2019; He et al., 2017; Soma et al., 2016; Sharman, 2014). Study has shown that the enhanced information disclosure through ICTs may build trust between various groups and empower marginalised groups in assessments and governance arrangements (Lamers et al., 2016).

In addition to the mediator for information disclosure, social media and other technologies have also been used for information dissemination and public coordination, especially in the disaster management. As indicated by Muller et al. (2015), the public is not only simply the information consumer, but can also be the information provider in the Information Age. The information provided by non-state actors through social media and other digital technologies, such as corporate volunteers (Yang et al., 2018), ordinary people (Albris, 2018), local community (Nahayo et al., 2017), can be of vital importance through the disaster management process. It covers the period of before, during and after the disaster occurrence. Not only do they have the advantage of disseminating information, they can also coordinate and organize collective response efforts of ordinary people to counter the threat of natural hazards. It is further referred to as the switchboard mechanism by Albris (2018), which can facilitate the transformation of online network activities to on-the-ground work by filtering and sorting the flows of communication between those who have the resources to help with those that need them.

Despite the advantage of enhancing public awareness of emergency, as information spread more rapidly and dynamically through online social networks compared to traditional platforms, social media is still criticized by its greater volume of inaccurate and false information spread through the multiplication of information flows, such as the case of Superstorm Sandy in 2012 (Alexander, 2014). Additionally, false alarms and misinformation can lead to panic and unnecessary alarm, leading people to destructive or irrational behavior, even though reality might be much less serious. This happens often in the case of disease or environmental disasters (Albris, 2018). Meanwhile, for those who are not quite familiar with the social media technology, they are being inevitably discriminated and marginalised in this context, falling into the information-poverty or digital divide trap. Moreover, although online virtual portals have been used as platforms for participatory approaches, research shows that it is difficult for participants to build trust among each other, which would further hinder the long-term commitment and high-quality participation (DeLorme et al., 2016; Wehn et al., 2018). A combination of both online and off-line activities is therefore suggested.

Platform rule IV: Promoting polycentricity order in information sharing mechanism at global level in order to facilitate multi-level and local-to-global interactions

The platform rule IV pointed out the role of polycentricity in sharing information at the global level, which was contributed the most by the sector of policy making (Galaz et al., 2016; Galaz et al., 2012; Andonova et al., 2009). Due to the multi-level and local-to-global interactions of climate change, we cannot take for granted that the international institution will emerge, thus the polycentric order (Galaz et al., 2012) and global network (Galaz et al., 2016) are suggested in order to facilitate better information sharing mechanism at the international level. Information sharing is seen as the key components in transnational networks, especially by supporting international actors to adjust their behavior in multilevel settings (Andonova et al., 2009). At the same time, it requires the investment of actors in creating a joint platform for communication and information sharing. The recent development of ICTs has significantly reduced the costs of information collection and dissemination (Galaz, 2009). Data and information from governments and international organizations can be integrated and disseminated through the coordination amongst international organizations and secretariats. Ostrom (1999) argued that polycentricity enables actors to share information on what has worked in one setting, which further ensured the trial-and-error learning processes.

Take the example of the World Health Organisation (WHO) dealing with the infectious disease outbreaks through the polycentric order (Galaz, 2009). In order to rapidly integrate and disseminate information and data from governments and international organizations, the UNEP Global Programme of Action “clearing house” mechanism has been developed together with a suite of additional information sharing mechanisms.

Platform rule V: To facilitate long-term commitment of two-way stakeholders' interaction by combining face-to-face and online participatory approaches

Platform rule V emphasized on creating participatory platforms with two-way stakeholders' interaction, such as between farmers and scientists or among various groups (Kraaijvanger et al., 2016; Pietri et al., 2015; Mitter et al., 2014). It is indicated that the participatory approaches can facilitate a long-term dialogue on climate change impacts and adaptation options among farmers, agricultural extension specialists, researchers, and climate scientists through the learning network and mutual trust (Pietri et al., 2015). Ison et al. (2013) used the metaphor theory to explain how knowledge can be constructed through social learning, which is understood from an epistemological viewpoint that sees knowledge not as an object that can be transferred between people, but as an emergent, relational dynamic of social interactions.

Compared to the face-to-face participatory approaches, ICTs, such as participatory geographic information system (PGIS) and the Environmental Virtual Observatories (EVOs), have been used by stakeholders to exchange, access and evaluate the information through the shared virtual platform. For instance, PGIS were developed to undertake the technical geographic information system aspects of the mapping process by an external facilitator who undertook the technical geographic information system aspects of the mapping process (Beckford, 2018). At the same time, EVOs is developed to enable the creation of the hybrid of different sources of environmental knowledge on web-based virtual platforms, incorporating information gathering, processing and dissemination technologies (Nyadzi et al., 2018). Although being part of the virtual system creates a sense of ownership among participants, it can be too time-consuming of providing regular data and information, which might further discourage long-term participation. As pointed out by Nyadzi et al. (2018), the limited commitment of participants can potentially reduce data availability and quality, thus the intensive collective interaction of scientists and other stakeholders from common ground is of vital importance.

The following table 2 presents an overview of the identified five types of platform rules in different sectors, including the involved sectors and general description.

Examples of platform rules	Description	Reference
Platform rule I (i.e. sector of agriculture)	to create focused networks in order to facilitate interdisciplinary collaboration between various research groups from local to international levels	Tumbo et al. (2018) Kipling et al. (2016) Rosenzweig et al. (2013)
Platform rule II (i.e. sector of agriculture, business and mountain development)	Developing ICTs-based information system with up-to-date and high-quality information to address the accessibility and inclusiveness barrier for broader community	Loboguerrero et al. (2019) Haworth et al. (2018) Mwalukasa et al. (2018) Bernard et al. (2018) Khezri et al. (2018a) Khezri et al. (2018b) Baird and Hartter (2017) Ndumbaro and Mutula (2017) Hasan and Ionescu (2017)
Platform rule III (i.e. sector of disaster management, policy making and urban adaptation)	Integrating public e-participation in decision-making through information disclosure and dissemination from social media and other online portals	Geldin (2019) Albris (2018) Yang et al. (2018) Nahayo et al. (2017) He et al. (2017) Sharman (2014)
Platform rule IV (i.e. sector of policy making)	Promoting polycentricity order in information sharing mechanism at global level in order to facilitate multi-level and local-to-global interactions	Galaz et al. (2016) Galaz et al. (2012) Andonova et al. (2009)
Platform rule V (i.e. the sector of agriculture)	To facilitate long-term commitment of two-way stakeholders' interaction by combining face-to-face and online participatory approaches	Beckford (2018) Nyadzi et al. (2018) Kraaijvanger et al. (2016) Pietri et al. (2015) Mitter et al. (2014)

Table 2: Summary of platform rules identified in the literature

In regards of the number of articles devoted to the platform rules, there are in total 20 articles covering six sectors being selected, shown in Figure 9 below. Similar to information rules, both the sector of agriculture and policy making attracted more than half of the total selected ones. The focal point of this part is to develop Information

Systems (ISs) that could facilitate stakeholder interaction, where information and knowledge can be better disseminated, exchanged and integrated.

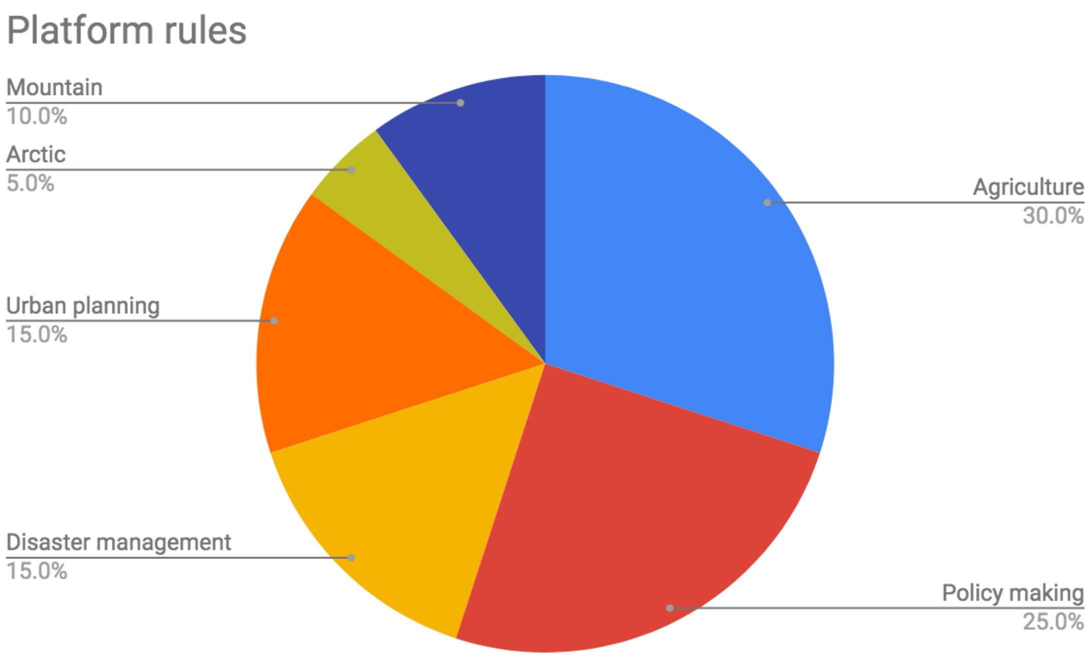

Figure 9: the distribution of sectors for platform rules

4.2.3 Stakeholder rules

Before proceeding to the examples of stakeholder rules found in the selected literature, I would like to address the various stakeholder interactions identified based on the articles, since stakeholders involved in climate change adaptation are diverse but interlinked with each other. There are in total four types of stakeholder interactions, including interaction between (i) scientific community and farmers/local community, (ii) scientific community and policy makers, (iii) citizens and policy makers, (iv) multiple stakeholders.

The first two types of stakeholder interaction attracted the major attention in the literature. There are in total 17 articles devoted to the integration of knowledge from both the scientific community and farmers/local community, especially in the topic of weather forecasting system in the sector of agriculture (Loboguerrero et al., 2018; Plotz et al., 2017; Soares and Dessai, 2016; Jiri et al., 2015). It is found that farmers care about most of the acquisition of technical knowledge and they are required to prepare in advance for the meeting (Kraaijvanger et al., 2016). One case study in Columbia showed that to bridge the gap between climate science and farmers, both sides need to put on efforts while communicating their knowledge and information to each other through the participatory process (Loboguerrero et al., 2018). For example, the scientists had to downscale the complexity of scientific knowledge in the way that everyone could understand. While the local participants learned to make their local tacit knowledge explicit to be included in the discussions with the scientists.

Similarly, the interaction between the scientific community and policy makers is another focal point in this research domain with 18 articles fell into this category. Bridging the usability gap between the information providers and the end-users is one of the major topics, especially when it comes to the sector of water, arctic and urban adaptation (Kiem et al., 2016; van Stigt et al., 2015; Astles, 2015; Kiem et al., 2014; Kiem and Austin, 2013; J. G. Timmerman et al., 2010). With the technology development of the smart software application, policy makers are expected to adapt to such technological changes with large datasets and more complicated models and to be informed with better decision making (Bettinger et al., 2013; Vacik and Lexer, 2014). Thus, there is an increasing call for knowledge brokers to facilitate communication as the technical and discipline translators (van Stigt et al., 2016; DeLorme et al., 2016).

Unlike the previous two types of stakeholder interaction, the literature exploring the connection between the citizen and policy makers is relatively less, mainly focusing on the sector of disaster management (Chatfield and Reddick, 2018; Mejri et al., 2017; Kelly et al., 2012). Specifically, there is a growing transformed viewpoint that citizens are not only the information consumers, but also the providers (Muller et al., 2015). In the case of disaster management, together with the effort from the government, the more informed decisions can be made when non-state actors of corporate volunteers or ordinary people can provide real time information through online platforms.

Additionally, there are four other articles aiming to engage all stakeholders, including administrative, private and civil society actors (Wehn et al., 2018; Termeer and Bruinsma, 2016; Schenk et al., 2016; Collier et al., 2013). The approaches such as joint-fact finding practice (JFF), online portals and other web-based technologies have been applied to facilitate the collaborative stakeholder engagement and integrate knowledge claims from various stakeholders.

Figure 10 below try to include the above-mentioned information and knowledge flows among stakeholder interactions identified in the selected literature.

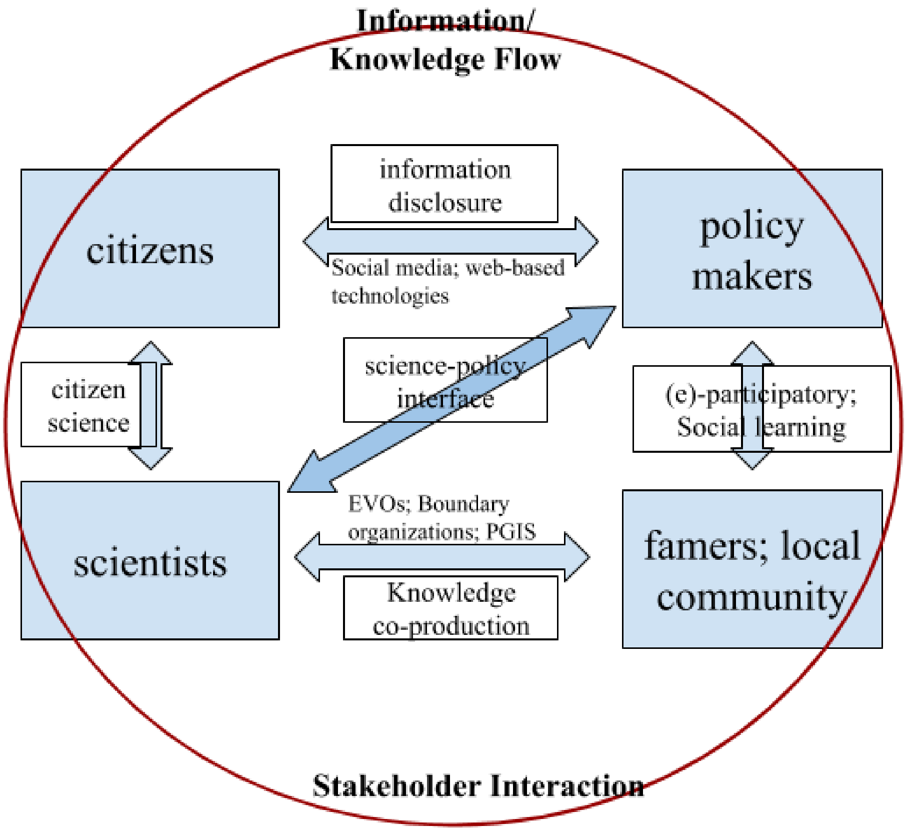

Figure 10: the information and knowledge flow among the stakeholder interaction

Recalling to the previous section discussing the analytical framework, stakeholder rules are defined as the rules that related to the responsibility, obligation and power of each stakeholder, especially in the aspect of whom is in charge of what. Similar to information rules, there are three types of stakeholder rules found out in this subsection as well.

Stakeholder rule I: employing the information brokers to address the usability gap between information providers and end-users.

The first type of stakeholder rules regarding the usability gap is one of the major topics that have been addressed by the literature, especially when it comes to the sector of water (Kiem et al., 2016; Kiem et al., 2014; Kiem and Austin, 2013; J. G. Timmerman et al., 2010), policy making (Bettinger et al., 2013; Vacik and Lexer, 2014), arctic (Astles, 2015), forest (Bettinger et al., 2013; Vacik and Lexer, 2014), business (Stechemesser et al., 2015), sea-level rise (DeLorme et al., 2016), fishery (Nguyen et al., 2017) and urban adaptation (van Stigt et al., 2016).

Despite the significant advances made in the climate science and adaptation field, as well as the science-policy-practice interface, translating scientific knowledge to robust and successful climate change adaptation policy or decision making remains a challenge. Numerous studies have been devoted to investigate the underlying barriers (Harjanne, 2017; Kiem et al., 2016; Kiem et al., 2014; Kiem and Austin, 2013; Timmerman et al., 2010), summarized as: (i) the uncertainty in science was not well communicated, but used as an excuse by end-users to do nothing; (ii) the misuse and misunderstanding of key terminology; (iii) instead of the lack of scientific information/knowledge as a barrier (Hart et al., 2012), it is the packaging of information that is consistent, legitimate, credible and useful for end users and decision-makers. As Harjanne (2017) pointed out, more information does not always lead to better decisions. Seeking for more information can thus lead to analysis paralysis where actions keep being delayed as more information is gathered or expected; (iv) the cognitive bias that there is a difference in end-users' view of available climate information depending on the type of decisions they are using the information for; (v) the conflicts between social, political, environmental and economic drivers. Furthermore, in regard to the technology development, the smart software application and climate models and tools have been enhanced largely by science, especially in the forest sector. The induced challenge is how can policy makers adapt to such technology changes with large dataset and complicated models and informed with better decision making (Bettinger et al., 2013; Vacik and Lexer, 2014).

By recognizing the epistemological difference between the two groups on what useful and salient information is, there is a call for boundary organizations to facilitate a two-way communication as the technical and discipline translators, focusing on the trans- and multi- disciplinarity co-production of knowledge. The term of boundary organizations is also referred as knowledge networks, information brokers and information intermediaries in the literature (Mitter et al., 2014).

The experience of one main author working as both a scientist and a policy-maker in Brazil indicated that the performance of boundary workers in the science-policy interface not only requires an ability to bring 'truth to power', but also the capacity to sense, anticipate and avoid political obstacles (Nunes, 2016). McGregor et al. (2018) emphasized the role of local small NGOs from the small state, who has been seen as the "voice in the political arena" by the Alliance of Small Island States (AOSIS) that bring many sources of expertise within and outside the country to bear on the work that they do. In the sector of business, the Environmental Consultancy Firms (ECFs) were created to develop environmental solutions and ensuring implementation and compliance by providing particular knowledge, management, and assessment skills (Stechemesser et al., 2015). Meanwhile, as the connection between the private and public actors, boundary workers can help scientists to frame questions and evaluate the feasibility of environmental management solutions to avoid political obstacles, leading to the co-production of new expertise and contribute to climate change governance by promoting collaborative efforts (Nunes et al., 2016; Bouteligier, 2011). To further bridge the gap, van Stigt et al. (2016) reversed the perspective and try to understand how local decision-makers perceive the use of scientific knowledge in decision-making of urban planning.

However, to implement the successful resource management in a variable and changing climate, it requires more than simply translating scientific knowledge into practical knowledge. There are multiple other issues that need to be considered such as the existing political situation (local, state and national), the costs and benefits of various adaptation options, demographics, social and cultural issues and historical and current controversy associated with some water resource management strategies (Kiem et al., 2016). By applying a sociological knowledge-action framework, Nguyen et al. (2017) found out that the perceived uncertainties and unclear relevance of telemetry findings by managers are the primary barriers for incorporating telemetry-derived knowledge into fisheries management practices. Thus, despite the academic and theoretical importance of contributions of these papers, the fact that successful implementation in practice is rare, has been a subject of criticism (Kiem et al., 2016).

Stakeholder rule II: multi-disciplinary knowledge co-production through collaboration and communication that facilitate social learning and mutual trust among various stakeholders

The second stakeholder rule regarding knowledge co-production among various stakeholders involves the sector of agriculture (Loboguerrero et al., 2018; Kraaijvanger et al., 2016; Pietri et al., 2015) , policy making (Bekker et al., 2018; Buizer et al., 2011), arctic (Astles, 2015), fishery (Holm and Soma, 2016) and urban adaptation (Carter et al., 2015; Collier et al., 2013).

The current literature is predominantly focused on the inclusion of traditional environmental knowledge of indigenous groups in science-driven resource management process, as well as empowering the role of local indigenous communities in the governance process (Dowsley and Martha, 2009). Similarly, there is consensus within academia that adaptive governance functions the best when diverse networks of actors cooperating to co-produce knowledge on resource conservation dilemmas, especially through mutual understanding and social learning process (Pulsifer et al., 2014). Rathwell et al. (2015) empathized the moral, political and practical motivations to connect various stakeholders with diverse knowledge systems from the theoretical perspective.

Meanwhile, the competing truth claims from various stakeholders have great influence on the policy agenda, especially when science is no longer considered the only legitimate knowledge base for policy agenda (Bekker et al., 2018; Buizer et al., 2011). For example, Lievrouw (2011) introduced the so-called ‘commons knowledge’ reservoirs created by citizens, also called the laypeople, therefore known as the “laymen’s knowledge”. Meanwhile, from the political view, political arguments shall be considered as equally valid as scientific knowledge since the beliefs and viewpoints of the responsible politicians represent people in a political community (Bekkers et al., 2018). Similarly, Edelenbos et al. (2011) suggested that in order to produce socially robust, policy relevant, and scientifically valid knowledge, three types of knowledge from three groups of stakeholders shall be integrated, namely: practical (or stakeholder, non-scientific), bureaucratic (or administrative), and scientific knowledge in the context of climate change adaptation. On the other hand, Schenk et al. (2016) pointed out another selection criteria for the participants, who should either be those that are most astute technically and those that have the authority, or representatives from different levels of each organization or constituency.

In order to facilitate good stakeholder involvement after selection, a number of initiatives for mutual learning and knowledge co-production have been proposed, including the learning network that could facilitate a long-term dialogue on climate change impacts and adaptation options between farmers, agricultural extension specialists, researchers, and climate scientists (Pietri et al., 2015). Meanwhile, in a case study of the development of the fishery sector in Europe, Holm and Soma (2016) found out that the successful integration of knowledge by scientists and fishers fully depends on one context dependent factor, namely trust. The conditions facilitating the development of trust in environmental governance are recommended as core themes for future research on informational governance.

In the case of the participatory interaction between farmers and scientists, It was found out that farmers care most of the acquisition of technical knowledge and they are required to prepare in advance for the meeting (Kraaijvanger et al., 2016). One case study in Columbia showed that to bridge the gap between climate science and farmers, both sides need to put on efforts while communicating their knowledge and information to each other through the participatory process (Loboguerrero et al., 2018). For instance, the scientists had to downscale the complexity of scientific knowledge in the way that everyone could understand, while the local participants learned to make their local tacit knowledge explicit to be included in the discussions with the scientists.

Similarly, in the sector of urban adaptation, stakeholder rule II was addressed by investigating how various actors, including urban communities, decision makers and researchers, can be involved in decision-making so that the collaboration and participation can improve the adaptive capacity of urban area (Carter et al., 2015; Collier et al., 2013). In the meantime, in order to implement the marine ecosystem-based management at regional and small spatial scales, Astles (2015) suggested a scientifically based and transparent process to engage all actors who need to be involved in addressing the issues raised by Ecological Risk Assessments (ERAs), including researchers, managers, stakeholders, communities, and government advisors.

Stakeholder rule III: to address the power imbalance among the various stakeholders

The sector of arctic contributed the most to this type of stakeholder rule, by investigating the role of environmental information and its access by various empowered groups when it comes to Arctic marine governance (Lamers et al., 2016). Information was identified as having either the enabling or constraining role. It is called enabling when it facilitates desired changes and cooperation between actors, while referred as constraining when the rapid information progress causes adverse consequences such as information overload, or the inability to guarantee the reliable information from the poor-quality ones (Lamers et al., 2016).

The issue of digital divide comes along as well. With varying capacity to access and deal with information, the already existing power imbalance can be unintentionally reinforced. Take the example of the market-based fish certification scheme operated by the Marine Stewardship Council (MSC) in the Russian Barents Sea (Gulbrandsen and Hønneland, 2014). It appears that MSC mainly benefits large certified fishing companies compared to Coastal fisheries, who are left out of the system due to the limited knowledge of MSC-related information. In that case, the powerful actors therefore have more opportunities to further empower themselves through information (Holm and Soma, 2016).

At the same time, the rising concern in the digitalisation period of the 21st century is the "access challenge" due to the intellectual property rights that make information fragmented and not always accessible by all the stakeholders (Ding et al., 2014). The Table 3 below summarizes the three types of stakeholder rules.

Examples of stakeholder rules	**Description**	**Reference**
Stakeholder rule I (i.e. the sector of water, policy making, arctic , forest, business, sea-level rise, fishery and urban adaptation)	Employing the information brokers to address the usability gap between information providers and end-users	McGregor et al. (2018) Nguyen et al. (2017) DeLorme et al. (2016) Kiem et al. (2016) Stigt et al. (2016) van Stigt et al. (2016) Stechemesser et al. (2015) Astles (2015) Kiem et al. (2014) Vacik and Lexer (2014) Kiem and Austin (2013) Bettinger et al. (2013) J. G. Timmerman et al. (2010)
Stakeholder rule II (i.e. the sector of agriculture, policy making, arctic, fishery and urban adaptation)	Multi-disciplinary knowledge co-production through collaboration and communication that facilitate social learning and mutual trust among various stakeholders	Bekker et al. (2018) Loboguerrero et al. (2018) Kraaijvanger et al. (2016) Carter et al. (2015) Pietri et al. (2015) Mitter et al. (2014) Collier et al. (2013) Buizer et al. (2011)
Stakeholder rule III (i.e. the sector of arctic)	To address the power imbalance among the various stakeholders	Lamer et al. (2016) Holm and Soma (2016) Gulbrandsen and Hønneland (2014)

Table 3: Summary of stakeholder rules identified in the literature

In addition to the three types of stakeholder rules identified above, Figure 11 below shows the distribution of various sectors in the scope of stakeholder rules. In contrast with the information rules and platform rules discussed before, there are more sectors (eleven) covered by the stakeholder rules. The sector of policy making takes up the highest proportion with around 20%. Despite the small proportion ones constrained by its limited number of selected articles, such as the sector of land-use, sea-level rise, fishery and arctic, the other sectors of agriculture, policy making, disaster management and water are more or less distributed in an equal way.

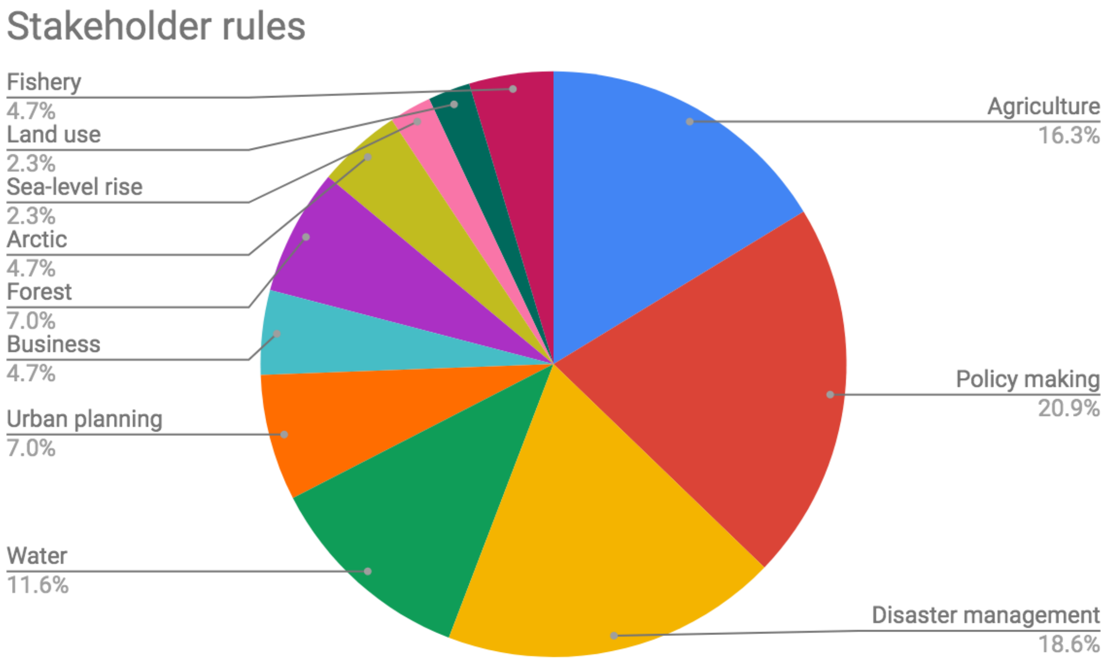

Figure 11: the distribution of sectors for stakeholder rules

4.3 The analysis of selected articles in each sector based on the three types of rules.

Climate change impacts many different sectors. The emphasis of the research varies with each other for different sectors. For example, agriculture is one of the most affected sectors by climate change (IPCC, 2007; FAO, 2008). Initiatives to develop and promote new varieties, breeds, and populations that are adapted to the abiotic and biotic stresses are underway around the world. In the context of the improvement of crop varieties, crop-climate models can be used as a tool to accelerate the development of crop germplasm adapted to future climates (Challinor et al., 2018). Access to such information for farmers, especially small-holder and family farms is of vital importance. On the other hand, when it comes to urban adaptation, despite the relatively new topic, significant advances have been made over recent years in policy, practice and research on climate change adaptation more broadly, and in urban areas specifically (Carter et al., 2015). Observations have shown that cities often suffer from weather and climate hazards, such as the Europe's 2003 heat wave that mostly impacted Paris, the Elbe floods of 2002 and the implications of drought conditions for Barcelona in 2008 (EEA, 2012).

In addition to the sector of agriculture and urban adaptation, various other sectors, such as disaster management, water, forest, Arctic, business have been discussed as well when it comes to climate change adaptation. There are in total 12 types of sectors identified in the selected articles. Figure 12 below shows the number of articles distributed among various sectors, ranging from 2 to 18 articles for different sectors. It indicates that the agriculture sector attracted the most attention compared to others in academia, covering 18 articles in total. In addition to agriculture sector, the sectors of policy making and disaster management are two of the popularly mentioned ones as well. On the other hand, the sectors of forest, arctic, mountain development, sea-level rising, land use and fishery covered merely two or three articles for each. Regarding the distribution of three types of rules identified in the framework, each sector got its focus and distributional pattern. For instance, only the selected articles from the sectors of agriculture and disaster management covered all three types of rules, while the ones from the sectors of forest and fishery merely focused on the stakeholder rules and the mountain development sector was devoted only to the platform rules. As to the other sectors, they all covered two types of rules.

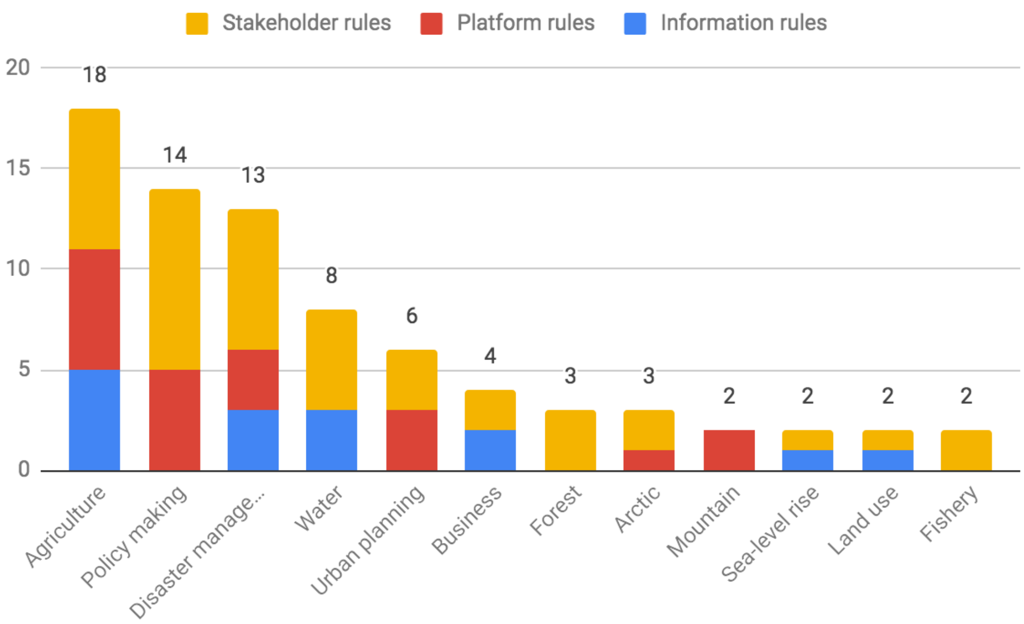

Figure 12: the number of selected literature by sector

5.Discussion

The section of discussion will be presented in two major parts. I will firstly recall the background of this study, including the research questions, objectives, methodology and analytical framework, followed by the major findings of the work. Specifically, the findings are presented in the context of four aspects related to: (i) the content of the rules identified in the literature; (ii) the distribution of the rules identified in the literature; (iii) the external environment of Information Age identified in the analytical framework; (iv) the use of the interlinked terms of data, information and knowledge in the context of climate change adaptation.

The background: research questions, objectives, methodology and analytical framework.

With the development of Information and Communication Technologies (ICTs) in the Information Age, society has been profoundly altered all around the world, with people and information becoming ever more connected (Buys et al., 2009). Such transformation of information and knowledge flows and their relationships with stakeholders started to be noticed by scholars in the field of environmental governance (van Deursen and van Dijk, 2014; Mol, 2006; Mol, 2008; Soma et al., 2016).

This study used a formal systematic review approach to investigate the transformative role of information and knowledge governance on climate change adaptation in the Information Age. Two major research questions related to the use of interlinked terms and three types of rules were proposed, as follows: (i) how the interlinked terms of data, information and knowledge have been defined in the literature? (ii) how the information rules, platform rules and stakeholder rules have been defined in the context of climate change adaptation in the Information Age?

To answer the above research questions, a formal systematic review was implemented in this study to assess the current state of information and knowledge governance in the adaptation literature. As relatively new analytical concepts, both terms of knowledge governance and information governance have not been explicitly applied in the literature, yet other similar terminologies and concepts have been widely contributed by social, environmental and economic sciences in the literature. Therefore, synonyms and replacement words within three main categories of keywords were identified through the database search process in the section of methods. In total there were 77 peer reviewed articles in English, selected for the research synthesis through the Scopus search, with the period limitation of year 2007-2019. All findings and conclusions were therefore restricted to the limited time period and the accessibility of the publications. It is possible that earlier studies and/or grey literature and/or non-English qualified publications might contain information with potential to fit into some of the knowledge gaps identified in this study.

Furthermore, to capture the emerging societal changes arisen from the Information Age in the context of climate change adaptation, an analytical framework, embedded with three types of rules, namely information rules, platform rules and stakeholder rules, was developed to assess the articles selected from the systematic review. Recalling the definition explained in the previous section, rules in this study are understood as the institutional solutions and settings that are developed to address the problems related to the three key elements of information, stakeholder and platform in the information and knowledge governance. Specifically, the information rules underly the information itself, clarifying the rules that define the quantity, quality, standards and usability of information and knowledge. The platform rules focus on the rules that facilitate the channels of the information and knowledge flows among various stakeholders. While the focal point of the stakeholder rules is the rules that related to the responsibility, obligation and power of each stakeholder.

Findings related to the content of the rules in the information and knowledge governance

One of the major contributions of this study is the identification of the specific rules regarding information, platform and stakeholders through the systematic review of the selected literature. Specifically, there are three types of information rules, five types of platform rules and three types of stakeholder rules. Each rule has its focus while tackling the research questions.

Firstly, to answer the research question of what are the rules that define the content, quantity, quality and standards of information and knowledge, I address the identified three types of information rules. Specifically, the information rule I aims to define the standards, quantity and equality of data in the scope of climate modelling in both sectors of agriculture and land use. The information rule II focuses on rules that could improve the quality of the climate model by relaxing the stationary assumption to climate-informed and regionally specific scenarios, which would further help inform better decision-making. At last, the information rule III is related to the rules that would gain a more complete and accurate information by integrating knowledge from local/indigenous communities with climate scientific communities.

Secondly, as to the research question of what are the rules that facilitate the information and knowledge flows among the stakeholders, five different rules were identified correspondingly. For instance, the platform rule I intends to create focused networks in order to facilitate interdisciplinary collaboration between various research groups from local to international levels. The platform rule II focuses on Developing ICTs-based information system with up-to-date and high-quality information to address the accessibility and inclusiveness barrier for broader community. The platform rule III aims to integrating public e-participation in decision-making through information disclosure and dissemination from social media and other online portals. The platform rule IV refers to promoting polycentric order in information sharing mechanism at global level, in order to facilitate multi-level and local-to-global interactions. Last but not the least, the platform rule IV is connected to the rules that facilitate long-term commitment of two-way stakeholders' interaction by combining face-to-face and online participatory approaches.

At last, in regard to the stakeholder rules, three types of rules were identified to answer the research question of what are the rules that address the involvement, responsibility, obligation and power of the involved stakeholders in the process of climate change adaptation. To start, the stakeholder rule I discusses the employment of the information brokers to address the usability gap between information providers and end-users. Meanwhile, the stakeholder rule II focuses on the variety of multiple stakeholders. The multi-disciplinary knowledge is co-produced through collaboration and communication that facilitate social learning and mutual trust. Last but not the least, the stakeholder rule III aims to address the challenge of power imbalance among the various stakeholders in the Information Age.

Findings related to the distribution of the rules in the information and knowledge governance

Starting with the distribution of the selected articles in the three types of rules. As presented in the result section, a substantial imbalance was discovered since more than half of the selected papers fell into the stakeholder rules (54.5%), while the other two types of information rules (19.5%) and platform rules (26%) shared the rest one more or less in an equal way. Furthermore, I identified three types of information rules, five types of platform rules and three types of stakeholder rules based on the selected articles, respectively. Notably, the stakeholder rules have higher diversity than the other two, regarding the examples of rules, though the number of articles that fell into its category (20) is significantly smaller than the stakeholder rules (40). On the opposite, despite the smallest number of articles under the information rules, it shares the same number of examples with the stakeholder rules.

Meanwhile, for each specific rule identified in the study, the broadness of the research scope regarding the number of selected articles and the involved sectors is different, which can further indicate the current state of the research focus and provide insights for future research topics. According to the results section, I also found out that stakeholder rules were covered by most of the sectors (11 sectors out of 12 in total) compared to the other two types of rules (6 sectors for each). Meanwhile, the first example of stakeholder rule, addressing the usability gap between information providers and end-users, attracts the broadest attention in the literature, involving 8 sectors and 13 articles. Similarly, the information rule III (10) and platform rule II (9) have slightly lowers number of articles than the stakeholder rule I. Specifically, the information rule III aims to integrate knowledge from local/indigenous communities with climate science to gain a more complete and accurate information, while the latter intends to address the accessibility and inclusiveness barrier for broader community by developing ICTs-based information system with up-to-date and high quality information.

On the other hand, there are certain types of rules that are merely limited to one or two specific sectors with relatively lower number of articles, such as the information rule I (with five articles in two sectors), platform rule I (with three articles in the agriculture sector), platform rule IV (with three articles in the disaster management sector), platform rule V (with five articles in the agriculture sector), and the stakeholder rule III (with three articles in sector arctic). It is thus recommended that more research in the future can focus on such topic to validate the current findings and provide more insights to the topics that are in lack of enough research evidence. For instance, in the platform rule IV, limited numbers of studies have addressed the issue of how to create the platform in detail to facilitate international cooperation, which can be one of the future research focuses. In the meantime, the stakeholder rule III, that addresses the power imbalance issue among various stakeholders, is only limited to the sector of arctic, and further solutions have not yet been proposed in the considered articles. Thus, the future study could expand the research scope to other sectors and explore the underlying barriers and solutions to tackle the issue.

Findings related to the external environment of Information Age identified in the analytical framework

The study results demonstrate that the developed analytical framework is useful in analyzing the literature and fit with the assumption of the external environment, especially the changing role of non-state actors and non-scientific knowledge claims with the development of Information and Communication Technologies (ICTs) in the Information Age (van Deursen and van Dijk, 2014; Mol, 2006; Soma et al., 2016). In other words, the assumption was further confirmed, that ICTs in the Information Age, with the centrality of information, has significantly transformed the traditional authority role of state actors and scientific knowledge. For instance, The role of scientific knowledge, as the authority has been increasingly challenged by other alternative truth claims, such as the layman's knowledge created by the public (Lievrouw, 2011), the indidenous knowledge system from the local indigenout community (Beckford, 2018) and the political arguments from the responsible political representatives (Bekkers et al., 2018; Soares and Dessai, 2016). It has been widely acknowledged by the academia to bridge various knowledge claims among various stakeholders from the moral, political and practical motivations, shown in the identified information rule III (Nyadzi et al., 2018; Beckford, 2018; McGregor et al., 2018; Canevari-Luzardo et al., 2017; Plotz et al., 2017; Soares and Dessai.,2016; Jiri et al., 2015; Chiang et al.,2014) and stakeholder rule II (Bekker et al., 2018; Loboguerrero et al., 2018; Kraaijvanger et al., 2016; Carter et al., 2015; Pietri et al., 2015; Mitter et al., 2014; Collier et al., 2013; Buizer et al., 2011). Approaches such as the intervention of information brokers, face-to-face or online web-based participatory experiments and online visualised platform have been introduced according to the platform rule IV (Beckford, 2018; Nyadzi et al., 2018; Kraaijvanger et al., 2016; Pietri et al., 2015; Mitter et al., 2014).

Secondly, the traditional role of state has been challenged in the decision-making process as well, especially with the higher e-participation of the public, through information disclosure and dissemination from social media and other online portals (Geldin, 2019; Albris, 2018; Wehn et al., 2018; Yang et al., 2018; Nahayo et al., 2017; He et al., 2017; Sharman, 2014). Muller et al. (2015) addressed the double role of the public, not only as the information consumer, but also as the information provider. Yet, the empowering capability of the ICTs to the economically and socially marginalised communities remains uncertain. On the one hand, the second type of platform rule shows that the ICTs-based information system can enhance the information accessibility and inclusiveness for broader community, especially the socially and economically marginalised ones (Loboguerrero et al., 2019; Haworth et al., 2018; Mwalukasa et al., 2018; Bernard et al., 2018; Khezri et al., 2018a; Khezri et al., 2018b; Baird and Hartter, 2017; Ndumbaro and Mutula, 2017; Hasan and Ionescu, 2017). On the other hand, it was found in stakeholder rule III that the development of ICTs might strengthen the existing power inequality among various groups, taken the case of the fish certification scheme in the Russian Barents Sea (Lamer et al., 2016; Gulbrandsen and Hønneland, 2014).

Notably, ICTs and other digitalisation technologies have greatly transformed the state of the complexity and channels of information and knowledge flows within the stakeholder interactions, with both benefits and challenges identified by the scholars. It is inevitable that the Information Age has brought up new patterns and structures of information and knowledge governance in the context of climate change adaptation. The involved stakeholders and institutions thus shall gain more insights to understand the new relationships in the information and knowledge construction, dissemination and exchange processes, especially the arising roles of public and local communities and their knowledge claims. The induced issue of power imbalance among stakeholders could be one of the major challenges in the Information Age, worth further research attention.

Findings related to the use of the interlinked terms of data, information and knowledge

The other research question addressed in this study is related to the ambiguous use of the interlinked terms of data, information and knowledge. It discovered that more selected articles have used the terms of information (30) and knowledge (30) rather than data (8). The literature that fell into the category of data, was usually connected with the climate and crop models in the agriculture sector, where data is taken as the major component. Neither data or information has been conceptually explained in the literature, unlike knowledge. The literature has viewed the concept of knowledge from the epistemological perspective as an emergent, relational dynamic of social interactions instead of just an object (Rydin, 2007; Ison et al., 2007).

When it comes to the articles using the mixed terms (9), most of them merely mix-used the terms without differentiating them beforehand. Scholars studying the information governance are one of the few scientists that have addressed the difference between information and knowledge and their interrelations (Mol, 2008; Mol, 2014; Holm and Soma, 2016). Information is understood as encompassing data and knowledge and points to meaningful flow of signs among targeted audiences (Mol, 2008). Meanwhile knowledge is seen as the final product of information exchange, where analyses allow conclusions to be drawn (Mol, 2014). For example, the literature on non-scientific information flows in the fisheries usually refers to knowledge, instead of information. However, Holm and Soma (2016) preferred to use the term information in their work. They argued that the focus is on the transfer of such knowledge to the governance of marine resources, and not as a final product of information exchange.

More explicit definitions have been made in my research to clarify the use of these interlinked terms. Following the logic of the *data-information-knowledge-wisdom hierarchy* (DIKW) developed by Davenport and Prusak (1998), the three terms are positioned in the different levels of the hierarchy (Rowley, 2007). Starting with the lowest level of data, it is viewed as “a set of discrete, objective facts about events” (Davenport and Prusak, 1998; p.2), which are not structured, and thus do not convey any meaning. Therefore, it does not contribute to the decision making directly. In the context of climate change adaptation, it is suggested to be used in the studies addressing information rules related to climate model. Higher than the level of data, information is taken as data put in context with further interpretation and analysis. The transfer of the information flows among stakeholders is recommended to be the focus, when it comes to the use of the term information in the literature of climate change adaptation. Finally, positioned at the highest level, knowledge is closest to the action and decision making, which is usually understood as the result of information exchange. Therefore, unlike the term information applied in the transfer of information to the governance structure, the term knowledge shall be used, if the focus of the study is the final decision-making or actions. For future research, it is of vital importance to build up rules to form standardised use of related terminology, in order to avoid ambiguousness and enhance communication and understanding among scientists.

6.Summary

To evaluate the current state of the newly developed analytical concepts of information and knowledge governance in the climate change adaptation literature, an analytical framework, embedded with three types of rules, namely information rules, platform rules and stakeholder rules, was developed in this study, to assess the selected articles using the systematic review approach. In order to address the proposed research questions, several major findings are displayed as follows: (i) the analytical framework is found useful analyzing the literature and fits with the assumptions of the external environment, especially the changing role of non-state actors and non-scientific knowledge claims with the development of ICTs in the Information Age; (ii) the specific examples for the information rules, platform rules and stakeholder rules identified in this study are able to answer the corresponding research questions by clarifying the specific rules; (iii) the distribution of the number of articles and research sectors among the various identified rules is not well balanced; (iv) a more explicit definition of the interlinked terms of data, information and knowledge was addressed in this work.

In addition to the major findings and the related future research suggestions pointed out in the discussion section, several limitations embedded in this study need to be addressed. First of all, there are some inherent flaws of the literature selection process for the systematic review. Due to the limit of time and costs, there is only one source of scopus being included to retrieve the relevant studies. Ideally, as suggested by Jadad et al. (1998), at least two different sources shall be included to increase the comprehensiveness level of the systematic review. Meanwhile, the selection criteria is restricted to the limited time period, English language and the accessibility of the publications. Therefore, it is possible that earlier studies and/or non-English qualified publications and/or grey literature might contain information with potential to fit into some of the knowledge gaps identified in this study.

Secondly, through the coding analysis, each of the selected article was assigned to one of the three types of rules in the analytical framework. However, I found out that it is hard to distinguish the only type of rule in the articles, especially when most of them actually cover more than one type of rule. Therefore, the major type of rule addressed in each article was assigned in the analysis, which might be an oversimplification of that study.

One of the major contributions of the study is the identification of the examples of various rules regarding information, platform and stakeholder in the information and knowledge governance, either based on the experience or the recommendation. The applicability of all the identified rules can be verified and refined by the empirical studies in the future.

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Appendix 1: The terms and their abbreviations

CCA: Climate Change adaptation

ICTs: Information and Communication Technologies. ICTs can be categorized into traditional (less interactive) and modern (more interactive) ones. The radio, television and telephony are traditional ICTs, which are less interactive and in most cases rarely enhance two-way communication. While modern ICTs include Internet, mobile phone applications, which are more interactive and allow more collaboration and provisions for instant feedback from the crowd.

IPCC: the Intergovernmental Panel on Climate Change. IPCC is the United Nations body for assessing the science related to climate change

IKM: Information and Knowledge Management. IKM is used to characterize the process of managing the rich array of data, information and knowledge required for adaptation and resilience planning and decision making.

IS: Information System. IS is a supportive socio-technical framework for integrating hardware, software, data, people, and procedures.

E-participation: ICT- supported participation in processes involved in government and policy-making.

Weather: reflects short-term conditions of the atmosphere while climate is the average daily weather for an extended period of time at a certain location. Succinctly, climate is what you expect, weather is what you get (NOAA, 2019).

LTK: Local Traditional Knowledge. LTK means a system of collective and cumulative intergenerational knowledge developed and used over time to address a plethora of specific local level issues. Also used as Traditional Ecological Knowledge (TEK), Indigenous Knowledge (IK), Local Knowledge (LK) or Traditional Knowledge (TK).

EVO: Environmental Virtual Observatories.

Appendix 2: scopus search ring and coding sample

Table 4: The keywords for scopus search query ring

(1) Climate change adaptation	**(2) Informational/knowledge governance**			**(3) Information age**
	Information rule of data/information/knowledge	Stakeholder rule of data/information/knowledge	General governance-related terms	
climate change adaptation; climate adaptation; climate change adaptation governance; CCAG; adaptive governance; transformational adaptation	data quality; information quality; knowledge quality; data standard; information standard; knowledge standard; data usability; information usability; knowledge usability; data reliability; information reliability; knowledge reliability; data transparency; information transparency; knowledge transparency"	data production; information production; knowledge production; Knowledge co-production data management; information management; knowledge management; data exchange; information exchange; knowledge exchange; data storage; information storage; electronic capitalism; information capitalism; knowledge capitalism; information rights; knowledge rights; information power; knowledge power; information commons; knowledge commons	e-governance; co-governance; digital governance; Self- governance; network governance; knowledge network; information governance; informational governance; informational institution; knowledge governance; knowledge institution	Information technology; ICT; Digital information; Digital age; Information age;

The first scopus search query with the result of 466 articles:

"climate change adaptation" OR "climate adaptation" OR "climate change adaptation governance" OR "CCAG" OR "adaptive governance" OR "transformational adaptation" AND "e-governance" OR "co-governance" OR "digital governance" OR "self-governance" OR "network governance" OR "knowledge network" OR "information governance" OR "informational governance" OR "informational institution" OR "knowledge governance" OR "knowledge institution" OR "data quality" OR "information quality" OR "knowledge quality" OR "data standard" OR "information standard" OR "knowledge standard" OR "data usability" OR "information usability" OR "knowledge usability" OR "data reliability" OR "information reliability" OR "knowledge reliability" OR "data transparency" OR "information transparency" OR "knowledge transparency" OR "data production" OR "information production" OR "knowledge production" OR “knowledge co-production” OR "data management" OR "information management" OR "knowledge management" OR "data exchange" OR "information exchange" OR "knowledge exchange" OR "data storage" OR "information storage" OR "electronic capitalism" OR "information capitalism" OR "knowledge capitalism" OR "information rights" OR "knowledge rights" OR "information power" OR "knowledge power" OR "information commons" OR "knowledge commons" AND "ICT" OR "Information technology" OR "Information Age" OR "digital age" OR "digital information"

The second scopus search query with the result of 210 articles:

"climate change adaptation" OR "climate adaptation" OR "climate change adaptation governance" OR "CCAG" OR "adaptive governance" OR "transformational adaptation" AND "e-governance" OR "co-governance" OR "digital governance" OR "self-governance" OR "network governance" OR "knowledge network" OR "information governance" OR "informational governance" OR "informational institution" OR "knowledge governance" OR "knowledge institution" OR "data quality" OR "information quality" OR "knowledge quality" OR "data standard" OR "information standard" OR "knowledge standard" OR "data usability" OR "information usability" OR "knowledge usability" OR "data reliability" OR "information reliability" OR "knowledge reliability" OR "data transparency" OR "information transparency" OR "knowledge transparency" OR "data production" OR "information production" OR "knowledge production" OR “knowledge co-production” OR "data management" OR "information management" OR "knowledge management" OR "data exchange" OR "information exchange" OR "knowledge exchange" OR "data storage" OR "information storage" OR "electronic capitalism" OR "information capitalism" OR "knowledge capitalism" OR "information rights" OR "knowledge rights" OR "information power" OR "knowledge power" OR "information commons" OR "knowledge commons" AND "ICT" OR "Information technology" OR "Information Age" OR "digital age" OR "digital information" AND (EXCLUDE (PUBSTAGE , "aip")) AND (EXCLUDE (DOCTYPE , "bk") OR EXCLUDE (DOCTYPE , "cp") OR EXCLUDE (DOCTYPE , "ch") OR EXCLUDE (DOCTYPE , "ip") OR EXCLUDE (DOCTYPE , "ed") OR EXCLUDE (DOCTYPE , "no") OR EXCLUDE (DOCTYPE , "sh")) AND (EXCLUDE (SUBJAREA , "COMP") OR EXCLUDE (SUBJAREA , "ENGI") OR EXCLUDE (SUBJAREA , "MEDI") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "PSYC") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "MATE") OR EXCLUDE (SUBJAREA , "MULT") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA , "NURS") OR EXCLUDE (SUBJAREA , "CHEM")) AND (EXCLUDE (LANGUAGE , "Italian") OR EXCLUDE (LANGUAGE , "Spanish") OR EXCLUDE (LANGUAGE , "Undefined"))

Table 5: The table for coding analysis with one paper as an example

Table A2.2: the table for coding analysis with one paper as an example

Authors	Year	Title	Location	General description	sector	Types of rules: 0=information rules; 1=platform rules; 2=stakeholder rules	Related terms: 0=data; 1=information; 2=knowledge; 3=mixed	Stakeholders and their interaction	concepts
Loboguerrero A.M et al	2018	Bridging the gap between climate science and farmers in Colombia	Colombia	Considering the fact that agriculture is highly sensitive to weather and climate variations, farmers need information about future weather and climate scenarios and the impact on their activities. A participatory process to combine both climate science and farmers' knowledge was therefore proposed by the authours	agriculture	2	3	Knowledge co-production between scientists and farmers to deliver usable information. During the process, both sides learned how to share their knowledge and information in an understandable way	Weather reflects short-term conditions of the atmosphere while climate is the average daily weather for an extended period of time at a certain location. Succinctly, climate is what you expect, weather is what you get (NOAA accessed, 2019)

Declaration:

I hereby declare that the present thesis has not been submitted as a part of any other examination procedure and has been independently written. All passages, including those from the internet, which were used directly or in modified form, especially those sources using text, graphs, charts or pictures, are indicated as such. I realize that an infringement of these principles which would amount to either an attempt of deception or deceit will lead to the institution of proceedings against myself.

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