Climate information as an object of economic research: state and perspectives

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FOREWORD BY JOHN ZILLMAN

Weather and climate impact pervasively on the economies of both developed and developing countries. But, while the theory and research literature of information economics provide considerable insight into the general role of information in decision making, there has been relatively little mainstream economic research into the specific contribution of meteorological (weather and climate) information and services to the overall working of the economy.
The establishment of the World Meteorological Organization (WMO) World Weather Watch in the 1960s, as the foundation for improved meteorological services around the globe, triggered pioneering collaboration between meteorologists and economists on assessment of the economic value of meteorological information. But most of what has been done over the past 50 years has been largely provider-driven and mostly published in the meteorological rather than the standard economics literature.

The decision of the more than 150 governments represented at the 2009 World Climate Conference-3 (WCC-3) to establish a new Global Framework for Climate Services (GFCS) 'to strengthen the production, availability, delivery and application of science-based climate prediction and services' has brought renewed attention to the economics of climate information with important initiatives now underway through the international Climate Services Partnership (CSP) and its Working Group on Economic Value of Climate Services, in collaboration with the WMO, the World Bank and other international and national institutions.
One of the essential starting points for this new work is a comprehensive assessment of that already done including, especially, research published in the economics journals and other interdisciplinary literature less familiar to the traditional climate community.

This initial study by Marco Ludolph and Paschen von Flotow of the German Sustainable Business Institute (SBI) makes a particularly valuable contribution to the international stock-take of meteorological information economics at three levels:

- Firstly, the authors provide a useful summary framework for analysis of climate information from an information economics perspective;
- Secondly, they undertake a careful analysis of the economics and related interdisciplinary literature on 'climate information' and 'climate services' under eight highly relevant headings, with geographical and other subdivision, and provide informative summary conclusions from many of the 200 individual publications identified; and
- Thirdly, they set out an insightful agenda for future research into much broader aspects of the economics of climate services.

I believe this report will be of great value as a resource for those guiding the implementation of the GFCS and especially those in both the economics and meteorological communities, working on the development, delivery and application of climate services at the national, sectoral and individual levels. The Sustainable Business Institute (SBI) and the authors are to be warmly commended on their initiative and this report. I am sure it will become a key source of insight to the published literature and a valued guide for future research.

- **John W Zillman**
  (University of Melbourne, Chair of the International Organising Committee for WCC-3)

FOREWORD BY SUSTAINABLE BUSINESS INSTITUTE (SBI)

This report reflects the economic perspective on the further development of climate services as well as the economic research needed to support this development. On one hand, it builds on economic theory and reviews the pertinent literature. On the other hand it benefits from the results of prolific discussions between the supply side of climate services and the demand side (represented by the financial sector). We have chosen the financial sector as it carries weather-related risks in many different ways for all sectors of the real economy across the globe. Based on studies regarding perceived risks and information needs of the financial sector in Germany (report "Jointly Developing Climate Information Systems: Requirements for the Climate Service Center (CSC) from the perspective of the financial sector") and internationally (report "Advancing Adaptation through Climate Information Services", in cooperation with UNEP Finance Initiative) several national and international workshops were held, in which the following institutions took part:

- National Meteorological Services (NMSs) and climate service providers, such as Federal Office of Meteorology and Climatology MeteoSchweiz (Switzerland), Centre for Climate Systems Modelling (Switzerland), Centre for Earth Research and Environment Management (India), Climate-Insight (Tunisia), Climate Service Center (CSC, Germany), CLIMPACT (France), Environmental Change Institute (UK), ESSLA-METEOPROTECT (France), Euro-Mediterranean Center for Climate Change (CMCC, Italy), Finnish Meteorological Institute, INPE/CPTEC – CCST (Brazil), Instituto Agronomico de Pernambuco (IPA, Brazil), International Research Institute for Climate and Society (IRI, The Earth Institute at Columbia University, USA), Italian National agency for new technologies, Energy and Sustainable Economic Development (ENEA), National Center for Atmospheric Research (NCAR, USA), National Oceanic and Atmospheric Administration (NOAA, USA), Norwegian Meteorological Institute, Royal Netherlands Meteorological Institute (KNMI), UK Met Office, University of Melbourne (Australia) and World Meteorological Organization (WMO).

- Financial services providers, such as Allianz, AXA, Banco Santander, Barclays, DEG (KfW Group), DekaBank, Desjardins Group, Deutsche Asset Management, Deutsche Bank, HSBC, KfW Development Bank (KfW Group), Munich Re, Nordic Investment Bank, Pax World Investment, Santam, Scottish Widows Investment Partnership), Swiss Re, Willis Re and World Bank.

- Further organisations such as the German Aerospace Center (DLR), Food and Agriculture Organization (FAO), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the Joint Programming Initiative Climate (JPI Climate), UNEP Division of Early Warning and Assessment (DEWA), World Wind Energy Association (WWEA) and other research institutes.

The authors wish to sincerely thank the Federal Ministry of Education and Research (BMBF), Germany, for funding the study as part of the project "CFI - Climate Change, Financial Markets and Innovation".

Furthermore, the authors are grateful for all suggestions, indications and explanations that contributed to the study's argumentation. Special thanks go to Lutz Cleemann (former Manager of Allianz SE) and John W Zillmann (former president of the Australian Academy of Technological Sciences and Engineering (ATSE) and WMO) for their invaluable comments. We are also grateful for discussions with David Grimes (President, WMO), Filipe Lúcio, (Head, Global Framework for Climate Services (GFCS), WMO), Maryam Golnaraghi (Chief, Disaster Risk Reduction, WMO) and Remco Fischer (Programme Officer - Climate Change, United Nations Environment Programme Finance Initiative). In addition we wish to thank Stephen Zebiak and Catherine Vaughan from the Climate Services Partnership (CSP) and the International Research Institute for Climate and Society (IRI), and Guy Brasseur and his colleagues at the Climate Service Center (CSC), Germany, for ongoing discussions about developing climate services. We also thank Ruhi Deol and Daniel Drews (SBI) for editing and finalising this study.

We hope that the findings and insights from this study will help to understand and overcome economic and other institutional barriers facing the development and implementation of climate services, and positively impact the integration of climate knowledge into risk management.

- **Dr. Paschen von Flotow**
  Sustainable Business Institute (SBI)

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KEY MESSAGES

1) Adaptation to climate change and climate variability is becoming crucial. To support adaptation strategies and risk management, National Meteorological Services (NMSs) and climate service providers are fostering the development of user-oriented information. On an international level, WCC-3 has initiated the development of the Global Framework for Climate Services (GFCS).

2) Along with the further development and implementation of adaptation strategies, climate services and national and international climate information policies, economic questions become more relevant to support the efficiency and effectiveness of invested budgets.

3) Climate research typically represents a public task. However, the case of user-oriented climate information services is more complex. While climate services possess the character of a public good to a certain degree, specific applications may indeed be characterized as private goods.

4) Under the auspices of the World Meteorological Organization (WMO), Member States agreed unanimously to the free exchange of essential meteorological data (which form basic elements of any climate related information service). Nevertheless, some National Meteorological Services withhold some data for sale on a commercial basis.

5) The analysis of a sample of economic and interdisciplinary academic literature shows an increase in scientific publications using terms like “climate information” or “climate services” in recent years, although in contrast to the economic relevance of climate information, economic research on climate services is rather limited.

6) Due to the multitude of climate and sector-related competencies and private players as well as a spectrum of diverse public-private responsibilities, role allocations at different value-added steps and governance options is imaginable. However, only a few articles reflect relevant challenges regarding further development of climate services with respect to regulation, cooperation and competition. Therefore, more research is needed regarding climate information “systems” focussing on institutional settings.

7) Most contributions to climate information issues that use economic concepts in a narrower sense are directed towards the economic valuation of benefits derived by climate information (services). The majority of such research derives the value of information by modelling decision-making processes of an information user (usually in a rather rudimentary way) and assessing these outcomes of decision-making in the presence versus absence of climate information. These research contributions should be supplemented by more market-oriented approaches assessing preferences and willingness-to-pay of potential climate information users.

8) With respect to economic sectors, research is in most cases directed towards agriculture and forestry. Academic research regarding other sectors is starting to develop rather recently. Economically highly relevant sectors like finance, energy supply and infrastructure are hardly being covered by such research today despite their exposure to weather related risks and their long-term capital commitment periods.

9) Research focussing on the analysis of information needs has just started recently. This type of research should include economic aspects like availability, accessibility, usability and related transaction costs (information costs).

10) There is a variety of research contributions focussing on (economic) impacts of climate change and variability as well as on feasible adaptation measures. Based on such climate-oriented research, some decision support systems have been developed, although there is little research on the integration of climate change information into the clients’ risk models, risk management tools and decision support systems.

11) The more the results of research are transformed into services, the more non-meteorological-experts will be using or further distributing such services and basing their decisions on this information. Consequently, economic questions regarding reliability and remaining uncertainties will become more relevant for the original information provider. However, currently policy makers and climate service providers cannot build on research regarding economic and institutional questions related to quality assurance.

12) Mapping and classification of existing information services and user needs is a relevant precondition to reducing transaction costs and identifying opportunities for cooperation on the supply side and definition of gaps between supply and demand side. Furthermore, the development of services will need sophisticated modelling of value-added processes and cost structures as a basis for negotiations and cooperation between different public (and private) partners along the value-chain and across nations. Furthermore, to support the management of service development, a better understanding of the role of service providers as intermediaries is highly relevant. However, the roles of service providers, their value chains and types of services have hardly been analyzed from an economic point of view so far.

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ABBREVIATIONS

BMBF	German Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
CFI	Climate Change, Financial Markets and Innovation
CSC	Climate Service Center (Germany)
CSP	Climate Services Partnership
CVM	Contingent Valuation Method
DSS	Decision Support System
DWD	German Weather Service (Deutscher Wetterdienst)
Ecomet	The Economic Interest Grouping of the National Meteorological Services of the European Economic Area
FAWN	Florida Automated Weather Network
GFCS	Global Framework for Climate Services
ICCS	International Conference on Climate Services
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
KIBS	Knowledge Intensive Business Services
NGO	Non-Governmental Organisation
NMHS	National Meteorological and Hydrological Service
NMS	National Meteorological Service
NWS	National Weather Service (USA)
OPTIMEC	EConomic OPTIMization (agricultural application)
OR/MS	Operations Research and Management Science
PPP	Public Private Partnership
SAS	Strawberry Advisory System
SBI	Sustainable Business Institute (SBI) (Germany)
SWCC	Second World Climate Conference
UNFCCC	United Nations Framework Convention on Climate Change
WCC-3	World Climate Conference-3
WIFA	Weather Info For All
WFM	Whole-Farm Model
WMO	World Meteorological Organization

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1. INTRODUCTION

1.1 Intention, Structure and Scope

The availability of decision-oriented information on climate change, climate variability, specific regional climate impacts and the extent to which different natural and human systems are affected, as well as the development of continuous information services, are essential requirements for an effective and efficient adaptation to climate change. The development of such information services requires conditioning / translating and distributing existing knowledge as well as further developing and applying climate, environmental, economic and other impact models.

Furthermore, questions regarding institutional and information economics arise. The generation and dissemination of such information, the utilization of private competencies, and the conception of value-added chains for providing relevant climate (impact) information constitute questions of deep economic significance. We assume that economic research could contribute towards the further design of various applied services for different customers, the definition of national and international climate research and information policies, as well as to the “Global Framework for Climate Services” (GFCS), merited as a major task for international climate policy in the coming years.

Following this assumption, this paper is designed as an initial analysis to reflect the current state of research on climate information from an information economics viewpoint. It thereby aims to offer insights into this subject to a cross-disciplinary readership which is concerned with climate change and adaptation. Furthermore, the intention is to propose an economic research agenda to support the further development of climate information services.

The paper is structured as follows: It begins by reflecting a conceptual information-economic perspective to illustrate why and how issues of generating and disseminating climate information pertain to economics, among other fields, and it points to the potentially high value of economic research on these subjects (chapter 2). Beyond this framework, a literature study offers insights into the extent that such economic questions are currently being addressed, and which roles climate information plays within different economic and interdisciplinary research contributions (chapter 3). From more than 600 economic and environmental journals, this literature study identifies especially those articles using terms like “climate information” and “climate services”. The analysis of more than 200 resulting articles shows that a majority indeed use and / or produce climate information in the context of scientific research. These contributions enrich the scientific knowledge base by using climate information, especially observational data, and producing climate information in a wider sense, such as for predicted impacts of climate change on certain natural or human systems. However, economic or institutional aspects regarding generation and dissemination or the availability of climate information do not constitute the research focus of these articles. Other articles occasionally implicitly or explicitly point to related economic issues and identify them as relevant research questions. Based on conceptual information-economic considerations, the results of the literature study and the authors’ experience of working with climate service providers and the financial sector, research gaps and directions for future economic research on climate information services are derived (chapter 4).

As noted above, the current literature review refers to more than 200 economic and interdisciplinary articles, but does not cover all journals expected to be relevant to the scope of this paper. We regard this work as a first step towards more in-depth literature reviews which would ideally cover further journals and perhaps lead to more sophisticated and nuanced insights, as well as further inspire the suggested research agenda. In addition, we also consider it a first step towards the development of an economic perspective on climate information and a necessary agenda for further research.

1.2 Background: Climate Information for Adaptation to Climate Change

For a decade or so after the UN Framework Convention on Climate Change (UNFCCC) came into force in 1994, political and scientific efforts revolved around issues related to the mitigation of (anthropogenic) climate change. Accordingly, most (economic) research on climate change during this period essentially served to justify and legitimize these mitigation activities.

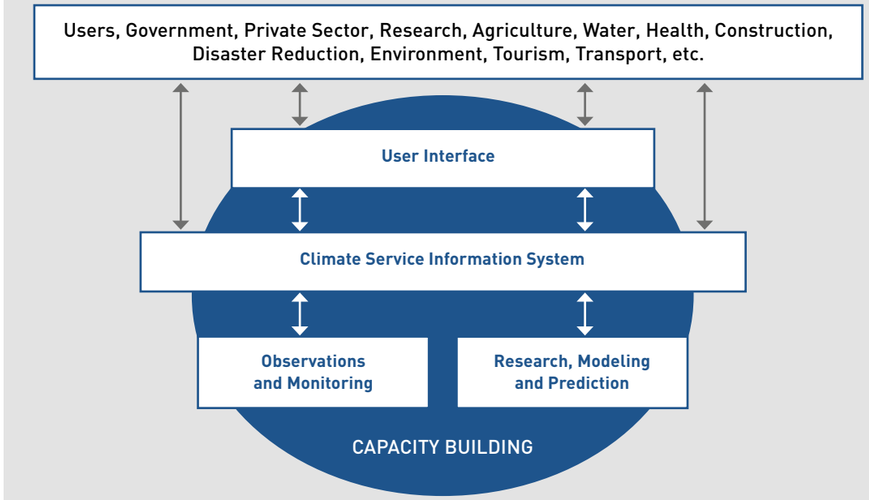
However, in recent years, it has become increasingly clear within both political and scientific discussions on climate change that – in addition to efforts to reduce global warming – adaptation to climate change impacts is unavoidable. Thus, economic climate change research today is increasingly directed towards a better understanding of the correlations between climate change and its expected impacts and risks, as well as towards feasible and tangible adaptation measures. A variety of potential climate change impacts affect different parts of society, economic sectors, and geographic regions (IPCC 2007). To counter, a host of applicable public and private adaptation measures exist, e.g. the choice of certain plant species or varieties in agriculture, strategic orientation in tourism or measures of disaster prevention in coastal areas. Of course, these changes require efficient capital expenditure and investments for which improving the information base is an important prerequisite.

Therefore, the more precise and robust climate information is, the more efficient and effective is the planning and implementation of adaptation measures, and the less is the probability of misallocated resources. Apart from national policies, decisions taken by enterprises, financial service providers, and private citizens also have far reaching long-term effects and long capital commitment periods. Integrating scientific knowledge on expected changes in climate and their specific impacts on infrastructure, businesses and private households into familiar decision-making processes can be extremely valuable for individuals, enterprises and the overall economy. Therefore, information formats and services are needed that best serve this integration of climate knowledge into decision-making processes. From an economic view-point, developing effective and efficient information services will enhance the availability, accessibility and usability of relevant information; which in turn will contribute to improving public and private climate risk management and reducing transaction costs (especially costs of information gathering) and costs of climate change adaptation.

Scientific insights lead to ongoing improvement of the knowledge base regarding climate change and its expected impacts. However, these insights usually cannot be used seamlessly in the decision-making processes of different public and private actors (Tompkins *et al*. 2010). In other words, there is a need for scientific information to be provided to different users for specific purposes in a decision-oriented way. Therefore, within current international climate change debates, great importance is attached to the subject of user-friendly climate information

services for climate change adaptation. In line with these challenges, the World Climate Conference 3 (WCC-3) explicitly bore the title “Better climate information for a better future“. Based on WCC-3, the “Global Framework for Climate Services” (GFCS) is under development, and aims to “*enable better management of the risks of climate variability and change and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale*“ (GFCS 2013). Figure 1 outlines the framework within which the goals of the GFCS will be achieved.

Figure 1: The Global Framework for Climate Services (WMO 2012)



1.3 Definition and Differentiation of Terms

Weather and climate:
Although the terms are often used flexibly and interchangeably, the meteorological community tends to separate “weather” from “climate”. This paper uses the definitions of the Intergovernmental Panel on Climate Change (IPCC), the World Meteorological Organization (WMO) and the German Weather Service (DWD). The IPCC defines “climate“ as “[…] *the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years* […]” (IPCC 2007b: 78). While the term „climate“, therefore, is always directed towards timeframes of at least several months, the term “weather“ describes the physical state of the atmosphere at a certain time or within short timeframes ranging from minutes to about 15 days (DWD 2013). This differentiation regarding different time horizons has respective validity for the differentiation between climate and weather fore casts and climate and weather information. Both terms – weather and climate –
may be directed towards the description of states or changes in states of meteorological parameters in geographical areas of different sizes. The terms “meteorological data” or simply

"monitoring data" are used for historical weather or climate information without explicit reference to timescales in this paper.

Climate change:
According to the IPCC (2007b: 81), the term "climate change" refers to "*a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/ or the variability of its properties, and that persists for an extended period, typically decades or longer*". Contrary to other understandings of the term, this definition does not refer to the reasons of climatic changes; these might be attributed to natural internal processes as well as to external (e.g. anthropogenic) forces.

Climate prediction / climate forecast:
The IPCC (2007b: 78) especially emphasizes the probabilistic nature of these terms: "*A climate prediction or climate forecast is the result of an attempt to produce an estimate of the actual evolution of the climate in the future, for example, at seasonal, interannual or long-term time scales. Since the future evolution of the climate system may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature.*"

Climate information:
In this paper, the term "climate information" covers a broad spectrum of types of climate-related information:

Information about climatic conditions or changes in these conditions within a certain geographic area and timeframe is denoted "climate information in a narrower sense". This leads to different categories of climate information:

- It may be empirical information on past climate or predictions on future climate.
- Both empirical information and predictions may refer to very different timeframes, ranging from months to years up to decades and centuries. According to the definitions above, shorter timeframes are covered by the term "weather information".
- The spatial resolution of the information may be very different and refer to e.g. the climate of a country or of a single city, or, in the case of empirical information, to a single monitoring station.
- The information may refer to a single climatic parameter, e.g. temperature, amount of precipitation etc., or to multiple parameters.

Further information, such as observed or predicted socio-economic impacts of changing climatic conditions (impact information), information on the individual (climate-related) vulnerabilities of natural or socioeconomic systems, as well as information about recommended adaptation measures to those changes, is defined as "climate information in a wider sense" in this research paper.

The term "impact information" thereby refers to (empirical or projected) information on impacts of changing climatic conditions on certain (natural or human) systems, while "information on adaptation" covers information about human measures of adapting to such changing climatic conditions. As with climate information in a narrower sense, climate information in a wider sense may also refer to historic or projected information, to very different timescales and spatial resolutions as well as to different climatic parameters or events.

Climate (information) service:
According to the GFCS, (WMO 2011: 18), climate services "[…] *encompass a range of activities that deal with generating and providing information based on past, present and future climate and on its impacts on natural and human systems. Climate services include the use of simple information like historical climate data sets as well as more complex products such as predictions of weather elements on monthly, seasonal or decadal timescales, also making use of climate projections according to different greenhouse gas emission scenarios. Included as well are information and support that help the user choose the right product for the decision they need to make and that explain the uncertainty associated with the information offered while advising on how to best use it in the decision-making process.*"

Therefore, a climate information service may comprise climate information in a narrower sense (including empirical data and climate projections) as well as a wider sense (information on climate impacts and adaptation). The types of information needed by a user in specific spatial and temporal resolutions depend on the context of the specific user's decision-making situation.

The term "decision support system" (DSS) refers to a tool which offers support to a decision-maker in a particular decision-making situation and thereby includes various kinds of relevant information, of which climate information may be one.

2. CLIMATE INFORMATION FROM AN INFORMATION ECONOMICS PERSPECTIVE

The scientific discipline of information economics takes into account the increasing importance of information for businesses and the economy. Information is sometimes considered an additional production factor next to labour, capital and raw materials (Linde 2005). While original neoclassical theory assumes "perfect information" for all market participants for reasons of abstraction, information economics directs its scope to information asymmetries and the role of information as a separate commodity (Akerlof 1970; Shapiro & Varian 1999, 2003; Shy 1994; Stiglitz 2000; Varian 1998).

The term "information good", which describes information as a commodity, may be defined as "*content-based definable quantity of data that is supposed to be useful for economic agents*" (Linde 2005: 7). In a narrower sense, information itself cannot be purchased, only data; the further advancement from data to information is made by the user. As implied in the definition above, a purchase of an amount of data, therefore, is conducted assuming that the data might serve to generate information that is useful to the buyer. This assumption of usefulness thereby has two elements: firstly, buyers assume their own cognitive ability to transform purchased data into information and, secondly, they assume the usefulness of the generated information.

A further advancement is made by connecting different units of information with each other and thereby generating *knowledge*[1] (Linde 2005). It is worth noting here that the transformation of data into information might occur at various points along the value chain depicted below e.g. meteorologists might convert data into information for their purposes, while end-users regard this information as data input for their own purposes.

Figure 2: Data, Information and Knowledge (authors' diagram)

Benefits of information usage arise when the information enables (public or private) decision-makers to achieve better outcomes than was possible without using the information (Freebairn & Zillman 2002). As Harrison *et al.* (2008: 21) state for seasonal to interannual climate predictions (as a certain type of climate information), "*the decision is everything: without serving as a basis for decisions, […] prediction would be little more than a stimulating intellectual challenge*".

[1] Data, information and knowledge are seen as elements of a larger "knowledge staircase", containing further elements up to "competitiveness" (e.g. Linde 2005: 6).

Information goods in general are characterized by special attributes that may compromise or even prevent their marketability (Linde 2005; Varian 1998). In the following sub-chapters, climate information is considered with regard to its information-economic dimension, and its special characteristics are depicted.

2.1 Climate Information as Experience Goods and Credence Goods

Many traditional goods may be classified as "search goods", since demanders are able to inform themselves about the properties and quality of the good prior to making the purchase decision. In the case of information goods, such an inspection is usually not possible because it would be accompanied by revealing the information at least partly and therefore by the loss of willingness-to-pay (Linde 2005). "*You can only tell if you want to buy some information once you know what it is – but by then it is too late*" (Varian 1998: 4). At the time of the purchase decision, the buyer of a climate information good, therefore, can basically only assume its usefulness[2]. So, climate information tends to have properties of "experience goods", whose usefulness can be assessed only after its usage (or "consumption"), and of "credence goods", whose usefulness cannot be assessed even after consumption since its substance and the adequacy of the decision this information was used for cannot be fully revealed (Goldhammer 2006). The possibility of subsequently assessing the usefulness of a climate information good especially applies to how the climate information is conditioned. Users can assess to what extent the received information is conditioned according to their needs, and to what extent it may support a certain decision situation. Regarding the pure information content, such an assessment seems distinctly more difficult; its substance is, especially in the case of climate predictions, hardly verifiable. So, while the format of information conditioning tends to show properties of experience goods, its content tends to have properties of credence goods[3].

[2] It should be noted that this statement generally applies to single information goods. In the case of long-time established climate information services, especially empirical data provision services, their usefulness may be well understood by certain demanders.

[3] In this context, a special feature of climate information should be noted. The classification according to "search", "experience" and "credence goods" usually refers to the information asymmetries between supplier and demander of an information good with respect to the information advantage of the supplier, whereby it is assumed that the supplier has better knowledge about the quality of his product (Linde 2005). In the case of climate predictions, however, even the suppliers do not know the substance of their prediction exactly; they may only be in a better position to estimate its robustness than the demander since they have better knowledge regarding reliability and functionality of the climate models used.

2.2 Climate Information as Public Goods

Furthermore, climate information goods usually show properties of public goods which mean there is non-excludability and non-rivalry in consumption.

In most cases, non-rivalry in consumption is a given for climate information since use of the information by one individual does not diminish the possibility of its use by others. The benefits from using the information remain unaffected; there is no "wearout" (Gunasekera 2010). However, Zillman and Freebairn (2001) point out the possibility of a situation with only one single information user – in this case, the non-rivalry issue can be neglected and the information does not represent a pure public good[4].

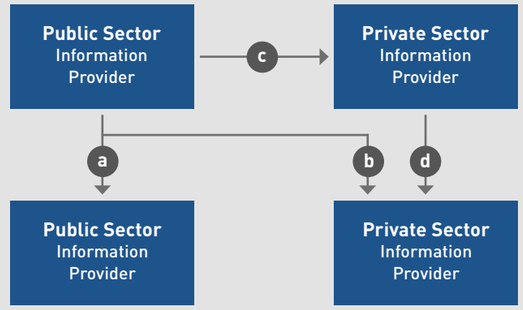
It is not generally impossible to exclude potential users from using climate information if they are not willing to pay for it. For a lot of goods, it is true that people basically could be excluded from usage, but for technical or economic reasons it is difficult to implement such measures. Exclusion may also be unwanted for socio-political reasons (Linde 2005). In the case of climate information, it can be assumed that the public sector has the duty to inform the community of citizens about climate change and its impacts and not to claim exclusive rights of use for paying citizens. In this regard, climate information may be considered predominantly a public good. However, climate information may not necessarily be classified as a public good in each case. It appears to be true that information tailored very distinctly to the needs of a certain user can be produced and provided for charge without appearing questionable in socio-political regards and without contradicting the responsibility of governments to protect the public.

For example, ski-lift operators may have a high interest in predictions on amounts of snowfall for certain future timeframes in their geographical areas. For the production of such information, the demander may have willingness-to-pay for business reasons, as strategic decisions may be based on this information. From a socio-political view, it does not seem questionable, but rather justified that demanders must pay for the production of such information as it serves to maximize their profit. So, the question to what extent people can (or should) be excluded from consuming climate information (also) depends on the degree of concretization with respect to the demander's specific requirements and the intended purpose.

It may be worthwhile to take a closer look at some of the potential public and private sector roles as climate information providers on the one hand and as users of information for decision-making on the other (see Figure 3).

[4] The deliberations of Zillman and Freebairn are directed towards the term "meteorological services"; they may also be applied to the term "climate information", which is central to this paper.

Figure 3: Public and Private Sector Climate Information Flows and Decision-Making (authors)



As outlined in Figure 3:

- Climate information produced by the public sector may serve to support public decision-making on adaptation measures (arrow a). In this case, the information needs to be considered a public good.

- The information may also serve to aid decision-making in the private sector (arrow b). If the public sector is providing this information for free, corresponding to its public welfare duties, it has to be classified as a public good as well.

- Special information tailored to the needs of a certain user, however, may be produced and supplied by private sector institutions on demand (arrow d). Such information no longer reflects a pure public good; a market-based supply is, in some cases, possible.

- Information generated and disseminated by private service providers may benefit from basic data and information generated by the public sector (arrow c). Public sector institutions contributing to the added value may have an interest in realizing a share of the profit and therefore may charge for providing the information. This could include charging for specialized services to contribute to the funding of the public share of these services. However, as Freebairn and Zillman (2002) state, this is an option that is discussed controversially.

- Of course, further constellations (especially with private institutions providing information to public ones) are also possible.

So, there might be very different constellations with varying roles of private and public institutions, with public roles ranging from producing pure public goods to participating in market activities.

In conclusion, there is no universally valid answer to the question as to when climate information is a public good and when it is a private good, as this differentiation depends on the type of information and its purpose.

2.3 Cost Structures of Climate Information

The production of most goods includes fixed costs as well as variable costs (costs for producing each individual item). Information goods usually have strongly dominating fixed costs (Linde 2005; Varian 1998). This is also true for climate information where fixed costs greatly surpass variable costs. As further specified in sub-chapter 2.5, user-oriented climate information may require complex value-added chains; enormous fixed costs may especially be assumed to arise at the first value-added steps, like the construction of meteorological observation stations or basic and applied climatological research. Variable costs for producing a single copy of a climate information good, however, are extremely low – only the costs of duplication and of data media are issues here.

2.4 Marketability of Climate Information

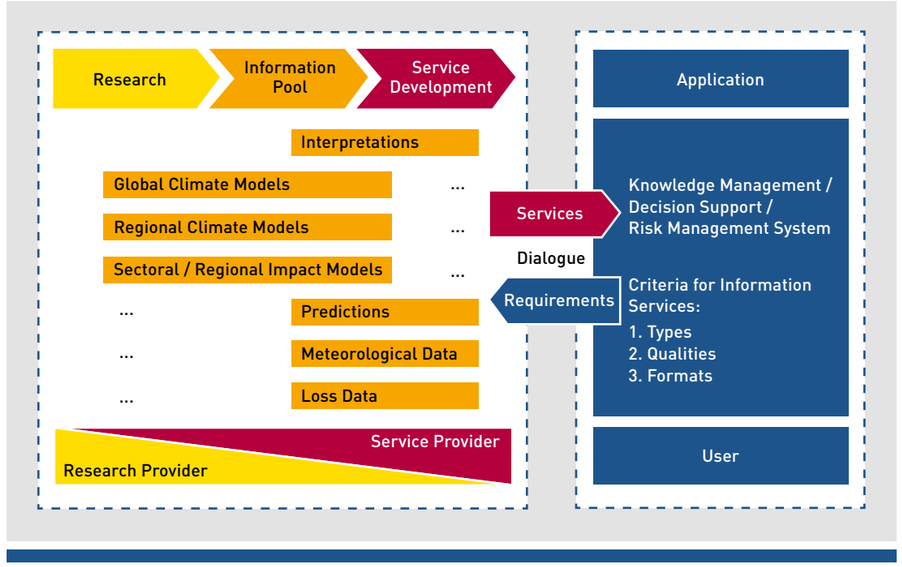
The more the characteristics described above are valid for a certain good, the more they usually compromise, or even prevent, its marketability. The uncertainty regarding its usefulness negatively influences the (potential) buyers' willingness-to-pay, the public good character provides incentives for consuming the information without paying for it and the dominance of fixed costs as well as the easy reproducibility of information goods can work as production constraints, thereby counteracting unfolding market-based trade (Linde 2005; Varian 1998). Therefore, a pure market-based generation and distribution of climate information would only work to suboptimal market results, if at all. Furthermore, it can be assumed that a pure market-based supply of different types of climate information may not be desirable for sociopolitical reasons.

However, the deliberations of sub-chapter 2.2 also show that climate information may not always be considered a public good, but may also include private good properties and thereby provide room for market activities. In their insightful article, Freebairn and Zillman (2002) therefore distinguish between "basic infrastructure, data and products", "basic service" and "special services". The first two categories are comprised of products and services that are widely available to the public and directed to the needs of major community sectors. These processes are *"[…] generally accepted as a fundamental responsibility of government"* (Freebairn & Zillman 2002b: 46) and represent public goods. "Special services", however, represent little value to other users. As these services show private good properties, charging for them may be possible.

2.5 Climate Information Value-Added Chains

As all reflections in chapter 2 refer to user-oriented climate information as an economic commodity itself, such information is considered to be the end product of a value-added chain, as schematically outlined in Figure 4. This information product may embody climate information in a narrower or wider sense, as annotated in chapter 1.3. Although considered an end product in these deliberations, the produced information may serve as an input for the production of other commodities and represent a component of further value-added chains. The climate information may be further processed and experience various integrations in different contexts. It may especially be used as a part of different risk management or decision support systems for public or private decision-makers. This may refer e.g. to DSSs designed to give farmers advice on treatment of plants in order to optimize yields using customized seasonal climate forecasts along with information on plant growth, soil conditions etc. Another example may be a tool to identify wind power sites, making use of climate information (e.g. predictions on future wind speed, humidity and other parameters) in parallel with further relevant inputs (e.g. grid connection and availability of support mechanisms). Within the following deliberations, only value chains of climate information are considered, independent of its further utilization.

Figure 4: Climate Information Value-Added Chain (authors)



As already indicated, value-added chains for user-oriented climate information often have complex forms. Initially, there is usually the acquisition and documentation of meteorological data. Depending on the request, there may be a variety of interim / processing stages leading up to the final user-oriented product (Leviäkangas 2009). For example, databases need to be maintained, basic climatological research conducted, global and regional climate models developed, processes need to be synthesized with other data (e.g. data on damages), impact models need to be developed to analyze potential impacts of climatic changes on different natural and human systems, and more.

Within the public and private sectors, there is a diversity of interests for different kinds of climate information and there are ample competencies of public and private actors regarding climate research and the economic sectors affected by climate change. Moreover, there are also ownerships of meteorological and further relevant databases distributed very diversely.

Given the high complexity of these value-added chains on the one hand and the diversity of interests and competencies on the other, it can be assumed that especially those concepts of generating and providing information will be working most efficiently and effectively that are designed in a way which enables them to satisfy these interests and requirements and makes the best use of the various competencies and data on the different value-added steps.

For the generation and distribution of climate information, different functions and role allocations of public and private actors are imaginable with respect to regulation, cooperation, and competition. To be able to analyze as well as to develop concepts for the provision of climate information with the involvement of different public and private actors, it is necessary to analyze the required value-added chains of the information products and the possible role allocations within the different value-added steps. Economic research on these subjects seems vital, since there is need for development of intelligent incentive-based systems and possible business models appropriate for the information-economic features and complex value-added chains inherent to climate information.

3. LITERATURE RESEARCH

Authored by Marco Ludolph

While chapter 2 highlighted why climate information and information services need to be topics of economic research, the literature research in this chapter deals with if and how this is currently the case. This literature research aims to reach three sub-goals:

- Overview of the role of climate information within different types of economic and interdisciplinary research
- Overview of issues analyzed by these articles
- Insights into how economic issues are approached with respect to characterization of climate information as an economic good and functionality and funding of corresponding information services, as informally highlighted in chapter 2.

3.1 Method

To assess the current state of economic and interdisciplinary research on climate information in an efficient but not exhaustive manner, this literature research study has been conducted using a literature sample derived mainly from the platform “ScienceDirect”. ScienceDirect is a leading scientific database offering articles from more than 2,500 peer-reviewed journals, covering a variety of natural and social sciences (ScienceDirect 2012).

Four categories of journals comprising economic and environmental sciences have been searched (“Economics, Econometrics and Finance”, “Business Management and Accounting”, “Environmental Science”, and “Agricultural and Biological Sciences”), involving 614 journals. The search therefore covers not only specifically economic articles, but also related contributions from other disciplines. This procedure has been chosen especially due to the fact that articles referring to climate change and adaptation are often interdisciplinary studies that draw on economic approaches (among others) but, as experience shows, often are published in journals of environmental sciences.

The four journal categories have been searched using full-text search with the terms “climate information”, “climate services”, “climate change information” as well as “meteorological information” plus “climate change”[5], as these terms are closely related to the subjects of this paper. This approach led to a result of 383 articles on ScienceDirect.

[5] In the case of non-economic journals (categories: "Environmental Science" and "Agricultural and Biological Sciences") the application of the additional search term "economics" served to limit target-oriented search results.

It should be noted that there are some meteorological journals that do not form part of the platform ScienceDirect, but are known for addressing issues within the scope of the current paper[6]. Of these, only "Meteorological Applications" (2012) was considered by the literature review, as a journal that provides a good overview of current debates in meteorology. In addition to the 383 articles identified on ScienceDirect, full-text search was used to search for the expression "economic" within the entirety of the published issues of "Meteorological Applications". The first 40 articles, ranked by relevance, have been considered. There might exist other relevant articles on issues covered by this paper, which are published in journals not covered here. Additionally, the chosen procedure only covers academic literature, and not the "grey" literature produced through various initiatives and projects referring to climate information.

Of the 423 total search results, those that did not fit the purpose of this paper have been excluded. This applies especially to articles using the search terms in a context that completely differs from the supposed context[7], as well as articles that do not contain any economic approach and do not indicate essential relevance for economic issues[8]. Furthermore, newsletters and book reviews have been excluded. Articles that exclusively focus on issues of climate change mitigation and do not contain essential references to issues of adaptation have also not been considered in the evaluation (in such articles terms such as "climate information" refer to information on the mode of action of the carbon cycle or the term "climate services" refers to climatic ecosystem services). Thus, the literature analysis covers 217 articles that may each be characterized as:

- an economic research contribution, or an interdisciplinary research contribution that uses economic methods (amongst others), or a research contribution from a different discipline that may have importance from an economic point of view; and likewise as
- a research contribution that refers to issues of adaptation (possibly amongst others) and in this context either addresses concrete issues of climate information or uses and / or produces such information in the context of its own research.

Figure 5 highlights the percentage of this paper's literature basis of 217 articles that is assigned to each of the four ScienceDirect journal categories, as well as to the journal "Meteorological Applications"[9]. Most of the articles of our sample have been published in journals assigned to the category "Environmental science" (47%), followed by "Agricultural and Biological Sciences" (27%), "Business, Management and Accounting" (6%) and "Economics, Econometrics and Finance (3%) plus "Meteorological Applications" (17%).

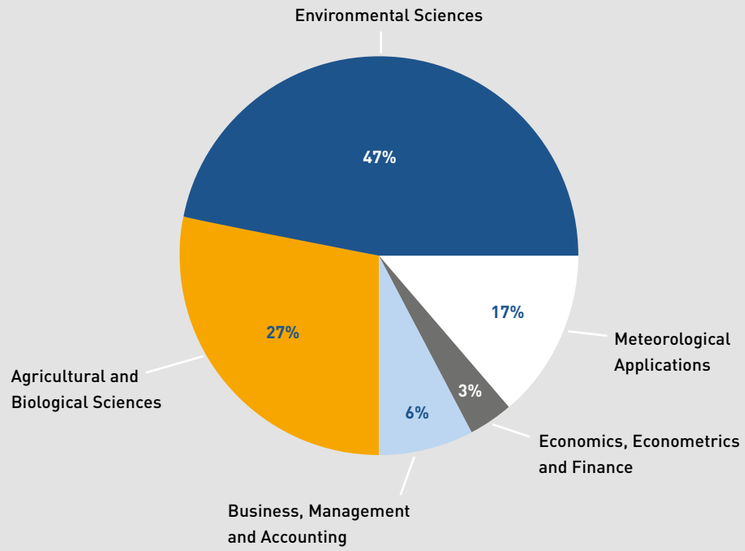
6 Among others, this applies especially to: "Bulletin of the American Meteorological Society" / "Climate Change" / "International Journal of Climate Change Strategies and Management" / "International Journal of Climatology" / "Journal of Applied Meteorology" / "Journal of Climatology" / "Meteorological Applications" / "Monthly Weather Review" / "Nature Climate Change" / "Quarterly Journal of the Royal Meteorological Society" / "Weather".

7 Such as articles in business journals dealing with office climate, investment climate etc. that therefore use terms like "social climate information", "investment climate information" etc.

8 This is often the case for non-economic articles that deal with purely meteorological research questions

9 Journals that are assigned to more than one of these four categories within the platform "ScienceDirect" are considered at equal share in each category (50% each in the case of double assignments and 33.3% each in the case of triple assignments)

Figure 5: Assignment of Literature Basis to Journal Categories (authors)



The following qualitative analysis of this literature basis, as well as additional quantitative analysis, must be interpreted against the backdrop of this literature research approach. Of course, neither the analysis nor the descriptions claim to be universally valid.

3.2 Categorization of Search Results

The literature search led to a huge range of heterogeneous search results which thus have been assigned by content to different categories as displayed in Table 1[10]. The articles in the categories A to C each deal explicitly with concrete needs or products, or they address issues of reconciliation of both sides. The articles assigned to categories D and E do not directly focus on issues regarding user-oriented climate information; instead, they represent studies that contribute by their research results to the scientific basis out of which (potential) user-oriented climate information products may be produced. A clear majority of the articles have an interdisciplinary character. Articles assigned to category F deal with basic aspects of capturing and handling meteorological observational data while categories G and H contain closest relations to the economic issues this paper is dealing with.

10 In many cases, there is fluent passage between the different categories. For example, articles assigned to the category "information needs" may also refer to existing information supply and vice versa. According to the main focus of the article, the authors chose the assignment that seemed most appropriate.

The following descriptions of the single categories reflect the dominating research foci and show the extent and ways in which the articles address economic issues connected to climate information and funding of information services.

Table 1: Categorization of Search Results (authors)[11]

Category		No. of articles
A	Information Needs	7
B	Information Supply	7
C	Reconciliation	30
D	Studies on Impacts	52
E	Studies on Adaptation	46
F	Articles on Observational Data	7
G	Value of Weather and Climate Information	45
H	Meteorological Services Market (Development)	2
I	Further Articles	21
	Sum	217

3.3 Results[12]

3.3.1 Information Needs (A)

Focus of investigation

The articles assigned to this category deal with the need for adequate climate information and corresponding information services in different parts of economy and society. Many of these articles focus directly on illustrating such needs. Other articles have a broader scope of investigation that comprise general relations between an economic sector and climate change, with information needs playing a crucial role (Jagtap & Chan 2000; Love 2010). In many cases, the articles assigned here are discussion papers reflecting insights from conferences, single expert interviews and / or further literature. A case study acquiring information needs by its own systematic survey (beyond single interviews) was indentified in only one case (Tribbia & Moser 2008).

Sectoral and geographical orientation

With respect to the economic sectors or user groups whose information needs are concerned, the articles cover agriculture (2 articles), tourism, transport, healthcare, coastal management, and ecosystem management (1 article each). The articles are not usually focused on certain regions, but rather refer to general sectoral information needs. In exception, there are two studies dealing with agricultural information needs in sub-humid and humid zones of Africa and Asia (Jagtap & Chan 2000) as well as with information needs for coastal management in California (Tribbia & Moser 2008).

[11] The numbers in the black boxes refer to the number of articles assigned to the referring category

[12] Within chapter 3.3, all references to sources which are not part of the results of the literature research are marked with an asterisk (*)

Recipients of information

Within the articles reflected here, recipients of information are not only the enterprises of each business sector, but also further (potential) user groups. Thus, users of climate information in the tourism sector may be enterprises, tourists or public institutions. In this context, public institutions are seen as information demanders (and not only as information providers), as they fulfill a role as "promoter" of their countries as well as provider of tourist attractions and necessary infrastructure (Scott & Lemieux 2010). An even broader scope of user groups is described in the article on ecosystem management; recipients of information are potentially all decision-makers and people involved in decisions that have a direct or indirect impact on ecosystem management; among others, this comprises scientists, policy advisors and NGOs (Munang *et al.* 2010).

Specification of information needs

The described information needs of the different user groups feature several intersections. Although most of the articles are constructed according to sector rather than regions, they usually emphasize the need for local climate information or for high geographic resolution of weather forecasts, climate predictions or impact studies (Jagtap & Chan 2000; Love *et al.* 2010; Rogers *et al.* 2010; Scott & Lemieux 2010).

The timeframes of the desired climate information are manifold; in virtually every reviewed sector, there is a variety of decision-making processes of different user groups that each benefit from short, medium or long term predictions (Love *et al.* 2010; Munang *et al.* 2010; Rogers *et al.* 2010). So the articles in the health and transport sector illustrate the need for weather and climate predictions for different time horizons, ranging from hours to decades and centuries (Love *et al.* 2010; Rogers *et al.* 2010). The information needs of coastal managers also span a broad time period; they predominantly refer to climate predictions for periods of 5 to 20 years (Tribbia & Moser 2008). Within the article on ecosystem management, short periods are more or less neglected; the need for climate predictions for the next 20 to 100 years is featured (Munang *et al.* 2010). By contrast, referring to the information needs of agriculture, Jagtab and Chan (2000) mention mostly weather forecasts; the time span of predictions needed by farmers has expanded from formerly only short-term / daily weather forecasts to climate predictions for time scales up to a year. Likewise referring to agriculture, Stigter *et al.* (2000) mention different needs for services (e.g. weather and climate forecasts, early famine warning systems and services to prepare for natural disasters) for very different time scales.

Virtually all articles that emphasize the strong relevance of user-oriented climate information in order to advance adaptation to climate change (Munang *et al.* 2010; Rogers *et al.* 2010; Scott & Lemieux 2010; Tribbia & Moser 2008) state increasing information needs in the examined sector (Jagtap & Chan 2000), or expect a future increase in this matter (Scott & Lemieux 2010). Also for the transport sector, abilities to support decision-making processes through climate information are recognized; however, the authors qualify the relevance of these abilities by stating: "*For the transport sector, climate-related information will rarely be the key driver of investment decisions, but rather one of many variables to be considered*" (Love *et al.* 2010: 141). On that note, there are some articles that emphasize the meaning of an integrated perspective i.e. the ability of climate information to support decision-making processes within the respective sectors should not be considered in an isolated way, but always in combination with further socio-economic and ecological factors that influence specific vulnerabilities to climate change (Love *et al.* 2010; Munang *et al.* 2010; Rogers *et al.* 2010). This is in line with the supply side of information products described in section 3.3.2 which can be classified as "decision support systems" because they offer support for concrete decision-making situations by incorporating a variety of aspects and go far beyond a pure supply of climate information.

Economic issues

Many of the reflected articles focusing on information needs do not explicitly address economic issues of (potential) information services that help to meet these needs. The articles, however, occasionally indicate general financial straits and funding needs for adaptation to climate change in their respective sectors (Munang *et al.* 2010; Tribbia & Moser 2008), or for an adequate network of meteorological stations in areas of Africa and Asia (Jagtap & Chan 2000). Furthermore, the need to involve experts from a variety of different disciplines including economics and financial management to create the structure of climate information services is being expressed (Love *et al.* 2010).

However, Scott and Lemieux (2010), who are dealing with information needs in the tourist sector and thereby refer to the existing information supply, explicitly differentiate between public and private (i.e. commercial) weather and climate information services. The commercial services tend to be manifold and user-oriented, especially for the purposes of the final consumers in the tourist sector. These information products and applications comprise, among others, customized offers for specific recreational activities like skiing, surfing and golf. In addition to cable television and internet, there are also recent smart phone applications serving as communication channels for these information products. Although Scott and Lemieux (2010) label these offers (partly) as "climate services", they are better described as applications of weather predictions due to their short-term orientation.

For the agricultural sector, (Stigter *et al.* 2000) envisage good prospects for cooperation between public and private sectors to develop agro-meteorological services. As a matter of principle, public-private partnerships are supposed to be feasible, although the article points out the potentially negative consequences of commercial exploitation of information: "*User fees may be a self-defeating solution if it restricts information delivery*" (C.J. Stigter *et al.* 2000: 213).

Rogers *et al.* (2010) draw attention to the diversity of different climate information sources provided by public and private suppliers. This diversity reflects the growing need for climate information on the one hand as well as the absence of defined structures to support climate services in most countries on the other. However, this situation is improving with the development of regional climate centres that contribute to the development of advanced climate predictions. Furthermore, the authors address the possibility of cooperation between public and private actors in favour of an advanced climate information supply in Africa. Examples for such cooperation can be found within the framework of the development program, "Climate for Development in Africa", which is sponsored jointly by the African Bank for Development, the Commission of the African Union and the United Nations Economic Commission for Africa, and which addresses climate observations, climate services, climate risk management and climate policy needs. "*[…] recognizing the synergy between the capacity of the private sector and the information needs of both the public and private sectors*" (Rogers *et al.* 2010: 39), new public–private partnerships have emerged, e.g. the "Weather Info for All" initiative (WIFA). In the context of this initiative, the telecommunications industry, NGOs and WMO members are cooperating "*[…] to fill the gaps in the surface observing network by installing automatic weather stations on cellular phone towers across Africa*" (Rogers *et al.* 2010: 39).

Potential conflicts regarding the funding of climate information are pointed out by Love *et al.* (2010) in their article on the transport sector. According to their estimation, publicly available studies on the benefits of weather forecasts in the aviation sector are quite scarce, perhaps because airlines fear an increase in government charges when their benefits from such forecasts, which are financed by tax-payers, are highlighted.

3.3.2 Information Supply (B)

Focus of investigation

Articles have been assigned to category B if they address emergence, development and / or use of concrete user-oriented climate information services. None of the information services these articles deal with focus solely on providing climate information. Instead, they involve climate information as a partial aspect of the information supply. All articles summarized here, therefore, can be classified as decision support systems as they offer assistance for concrete decision-making situations.

Sectoral and geographical orientation

All articles reflected here and the DSSs they describe are assigned to agriculture, or in one case relating to forestry. They can be differentiated especially with regard to the decisions they are designed to support, their geographical scope of application and the role and meaning of the climate information incorporated in the system.

The application areas of these systems span regions in the USA (two in Florida), Australia (two), New Zealand, Greece, and Spain. In part, the authors emphasize that the geographic connection serves as a field test for demonstration and validation of a system which was actually developed for a broader geographical applicability (Bonazountas *et al.* 2007; Montesinos *et al.* 2001). Other systems feature a stronger connection to their region of implementation while in some cases, the authors point to options for adapting the system to other areas (Roberts *et al.* 2009).

Role of climate information

The heaviest emphasis on climate information within a DSS may be assigned to the "Florida Automated Weather Network" (FAWN 2012)*. Via the Internet, it offers a variety of observed and predicted weather and climate information as well as decision support. The latter contains, among other things, a toolkit for cold protection, a freeze alert system and an irrigation scheduler for different kinds of plants. Furthermore, "agricultural weather schools", which offer a forum for technical exchange between growers and local climate and weather service providers, are being organized in the context of FAWN (Jagtap *et al.* 2002).

The "Strawberry Advisory System" (SAS) described by Pavan *et al.* (2011) provides information to strawberry growers on current risks of fungal diseases and was implemented as part of the internet platform "AgroClimate" (2012)*. In general, AgroClimate serves to provide climate information in combination with risk management tools for selected areas of agriculture in Florida. Within the SAS module, location-based predictions for the occurrence of fungal diseases are offered as well as interactive recommendations for the use of fungicides. Thus, SAS (in addition to disease models) uses weather information within the framework of a user-oriented information and decision support system. The aim is to contribute to a more efficient usage of fungicides and thus reduce strawberry production costs in Florida. So far, the system makes use of observed meteorological data and short-term weather forecasts; however, the developers plan to include seasonal climate forecasting in their future work.

Beukes *et al.* (2008) introduced the "WFM" (Whole-Farm Model), a computer program for pasture-based dairy systems. It was developed to predict the outputs of a whole farm, paddocks or of individual animals. The model consists of a software framework that combines daily meteorological data with model components for pasture growth, animal metabolism, and management policies. Accordingly, it can be used to predict impacts of alterations in climatic conditions or of different management options regarding the outcome of a dairy farm. The article does not refer to climate change explicitly, but links changing dairy management practices with climate challenges such as summer droughts. The meteorological data used by WFM includes minimum and maximum temperature, wind run, rainfall, evapotranspiration, solar radiation and sunshine.

The development of an agricultural application for economic optimization of seasonal furrow irrigation (OPTIMEC) is described by Montesinos *et al.* (2001). The underlying model features four main components: a soil moisture model that uses meteorological data (amongst other data), an irrigation hydraulic model, a crop yield model and a component for economic optimization.

Bonazountas *et al.* (2007) report on the development of a DSS for prevention and management of forest fires. The system is designed to support forest managers and emergency management as well as to report to the general public. It integrates several modules, including a module for acquisition and processing of data like satellite images and meteorological data. This DSS does not represent a climate information service in a narrower sense; however, meteorological data is embedded in the system to predict incurrence and potential development of wildfires. As long as increasing wildfires are seen as a consequence of climate change, such a system can be interpreted as a contribution to adaption (for some regions, the IPCC (2007)* considers an increase of wildfires as a potential climate change although this is a controversial subject).

The prototype of the web-based DSS "eFarmer" is described by Roberts *et al.* (2009). It was developed to support farmers in Victoria, Australia and focuses especially on providing access to spatial information and on supporting users with regard to various issues of agricultural business. The extent to which climate information is being used by "eFarmer" is not conclusively evident from the article; but it indicates that this kind of information has a subordinate meaning within the system. However, in a document published on the webpage of the Victorian Department of Sustainability and Environment (Australia), "eFarmer" is described as a contribution to deal with new challenges for land management including climate change (DSE 2011)*.

A further application in the context of Australian agriculture is presented in the article by Laughlin *et al.* (2007). It deals with the computer program GROWEST and with the extension GROWEST PLUS. The basic program – already developed in 1970 – serves to analyze potential plant growth, based on data of solar radiation, temperature and soil moisture. The extension GROWEST PLUS offers a flexible user interface and enables users to visualize potential plant growth as well as analyze the plant growth of a current season versus the historical record by using a long time-series of real historical data. As Laughlin *et al.* report, GROWEST is used by the "Bureau of Rural Sciences" of the Australian Government to assess whether an event (in most cases related to droughts) may be considered "rare". If this is the case and the event is additionally declared "severe", the Government can provide financial assistance to affected producers in the context of the "Exceptional Circumstances policy". Furthermore, the article indicates that, beyond this kind of use, some program functions may have the potential to assist in agricultural risk management decisions.

Economic issues

Although all supply-oriented articles reflected in this section describe already existing information and decision support systems, economic issues, such as those referring to public and / or private funding of these systems take up very little space, if any.

For example, the acknowledgements section of the article on SAS reveals that the project was funded by the US Department of Agriculture (Pavan *et al.* 2011) and a visit to the system's website shows that it is publicly accessible.

The development of WFM was funded by "Dairy InSight" and the "Foundation for Research, Science and Technology" (Beukes *et al.* 2008). "Dairy InSight" is the precursor of today's "DairyNZ" (2012)*, the industrial goods organisation that represents New Zealand's dairy farmers, funded by the government as well as by a levy on milk solids.

Whether the OPTIMEC model developed by Montesinos *et al.* (2001) to support irrigation planning was ever applied for real use could not be verified via internet research.

The internet platform FAWN (2012) is publically accessible; a magazine for citrus growers calls it a "free weather source" (HCCGA 2011)*.

The project eFarmer was initially founded by the Victorian Department of Sustainability and Environment (Australia). If and to what extent commercial exploitation might play a role in the future development of the application is not clear in the article. The previously mentioned document by the Victorian Department of Sustainability and Environment states: "*The "next generation" eFARMER should be housed and supported by government […]*" and: "*Access to the base functionality of eFARMER should be* ***free*** *to all users across the Victorian landscape* ***at all times and in all places*** (DSE 2011)."

The article on the DSS for prevention and management of wildfires does not address issues of financing and distribution either; although as a contribution to emergency management the public character of the system might be self-evident. The research for the development of the DSS was funded by the European Commission (Bonazountas *et al.* 2007).

Internet research reveals that the computer program GROWEST is distributed commercially. The Australian National University offers licenses for the basic program GROWEST 2.0 at tiered prices for academic users, government users, and commercial users (ANU 2012)*.

3.3.3 Reconciliation (C)

The 30 articles assigned to category C address issues of reconciling scientific knowledge and information needs of users, usually on a more abstract level than the articles of the previous categories. In most cases these do not represent economic articles in a narrower sense though they are of interest from an economic perspective in which enterprises, along with political decision-makers and households, are often seen as (potential) recipients / users of scientific knowledge with respect to economic problems. With this in mind, these contributions serve to separate economically important information within science, to produce usable data for decision makers, and therefore to increase overall economic and social benefits of scientific research on climate change.

Focus of investigation

A large portion of the articles deal with issues of communicating climate information, or of communicating probability statements and uncertainty, and partly develop recommendations for better user-orientation in information conditioning (de Boer *et al.* 2010; Hulme *et al.* 2009; Marx *et al.* 2007; Morss *et al.* 2010; Patt 2007; Patt & Dessai 2005; Spence & Pidgeon 2010; Whitmarsh 2011). Further articles focus on such topics as the manner of presenting aspects of climate change in the mass media (Ahchong & Dodds 2012; Boykoff & Boykoff 2007; Doulton & Brown 2009); on general aspects regarding usability of scientific research, using research on climate change as an example or in the context of a case study (Cash & Moser 2000; McNie 2007; Sarewitz & Pielke Jr. 2007); or on efforts or potentials of a certain scientific discipline to contribute to more application-oriented climate-related research (agro-meteorology (Olufayo *et al.* 1998; Stigter 2008), geography (Moser 2009); as well as Operations Research und Management Science (OR / MS) (Regnier 2008)).

Some of the articles also refer to the roles of intermediary institutions – a concept from the discipline of organizational theory. Most of the articles with such references mainly see the role of intermediaries in linking the supply and demand chains of climate information and fostering communication between them. In this sense, McNie (2007: 28) argues that "*Boundary organizations act as intermediaries between scientists who produce information, and decision-makers who use the information*", Moser (2009: 8) identifies a need for "*translators and intermediaries between research, decision-makers and wider stakeholder communities*", and Sarewitz and Pielke Jr. (2007: 9) state that "*Intermediary institutions – sometimes called boundary organizations – may enhance the pursuit of well-ordered science by mediating communication between supply and demand […]*". Similar examples can be found in Davey and Brookshaw (2011), Gawith *et al.* (2009) and Hammer *et al.* 2001). Further articles (Cash & Moser 2000; Olufayo *et al.* 1998; Stigter 2008; Vogel *et al.* 2007), however, take a deeper look at such intermediary institutions and / or see broader scopes for them.

Economic issues

With respect to a responsibility to produce and provide information on climate change, most articles in category C place emphasis on the public sector (Moser 2009; Sarewitz & Pielke Jr. 2007; Spence & Pidgeon 2010; Storch 2009). McNie (2007), for example, mentions in a footnote that the problem of unfulfilled information needs may be considered a problem of public goods. Recipients of information are public as well as private actors (Gawith *et al.* 2009; Patt & Dessai 2005; Regnier 2008).

However, some of the studies regard private enterprises as having a more active role regarding the supply of climate information. Thus, they address the need to better combine public and private research in future (Lemos & Morehouse 2005). In the context of the above cited reference to "boundary organizations" by Cash and Moser (2000) whose task is seen as "translating" scientific insights, the authors mention the need to also consider research conducted by the private industry. Sarewitz and Pielke Jr. (2007) explicitly focus on publically as well as privately funded scientific work, and McNie (2007) points to private organizations that deal with the transfer of information between the scientific community and society. Others mention the existence of private / commercial agro-weather services and advisors (Hammer *et al.* 2001; Sivakumar 2006); moreover, Hammer *et al.* (2001) raise the question of who should pay for research on advanced climate predictions. This question arises especially given the potentially high value of such predictions for producers as well as for consumers of agricultural products. Also Regnier (2008) addresses commercial weather services whose activities – such as those regarding climate predictions – have greatly expanded in the recent past. On one hand, they are conditioning and "packaging" data from (public) National Weather Services (NWS), but on the other, they have also developed their own meteorological models and some have even built their own networks of weather monitoring locations. The author mentions the example of "AWS Convergence Technologies, Inc.", an enterprise that, after only 10 years in existence, already boasts of more observation locations than the National Weather Service (NWS) of the

United States. Within the articles that deal with analyzing the presentation of climate change in the mass media, there are, of course, also private enterprises taking the role of information providers (Boykoff & Boykoff 2007; Doulton & Brown 2009).

For agrometeorological information, the research contribution by Sivakumar (2006: 28) states (with reference to Kruger & Dommermuth (1999)*), what the current paper reiterates regarding tailored climate information in general: .

3.3.4 Impact Studies (D)

The literature reflected in the previous chapters addresses questions that may be assigned to the subject of user-oriented information formats and systems. Basically, it is about the application of climate information by decision-makers – in politics, economy or on a household level. The literature assigned to category D deals with the scientific application of climate information and with its academic use to produce climate information in a wider sense. This concerns impact studies (category D) as well as adaptation studies (category E).

The headline “impact studies” collects articles that focus on the analysis of consequences of climatic conditions for certain societal or natural systems. With 52 out of 217 articles, the impact studies form the largest category of this literature research.

Focus of investigation
Many of the articles assigned here may be divided according to their temporal orientation into prospective and retrospective studies.

Prospective studies are concerned with potential impacts of climate change on certain systems, such as agricultural production in a certain area and / or in a certain agricultural subsector. Alternatively, they focus on general, sector-overlapping impacts of climate change. Many use climate models in combination with specific (sub-)models to illustrate aspects such as tourism flows, growth of types of corn, stream flow of rivers, or global streams of commerce for agricultural products.

Further articles examine statistical correlations between observed weather and observed changes in the explored system (e.g. between “empirical snow depth” and “number of overnight stays” in a ski area (Falk 2009)). These kinds of studies do not always refer directly to current issues of global warming and are therefore not always about potential impacts of climate change, but refer more generally to impacts of climatic conditions or impacts of changes in these conditions. In some of these studies, climatic factors are not the only examined influences on a system. This applies to studies that deal with the identification and analyses of land use changes in an area of investigation, thereby including socio-economic and / or biophysical factors in addition to climatic ones (Amsalu 2007; Oberthür 2011; Odgaard 2011; Wang 2008).

Further examples of investigation foci of impact studies are:

- regional vulnerabilities to socio-economic results of climatic changes in different areas (Belliveau *et al.* 2006; Chhetri 2010; Fraser *et al.* 2008; Polsky & Easterling III 2001),
- risk factors for animal mortality in livestock production (climatic risk factors, among others) (Basumatary *et al.* 2009; Tibbo *et al.* 2003),
- elasticities between precipitation, potential evapotranspiration and streamflow for water resource management (Liu & Cui 2009).

Sectoral and geographical orientation
As already apparent from the deliberations above, the articles may furthermore be differentiated according to their field of application or to the system within which impacts of climatic changes are analyzed. With 25 articles, a majority of the investigated impact studies deal with agriculture. Sixteen articles make contributions either for the tourist sector, fisheries, ecosystem management, water resource management, the energy sector, retail or transport / traffic, while eleven have a sector-independent or sector-overlapping focus. In addition to sectoral specification, most articles have a regional focus and present results from case studies. Geographically, these case studies are widespread and cover all continents. Some articles (region-overlapping) refer to climate impacts in certain sectors (Badjeck *et al.* 2010; Francisco & Guise 1988; Kang *et al.* 2009; Miller *et al.* 2010; Reilly *et al.* 1994) while some (sector-overlapping) to climate impacts in certain regions (Changnon & Changnon 2005; Falloon & Betts 2009; O’Brien *et al.* 2009; Ploner & Brandenburg 2003; Sosa *et al.* 2011; Stuart *et al.* 2011; Turner *et al.* 2009). No single region or sector is emphasized by Martens *et al.* (2010), who provide an overview of literature on the potential impacts of abrupt, extreme, and irreversible climatic changes.

Further articles have no sectoral or geographical orientation, but deal with general methodical questions regarding impact analysis or contribute to methodical advancements. One such study is by Lorenzoni *et al.* (2000), and considers the integration of climate scenarios in the context of impact assessments, while the article by Malone and Yohe (1992) reflects on the results of the Second World Climate Conference (SWCC) and of an immediate follow up workshop. The latter discusses an approach for the development of a general methodical framework to assess regional climate change impacts.

Reference to climate information and economic issues
With regards to the term “climate information”, which is the focus of this paper, impact studies play a dual role. On one hand, they represent a type of application of climate information in their own right, as they use information on meteorological parameters in the study area (often simple observational data) to analyze correlations between changes in these data and changes in the investigated system, or to integrate measured data or modelled predictions into system models. On the other, impact studies not only use, but also produce more sophisticated climate information (climate information in a wider sense), therefore contributing to an advanced level of knowledge about potential climate change impacts and enriching the scientific basis for (potential) user-oriented information services.

Direct references to questions of responsibility for the establishment of climate information services barely appear in the impact studies reflected here. In some cases, the great importance of gaining access to information in order to enable adequate adaptation decisions for certain communities is mentioned (Changnon & Changnon 2005; Fraser *et al.* 2008). However, the article by Agnew and Thornes (1995) which examines the weather sensitivity of the UK food retail and distribution industries calls attention to the potentially high economic benefits of using meteorological information in decision-making.

3.3.5 Adaptation Studies (E)

A further group of articles deals primarily with adaptation to climate change. Similar to the impact studies, most studies are sector and region-specific case studies.

For these, especially the type of adaptation measures can be differentiated. While a significant number of the articles (18 of 46) focus on adaptation measures of single actors / households, others deal with public adaptation or public / institutional measures to create adaptation frameworks (12), and sometimes with policy advice. Sixteen others address general or overlapping questions and cannot be clearly assigned to either of these two types.

Focus of investigation
Some of the studies examine political adaptation strategies (Biesbroek *et al.* 2010; Falaleeva *et al.* 2011; Tompkins 2005; Trotman *et al.* 2009), while others analyze adaptation measures that have (or have not) been implemented at an individual level (Buzinde *et al.* 2009; Gössling *et al.* 2012; Li *et al.* 2010; Mortreux & Barnett 2009) or an overlapping level (Doswell III 2003; Hisali *et al.* 2011; Tompkins *et al.* 2010). Other articles do not address actual adaptation measures but deal with the adaptation capacities of certain communities (Crane *et al.* 2011; Hobson & Niemeyer 2011; Picketts *et al.* 2012; Simoes *et al.* 2010). Still others deal with the examination of agro-meteorology to support adaptation to climate change (Salinger *et al.* 2000; Sivakumar *et al.* 2000), identifying factors that influence choice of adaptation measures (Bryan *et al.* 2009; Deressa *et al.* 2009; Jones & Boyd 2011), or undertake the analysis of (cognitive) perceptions of climate risks and their implications for choosing adaptation measures (Patt & Schröter 2008; Tschakert 2007).

Eight articles focus on a certain instrument of adaptation, reflect its functionality and / or analyze its applicability for a certain community (Abel *et al.* 2011). Seven of these analyze instruments of the financial industry like (micro-)drought-insurance for smallholders in developing countries (Conway & Schipper 2011; Meze-Hausken *et al.* 2009; Patt *et al.* 2010), agricultural insurances in general (Leblois & Quirion 2011) or weather derivatives (Beyazıt & Koc 2010; Jewson & Caballero 2003; Pollard *et al.* 2008). It should be noted that two of these have no (Jewson & Caballero 2003) or only casual (Leblois & Quirion 2011) reference to climate change, and their focus is on financial instruments that serve for adapting to climate or weather variability.

Sectoral and geographical orientation
Of the 46, 21 articles, assigned to the category "adaptation studies", focus on agriculture. In this context, it is noteworthy that agricultural production is the primary source of livelihoods for households in many developing countries, so many of the adaptation studies regarding agriculture focus on adaptation measures and capacities of smallholders. Other articles can be assigned to the tourism sector, coastal management, water resource management and ecosystem management. Nine articles are not sector-specific, or have a sector-overlapping focus.

The study areas in these adaptation studies are also very widespread. The 33 articles that can be assigned to a geographical study area comprise regions on all continents. With ten articles on Africa and five on South America, emerging and developing countries are very well represented.

Reference to climate information and economic issues
Similar to the impact studies, the adaptation studies also focus on questions that do not directly deal with climate information services. However, some studies admit that climate information may play a crucial role in the application of adaptation measures.

Some articles on agriculture in emerging and developing countries identify a lack of access to climate information as an obstacle for taking adaptation action (Bryan *et al.* 2009), or the availability of such information as positively correlated to instituting adaptation measures or strengthening adaptive capacity (Deressa *et al.* 2009; Simoes *et al.* 2010). In this sense, the authors give recommendations like: "*[…] greater efforts should be made to improve the accessibility and usefulness of information provided to farmers to facilitate their adaptation*" (Bryan *et al.* 2009: 424). Corresponding measures that aim to communicate climate information in a way that is comprehensible and useful for the farmers are called "public efforts" in the cited study (Bryan *et al.* 2009). A further study confirms the important role of climate information for the application of adaptation measures, but qualifies the meaning of pure information access. Based on the experiences of a failed initiative to enhance climate risk reception of farmers in Mozambique, the authors conclude that a simple increase of the supply of climate change risk-related information is not sufficient to foster practical and grassroots adaptation activities. Rather, more complex programs are needed which foster active dialogue processes between different stakeholders and secure their involvement in designing adaptation strategies (Patt & Schröter 2008). Frank *et al.* (2011) consider agricultural cooperatives for smallholder coffee farmers in Chipas, Mexico, to be a good forum for such a dialogue. This "forum-function" of cooperatives could serve to transfer climate information from external suppliers to the common "ownership" of groups of farmers, thereby enhancing the legitimacy and credibility of the information for the farmers.

Lack of information is a great obstacle to adoption of adaptation measures, not only in emerging and developing countries but also in industrial ones. (Biesbroek *et al.* 2010: 445) compare the national political adaptation strategies of seven European countries, state about the European population: "*[…] people often lack a clear understanding of the climate problem and the potential impacts and consequences for their daily routines, something which […] is still seen as a major barrier to adaptation*". In this context, measures of climate information supply as part of national adaptation strategies serve to raise awareness among the population and to enhance societal adaptive capacity in the long-term. Examining respective national communication measures, the authors criticize the usually low level of coordination of information supply in connection to the absence of a superior communication strategy in most countries. Crane *et al.* (2011: 184) hint at problems with integrating existing information into business decisions by farmers in Georgia (USA): "*Still, the integration of new information into agricultural management practices is something that itself takes skill.*"

The article by Tompkins *et al.* (2010) on adaptation measures in Great Britain labels providing climate information a political, public task. The effectiveness of information supply thereby depends on several factors including the insecurity of scientists about appropriate information formats that are useful for decision-makers. A previous article by Tompkins (2005), dealing with adaptation to the risk of hurricanes on the Cayman Islands in the Caribbean, recommends integrating climate predictions into planning processes for a more robust infrastructure. With respect to a region in Australia, Hobson and Niemeyer (2011) deal with issues comparing "pure" climate information supply with deliberative platforms for adaptation action.

Some basic issues regarding public responsibility and increasing commercialization in the area of climate and weather prediction are addressed in the article by Pollard *et al.* (2008), in the context of a paragraph on developments that influenced the emergence of the weather derivatives market. The authors illustrate that although WMO Member states agree to freely exchange essential meteorological data, some NMSs withhold some data for sale on a commercial basis. This is especially true for the European Union where price and product lists are determined by the Economic Interest Grouping of the NMSs of the European Economic Area (Ecomet). The US government policy, however, considers meteorological data to be freely accessible which, according to Pollard *et al.* (2008), might be critical as the weather derivatives market depends on such data and might contribute to value addition. Furthermore, referring to the increasing commercialization of weather and climate predictions, the authors note that both public and private weather services today sell their forecasts to government departments, industry and the media. However, all potential implications of such growing commercialization might not comply with the objectives of sustainable development.

A further reference to climate information is found in the article by Falaleeva *et al.* (2011), who outline the potentials of an integrated policy approach for better linkage of climate policy and coastal management in Ireland. The study refers to a proposal of a "national climate change information platform" in order to support local adaptation action. The setup of such decision support systems requires, in addition to substantial political will, financial support by various sources, including through PPPs at the local level. Options for the respective division of tasks are not specified any further.

The article by Doswell III (2003), which is concerned with societal impacts of severe thunderstorms and tornadoes and illustrates adaptation measures in the USA, features numerous references to public and private responsibility, including responsibility for the supply and distribution of information (extreme weather warnings). Official warnings are provided by the NWS and distributed especially via television. Additionally, commercial services provide such warnings in a tailored fashion to specific user-groups. Due to the huge diversity of information users, public-sector meteorologists should not make decisions about the actions users should take. They rather "*[…] should provide useful and valuable meteorological information, and allow users to make their own decisions based on that input, in combination with all the other factors affecting their individual decisions*" (Doswell III 2003: 147). Private sector services, however, can be customized to meet the specific needs of different users. Doswell III (2003) also draws attention to the personal responsibility of each member of society to use the available information in their own best interests. In the USA, it is not unusual for tornadoes to occur unexpectedly for a number of affected persons, although official warnings have been issued by the NWS. In addition to the role of information in terms of forecasts, the author also refers to the bearing of empirical information on such events. With regard to Europe, he criticizes the lack of available data and the lack of assignment of responsibilities for systematically recording events and for maintaining a corresponding archive. Neither public nor private institutions regularly record such data, with the possible exception of insurance companies, who regard it as their own property.
Further articles draw attention to the lack of financial resources for acquiring meteorological observational data in some countries (Sivakumar *et al.* 2000), resulting in vague and inadequate climate projections (Jones & Boyd 2011).

3.3.6 Observational Data (F)

Articles assigned to this category deal with issues of generating and distributing data from monitoring stations and observing systems. Thus, these articles are about the general supply of data that also serves user-oriented information services. Climate modeling requires corresponding data input; scientific studies on the value of weather and climate information, impact analyses, adaptation studies and further research contributions either also need direct input from observational data, or draw indirectly on such data by using results of climate models. From an economic perspective, the establishment and operation of monitoring stations and observing systems, and the generation and management of observational data may be viewed as early and pivotal basic steps within the value-added chains for user-oriented climate information formats.

The seven articles assigned to this category deal with:

- Aspects of weather observation and climate research in developing countries (Hills 1981; Sah 1979)
- Needs for and capabilities of earth and climate monitoring with respect to (user-oriented) climate information services (Karl *et al.* 2010; Manton *et al.* 2010)
- A report on the development of an observing system (Malone *et al.* 2010)
- Aspects of data management and data policy in the context of global change research (Morrissey 1993)
- The identification of barriers to a free exchange of hydrometeorological data in Europe (Viglione *et al.* 2010)

Economic issues
Aspects regarding the characterization of climate information as a public or private good can be found relatively often in this category of literature. It is noticeable that the two oldest articles of this category basically treat climate information as a public good. So, agrometeorological services are declared as "public services" (Hills 1981) and investments in acquiring and disseminating useful weather and climate information as an "alternative form of public investment" (Sah 1979). The latter article further refers to the potentially high economic value that may arise from the availability of useful weather and climate information for developing countries, since especially local climate information may add to productivity in all economic sectors (Sah 1979). In an article published 31 years later, Manton *et al.* (2010: 186) state:

"*Particularly over the last thirty years, seasonal climate prediction has become an accepted public (and commercial) service in many parts of the world.*" Therefore, the authors point to climate prediction services that have developed in the form of public as well as of commercial services. Manton *et al.* (2010) recommend the recognition of the basic monitoring data as a public good as done by the UNFCCC, WMO and Intergovernmental Oceanographic Commission (IOC).

A similar recommendation can be found in an article from the same year by Karl *et al.* (2010). Though the articles do not explicitly refer to economic properties of goods, the authors suggest that the availability of "climate-relevant data" should be ensured for "all communities". However, they note major barriers to the international exchange of corresponding data; in addition to technical and financial problems, this also refers to the refusal (for numerous socio-political reasons) of some countries to make their data available. This issue is also taken up by a further article: Viglione *et al.* (2010) deal with the identification of barriers to the exchange of hydrometeorological data in Europe. While most of the other articles that deal with such questions reflect discussion contributions and workshop reports, this article reflects a rare case study that examines economic aspects (among others) of climate information, in this case "barriers to free data exchange". A survey among European data providers and users offers corresponding insights into these barriers. Referring to the occasional reluctance to make data publicly available, the authors offer some background information. In recent decades, National Meteorological and Hydrological Services (NMHSs) have often suffered financial pressure due to reduction of traditional public funding. Therefore, a situation has emerged in which NMHSs regard their databases as their own assets that can be used to generate short-term revenues and to recover the costs of data generation. This development has again led to conflicts regarding free data exchange. Furthermore, the authors point to the number of private companies collecting data, such as hydropower producers, irrigation companies or inland navigation companies. These organizations tend to consider the data sets as their own property while others consider them a public good.

3.3.7 Value of Climate and Weather Information (G)

Articles assigned to category G deal with the examination of the economic value of climate and weather information. Major parts of the literature reflected before were published especially in recent years and offer contributions to analyze current, heavily discussed problems related to climate change. The articles assigned to category G, however, have a long history; there is a multitude of studies dealing with the question of which value should be assigned to information about future climatic conditions for different actors in the context of different decision-making situations. Therefore, the average publishing year of the 45 articles on the value of climate and weather information is 2001, while that of the overall literature basis is 2006.

Focus of investigation
Some articles deal with the microeconomic benefit a user or user-group may gain from applying weather or climate information (services). These studies assess such benefits usually with respect to concrete business decisions. Other articles deal with overall economic advantages of using climate information.

Sectoral and geographical orientation
Of the 45 ar ticles assigned to the category "value of climate and weather information", 22 are located in the area of agriculture, while a fur ther three focus on the transpor t sector. The rest have no sector-specific character, or repor t on sector-overlapping case studies. A total of 31 ar ticles repor t on case studies that may be assigned to cer tain geographic areas, primarily located in Nor th America (11), Australia (9), and Europe (5).

Methods
The studies with a microeconomic perspective often use the same methodological approach that bears different names in literature; in the present paper it is called "economic quantitative decision model". A lot of the studies reflected here use such decision models either in the context of their own case studies or as a basis for discussion and, thus, possibly contribute to methodological advancements.

As already stated in chapter 2, the benefits of using climate information arise if the decisions it influences achieve better outcomes than they would without using the information. The economic quantitative studies focus on precisely this issue as they assess the value of informa-tion (usually a prediction) by assessing this additional outcome obtained by using the information in the context of a decision-making situation. So, usually these studies proceed on the assumption that the value of a prediction results mainly from the effect that the prediction has on the decision of an individual user who is active in a climate-sensitive area. To analyze these effects and thereby the value of the prediction, economic quantitative decision models are used. These may be divided into descriptive and prescriptive approaches. Descriptive approaches aim to reproduce decisions; therefore, they need a model that can depict the actual decision processes of an actor. Prescriptive models, however, are directed towards identifying optimal decisions ex ante. They comply with a normative approach since they need basic assumptions from which logical decision rules may be deduced (Stewart 1997)*. In the context of a prescriptive study, the value of a prediction is interpreted as the value that occurs to an idealtypical decision-maker who acts optimally according to a normative decision rule. Descriptive studies, however, assess the value of a prediction for a real decision-maker who may not be optimally using the information. In both cases, a payoff matrix for a specific decision situation is used; payoffs accrue from the decision made (e.g. "irrigating the field" or "not irrigating the field") and from the realization of the weather (e.g. "rain" or "no rain"). Stewart (1997)* gives an example of the value of a weather forecast for a building contractor who needs to decide whether to pour concrete or not. Generally, he does not want to pour if it will rain before the concrete sets. So, the economic consequences of his decisions depend on the realization of the weather in the relevant timeframe as displayed in Table 2.

Table 2: Payoff Matrix (Stewart 1997)

	Do not pour	**Pour**
Rain	EUR -250	EUR -1000
No rain	EUR -250	EUR 1700

The decision not to pour concrete always leads to an economic loss of EUR 250, independent of weather realization. Pouring, however, leads to a EUR 1700 payoff in case of no rain and to a loss of EUR 1000 in case of rain. If there is no forecast available for the relevant time horizon, the contractor considers the empirical probability of raining. In the example, the author assumes this to be 26%. The expected payoff for the contractor's decisions can be calculated for pouring (equation 1) and for not pouring (equation 2):

(1) (- 1000 * 0.26) + (1700 * 0.74) = 998

(2) (- 250 * 0.26) + (- 250 * 0.74) = - 250

Without an available forecast, an ideal-typical and risk-neutral contractor who aims to maximize his profits would always choose to pour, as this leads to the higher expected payoff. If a rain forecast for the relevant time horizon is available to the contractor, this situation might change, of course. The value of the forecast then is calculated as the difference in expected payoffs when a) using the forecast and b) not using the forecast. This description explains the most basic model that is used by these studies, which is rendered more complex with the addition of further information (e.g. on decision rules, accuracy of forecasts, risk behaviour etc.).

Such decision models, especially those following a prescriptive approach, represent this commonly used technique to estimate the value of meteorological information (Frei 2010). Further methods include techniques to reveal user's preferences, like the contingent valuation method (CVM) and the conjoint analysis (Freebairn & Zillman 2002; Frei 2010). However, studies using such approaches are comparably few in number. In the context of this literature research, the articles by Anaman *et al.* (1995, 1997) and Anaman and Lellyett (1996) deserve mention as they discuss the usefulness of the CVM for assessing benefits of meteorological services in Australia and report on respective surveys. Rollins and Shaykewich (2003) use CVM to asses the value of weather forecasts for multiple economic sectors in Canada.

Freebairn and Zillman (2002) offer keen micro-economic insights into the subject of economic benefits of meteorological services in general, as well as an overview of valuation methods in particular. Furthermore, the contribution by Leviäkangas (2009) also offers insightful and current deliberations in this regard. This author stresses that the value of information consists of various components or attributes, as displayed in table 3, and that these attributes are prioritized differently by different actors, according to their personal preferences (Leviäkangas 2009).

Table 3: Attributes of Information Value (Leviäkangas 2009)

Accessibility	**Accuracy**	**Availability**	**Completeness**
Consistency	**Contents**	**Cost**	**Effectiveness**
Form	**Objectivity**	**Relevance**	**Reliability**
Reputation	**Timeliness**	**Uniqueness**	**Validity**

When it comes to choosing the valuation method for a certain investigation, particular attention should be paid to the existence of these attributes. Leviäkangas (2009: 320) states that *"[…] methods and techniques must be applied with understanding and skill, being aware of the limitations and especially of the fact of how well the relevant attributes of information are covered and in which part of the information value chain the measurement takes place."*
For a recent initiative concerned with the enhancement of economic valuation of climate services, especially see Clements *et al.* (2013)*.

Economic aspects
More than the categories reflected before, the articles assigned here are each directly focused on economic issues, or on a certain set of economic issues that are, among a huge variety of further (largely unaddressed) issues, relevant in the context of climate information services. The research foci and the set of methods used by these articles are quite limited.

Aspects referring to information services and to public and private responsibilities for their funding are addressed only occasionally. Overall, mostly public institutions are seen as information providers. Bert *et al.* (2006: 186) state that *"climate information and forecasts in many countries often are provided and subsidized by the public sector"*. Thus, studies on the value of climate information can contribute to justify public investments in necessary (meteorological) technologies. Hansen (2002: 322) points to politically directed institutions that provide climate predictions and supports their use, *"allocation of public resources to research, education and development can either constrain or enhance the effectiveness of such institutions."* Gunasekera (2010) writes in favor of characterizing climate information - including production, distribution and use - as a global public good since both characteristics of a public good, i.e. non-rivalry in consumption and non-excludability, apply. This means free and unrestricted access to climate information for everyone. Although Gunasekera (2010) strongly stresses this public character of climate information, he expects the need for significant public and private investments to lead the GFCS and to accompany national efforts to success. Aspects regarding incentives for such private investment are not addressed further. Kaiser and Pulsipher (2004) briefly address the existence of commercial enterprises providing information services on currents, winds, and waves to private ships for routing issues. Here, both public and private actors are viewed as recipients or beneficiaries of weather and climate information.

As stated earlier, the contributions of Freebairn and Zillman (2002) and Leviäkangas (2009) offer very insightful deliberations on economic perspectives beyond "common" issues of evaluating benefits.

3.3.8 Meteorological Services Market (H)

While there are plenty of articles focusing on the value of weather and climate information as a special economic issue, very few articles emerged in this literature review that focus on economic questions of market development for meteorological services. While some occasionally refer to such issues, the two summarized here contain an explicit focus on these questions. Firstly, the contribution by Pettifer (2008), bearing the headline "Towards a stronger European

market in applied meteorology", reflects on the past and current size of the European meteorological services market and assesses its future potential. The author observes a very slow market development in recent years, which he ascribes to several distortions. The most important refers to the dominant characteristic of NWSs to act as both (more or less monopolistic) data suppliers to commercial services and simultaneously as their competitors.

Secondly, Freebairn and Zillman (2002) characterize meteorological services with regard to their economic properties, as highlighted in section 2 of the current paper. The authors use a simple economic model to describe production processes for information services that include two stages, a public and a private one. They derive and discuss implications for public and private funding for different types of services.

3.3.9 Further Articles (I)

Focus of investigation

Category 1 comprises articles that could not be assigned to any of the chosen categories. It forms a very heterogeneous group, and includes studies such as economic optimization of moth thresholds on cotton considering climatic conditions (Cox *et al.* 1991), performance tests of micro-wind turbines including wind speed prediction tools (James *et al.* 2010) and potential contributions of dendrochronology to climate modeling (Beniston 2002). Further studies reflect the history of research programs (Pielke Jr. 2000) or deal with the development of a conceptual framework for better integration of mitigation and adaptation on a community level (Shepperd *et al.* 2011) and more. In most cases, climate information plays a superficial role within these articles.

Reference to climate information and economic issues

Shepperd *et al.* (2011) rate "salient information" for local decision-makers amongst the requirements for an improved process of building awareness, as well as capacity, for developing climate change solutions at the community level. When describing the evolution of the "US Global Change Research Program", Pielke Jr. (2000) states that the program fell short of providing information usable to decision-makers.

3.4 Key Findings

3.4.1 Quantitative Findings

The majority of the identified research articles related to climate information were published in recent years. As Figure 6 shows[13] , there is a clear trend of rising numbers of publications (blue columns) over time. However, this observation does not apply to those articles dealing with the economic value of climate and weather information (category G). For the number of publications within this literature category (orange columns), there is no such trend perceptible. As discussed in chapter 3.3.7, these research contributions have a long tradition, independent of the rising awareness of climate change. Therefore, they often refer to short-term weather forecasts than to long-term climate variations.

[13] Blue columns represent the publication years of the entirety of articles in the literature basis that have been published before 2012 (197 out of 217 articles). Orange columns represent the publication years of those articles assigned to category G (value of climate and weather information) that have been published before 2012 (43 out of 45 articles).

Figure 6: Publication Years of Search Results (authors)

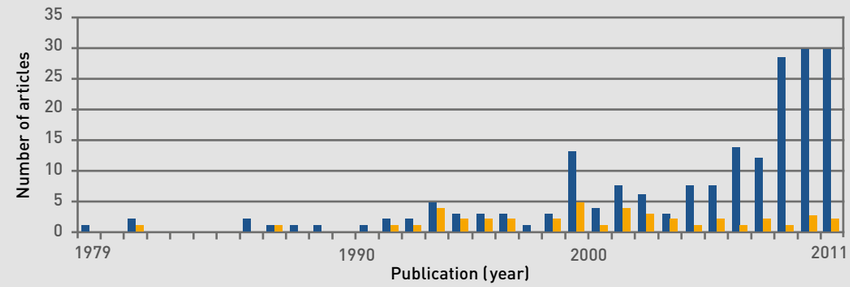
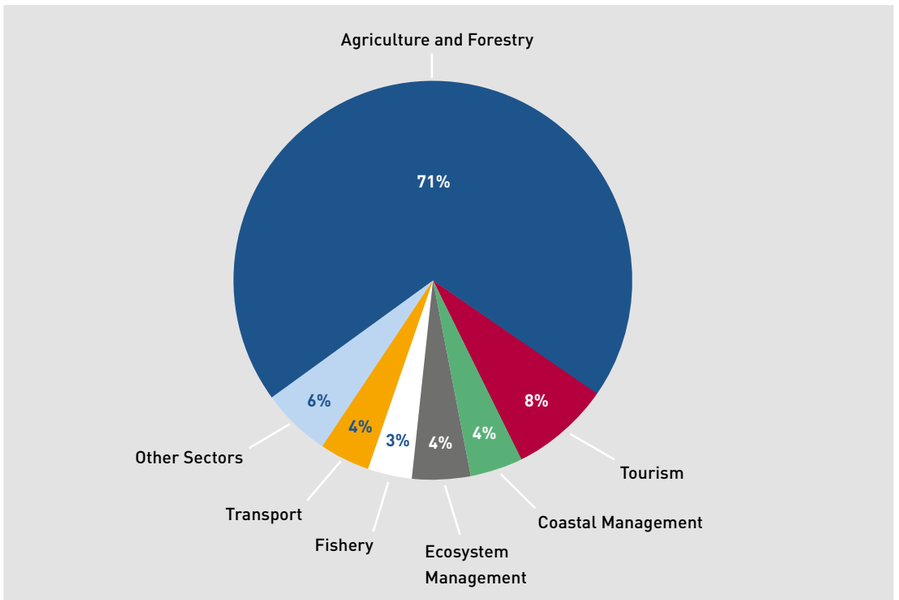


Figure 7 shows that more than half of the articles (124 out of 217) take up investigations that can be assigned to a certain sector of the economy[14]. Amongst those, the agriculture and forestry sector dominates considerably, with 87 articles. Other articles relate to tourism (10 articles), coastal and ecosystem management (5 articles each), transport (5 articles), fishery (4 articles), energy (3 articles), water resource management (3 articles), human health (1 article) and food retail and distribution (1 article).

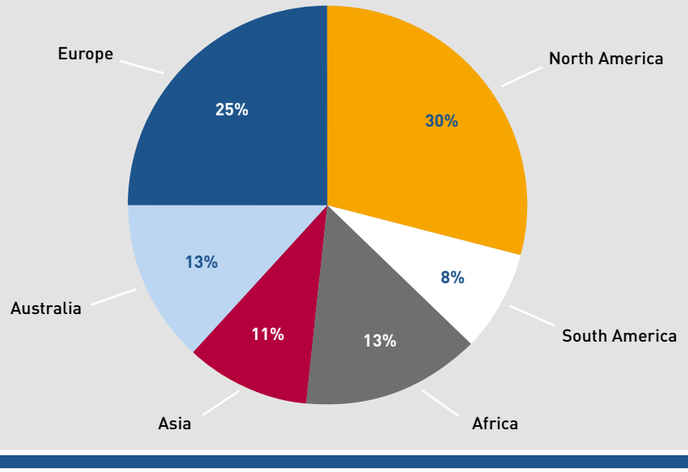
Figure 7: Sectoral Research Focus of Search Results (authors)



[14] Articles that take up investigations referring to more than one economic sector have not been taken into account here.

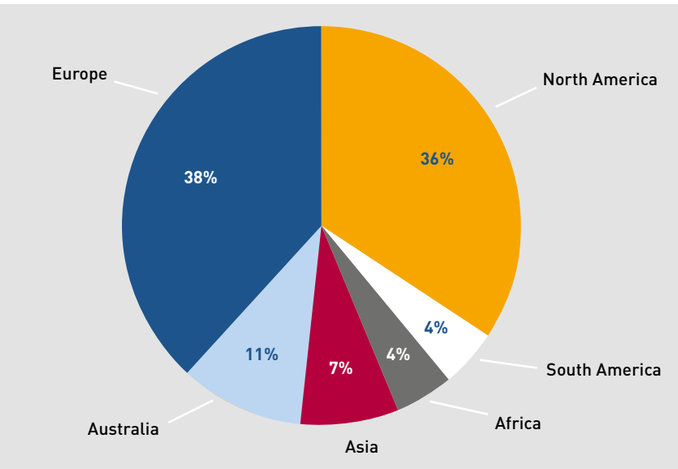
Furthermore, many of the identified research contributions reflect on investigations in a certain region. Of the 217, 143 articles can be assigned to a certain continent[15]. This regional orientation reflects more balance than the sectoral one, as shown in Figure 8. The articles cover regions on all continents; however, research areas in the industrialized world are in the majority with more than half of the region-specific articles concerned with North America (30%) and Europe (25%).

Figure 8: Geographical Research Focus of Search Results (authors)



The imbalance of research areas in North America and Europe might be partly ascribed to the origin of the research articles. As Figure 9 shows, nearly three-quarters of the 217 articles were written by authors representing institutions from these two continents[16].

Figure 9: Geographical Origins of Search Results (authors)



[15] Articles that take up investigations in multiple regions that are located on more than one continent have not been taken into account here.
[16] Figure 8 refers to the origin of the research institution represented by the lead authors of the articles. Subordinate authors have not been considered in this portrayal. If an article is assigning the lead author to more than one institution, they have been considered in equal shares.

3.4.2 Qualitative Findings

This research shows conceptual information-economic considerations that illustrate why and how issues of generating and disseminating user-oriented climate information become economic issues; and it points to the high relevance of economic research on these subjects.

The literature analysis reflected in this paper offers insights into the extent that such economic issues are currently being addressed and the role climate information takes within different, sometimes very heterogeneous economic and interdisciplinary research contributions.

The analysis shows that there is much less economic research activity on climate information (systems) than the high relevance generally attached to the development of such systems may suggest. As shown, there are contributions focusing on information needs (A), information supply (B) or on the reconciliation of both (C), which occasionally mention issues of public and private responsibilities or examples of cooperation.

Other articles focus on producing knowledge on climate (change) impacts (D). Within these kinds of studies, economic aspects are often compiled with reference to climate impacts whereas economic issues referring to information itself or to systems for disseminating information are usually insignificant. The articles that focus on adaptation to climate change (E) quite often stress the role of availability of adequate information to support adaptation activities. Within these, there are many references to public and private responsibilities for adaptation to climate change in general and quite a few references to the production and dissemination of climate information in particular. Two articles explicitly address economic issues of climate information; with respect to observational data in one case (Pollard *et al.* 2008) and to extreme weather warnings in the other (Doswell III 2003).

References to climate information as a public or private good can be found relatively often in the literature category on observational data (F), especially with respect to empirical data and in some cases also with respect to forecasting services. Articles addressing the value of climate and weather information (G) are thereby indeed directly dealing with economic issues, or with a certain set of economic issues that are, in addition to a huge variety of further (widely unaddressed) issues, relevant in the context of climate information services. The research foci and the set of methods commonly used by these articles are quite limited. Two further articles focus on funding options and market development for meteorological services (H) and thereby on further economic aspects of climate information considered highly relevant by the authors of this paper.

A few articles address and focus on economic issues in the context of their own investigation. However, a number of others at least mention economic and institutional aspects of climate information services such as the economic relevance of their availability or the potential roles of public and private actors.

The analysis has revealed that the scientific community working on climate change information issues applies an economic perspective to these issues only to a limited degree. Issues regarding the information-economic properties of climate information, as well as possibilities and impediments of public and private cooperation to establish climate information services, are currently barely being addressed.

4. PROPOSAL FOR A RESEARCH AGENDA

The following research proposals refer not only to information economics as this paper's initial perspective but also to other (economic) disciplines like institutional economics, organizational theory, risk modeling, value chain management, business economics etc.

In addition to economic theory and the literature review, it builds on the authors' co-operation with the financial sector since 2008 (see e.g. von Flotow and Cleemann (2009), von Flotow *et al.* (2011), or CFI (2012)) and dialogues with NMSs and climate service providers. These activities of the Sustainable Business Institute (SBI), Germany, are part of the project "CFI - Climate Change, Financial Markets and Innovation", funded by the Ministry for Education and Research, Germany. Special focus lay on the elaboration of information needs of the financial sector. Several workshops have been conducted as part of the service development of the Climate Service Center (CSC 2012), and on the international level, in co-operation with the UNEP Finance Initiative, WMO and the Climate Services Partnership Initiative (CSP) at the International Conference on Climate Services in 2012 (ICCS2).

In addition to scientific climatological issues, the development of climate information services also faces economic and institutional challenges. This applies especially to the fact that adaptation to climate change in general and the supply of climate information in particular do not represent issues that lie clearly within the responsibility either of the public or the private sectors, but rather constitute issues of shared interest and responsibility. Given the current high priority of climate information tailored to user needs, allocation of responsibilities to the private or public sector regarding the generation of necessary information, operation or implementation of services, development of feasible business models, or roles of public private partnerships (PPP) will gain increasing significance in the future. Studies related to the economic value of climate change (impact) information, the operability of climate information markets and the development of institutional arrangements to overcome market frictions could contribute to overcome such challenges.

For now, we suggest structuring the proposed research agenda as follows:

User / demand side oriented research (4.1)

- Analysis of information and service needs and identification of respective gaps
- Economic analysis on the value of climate information
- Research on integration of climate change information into risk models / risk management tools of different users

Provider / supply side oriented research (4.2)

- Mapping and classification of information services
- Modeling of value-added processes and cost structures
- Management and coordination of scientific work and service development
- Understanding and developing the role of service providers
- Uncertainties and quality assurance

Governance oriented research (4.3)

- Development of roadmaps
- Governance options and PPPs

4.1 User / Demand Side Oriented Research

Analysis of information and service needs and identification of respective gaps
There are a huge variety of climate-related information needs of decision-makers in different sectors and regions and for different purposes. The literature research identified several articles that deal with climate information needs in certain economic sectors (category A). However, such contributions, especially those that survey information needs, are few in number. The current literature indicates that there is increasing, though overall still little, research activity in sectors other than forestry and agriculture.

We recommend research and action to analyze the information needs of different types of (potential) climate information users in various economic sectors and regions, and to systematically analyze respective gaps. Such research would constitute the first step in bridging these gaps and would serve as a precondition for the further development of user-oriented services. Furthermore, from an economic perspective, the availability and accessibility of the information needed, the related transaction costs (especially information costs) of the users and the preferred information formats as well as the distribution channels should be specified and investigated. Suggested research should also include economically strategic sectors that are capital intensive and exposed to climate risk like finance, energy supply and infrastructure (with long capital commitment periods).

Economic analysis on the value of climate information
As noted earlier, benefits of information usage arise when using the information enables decision-makers to achieve better outcomes and to reduce risks than not using the information (Freebairn & Zillman 2002). Analysis on the value of information therefore serves to gain insight into potential economic benefits or welfare gains from supplying single users, certain user groups or society with this information, and for making costs and benefits of this provision comparable. Studies on the value of climate information reflected in the literature analysis derive the value of certain types of information usually with respect to a limited set of decision options available to the information user. Within literature, there is some criticism that this type of study lacks realism (Meza *et al.* 2008), so it appears advisable to supplement it using analyses which assess preferences and willingness-to-pay of potential climate information users. For the tourism sector, Scott and Lemieux (2010) lament the complete absence of such studies. The analysis of willingness-to-pay contributes to the assessment of economic value regarding societal welfare gains and thereby legitimates public spending. Beyond, such research supports the analysis of market potentials and the conception of business and pricing models for climate services[17]. However, it is relevant to note that not many (potential) users have already established the expertise needed to assess the (potential) value of climate information services.

[17] For a recent initiative concerned with the enhancement of economic valuation of climate services, see Clements *et al.* (2013)

Research on integration of climate information into risk models / risk management tools of different users

Applied research is needed (e.g. demonstration projects and / or case studies) to provide the (potential) information demanders with advice and support in order to foster informed customers with self-assessment and decision-making capacities. Furthermore, current risk modeling capacities have to be upgraded to integrate results of climate research and modeling.

Climate service providers today are typically not in the position to accomplish these tasks, due to the complexity of sectoral and customer specific decision-situations (beyond climate change issues). This kind of applied research requires competencies beyond climatology and typical adaptation and / or impact research (sectoral, engineering, economic and specific business competencies, operations research and risk modelling competencies etc.). Beyond, the sensitivity of the customer's data as well as the sector-specific or customized and unique risk management system they may have implemented, turn out to be additional challenges for such research and development efforts. Nevertheless, such type of research and development is of high relevance and seems to have been much neglected in the past. It would contribute tremendously to enabling the integration of climate information into different kinds of risk models and management tools and thereby to the further development of customized services.

At the same time decision-makers need to invest in the development of their own capacities for integrating climate (impact) information into their risk assessment, modeling and management, i.e. their decision support systems. Developing necessary information services requires enormous capacities and competencies on the demand side during a relevant time span. Building up these necessary development capacities, in addition to those required on the supply side and within intermediary institutions, may become a critical barrier in the process, especially as costs and benefits of these efforts are not very predictable.

4.2 Provider / Supply Side Oriented Research

Mapping and classification of information services

Currently, for non-experts the (potential) climate information services are not self-evident and often difficult to obtain. Therefore, the identification and mapping of different institutions already offering climate information services is a pragmatic and important short-term task[18]. This should involve the identification of service providers and their institutional backgrounds (institution-related mapping), as well as the identification of services they currently offer for different types of customers (content-related mapping), for e.g. different types of hazards and parameters, different projected climate impacts, time-scales, geographies or spatial resolutions. These mapping activities are supposed to reduce information / transaction costs between the supply and demand sides, while providing a better understanding of the supply side of climate services. Thereby they form the necessary counterpart to demand side oriented analyses. It also supports the determination of feasible governance options for climate service provision (see governance oriented research, p. 56). The related research task is especially to develop methodologies in the context of national or regional mapping activities that are adaptable to other regions.

[18] Such activities are currently beginning to be conducted in the context of several initiatives, in the European Union especially within the framework of the Joint Programming Initiative - Climate.

Modeling of value-added processes and cost structures

The identification of value-added steps and related costs is a vital task in order to enable preferably exact modeling of value-added processes, to reduce transaction / information costs and develop feasible international and national public and public-private role allocations. Further research on models and methods of how to analyze and share costs can help organize these processes and develop cost sharing and pricing models. Different value-added processes, from acquiring observational data to designing user-oriented final climate information products[19], have to be identified and their different types of fixed and variable costs should be scrutinized. For example, the following types of costs might be relevant: costs for infrastructure to gather meteorological (observational) data, for transfer and application of data, research infrastructure, the development of research models, applications of the models etc. The more actors involved in a value chain, the more the question will arise of who will carry the different costs or pay for them. Within the current literature research, no such contributions have been found.

Management and coordination of scientific work and service development

Developing climate-related information services to support decision-makers requires different types of scientific inputs and the establishment of scientific value-added chains which might differ considerably, according to the type of service. As an information service might need to incorporate information from e.g. climatology, hydrology, and agricultural sciences, the challenge is to coordinate interdisciplinary scientific work in a service-oriented way. Additionally all contributors must be able to support the statements delivered by the service at the end.

This service-orientation requires building up scientific value-added chains of information services, a crucial (management) task that goes beyond the oft-quoted needs for user engagement, communication strategies and interdisciplinary research. Furthermore, the customer-oriented distribution of the information is an additional management task in itself. Organizational theories that focus on value chain management can help design and manage the required information value-added chains for climate services. A business economics perspective may render further relevant contributions, particularly by the discipline of information management and its sub-discipline of information logistics.

Understanding and developing the role of service providers

Climate information service centers currently have different institutional origins, mostly emerging from NMSs and (public) scientific research centers, and are challenged to develop and define their new role. In the context of this literature review, most articles that refer to such issues note that the role of intermediaries is primarily to link the supply and demand sides of climate information (e.g. McNie (2007), Moser (2009), Sarewitz & Pielke Jr. (2007)), as described in sub-chapter 3.3.3). Other articles reiterate the roles of such intermediary institutions and / or see broader scopes of tasks for them (e.g. Cash & Moser (2000), Olufayo *et al.* (1998), Stigter (2008), Vogel *et al.* (2007)).

Contributions from organizational theory that focus on consultancy, knowledge management, technology brokerage (Howells 2006), demand articulation and co-production (Boon *et al.* 2008, 2011) as well as theories regarding the role of KIBS (Knowledge Intensive Business

[19] As indicated schematically in chapter 2.5

Services) and intermediaries for systemic change (Howells 2006; van Lente *et al.* 2003) may help to address their challenges. Given the complex organizational issues surrounding the coordination of scientific research on climate impacts, further development of such approaches might lead to useful results.

Uncertainties and quality assurance

Delivering information services also involves questions of how to assure (scientific) quality within such complex scientific value-added chains and how to deal with remaining uncertainties as an inherent characteristic of all climate services (climate predictions, climate impact predictions and all services building on them). Stressing the need to work on uncertainty communication is in line with a large number of articles identified in the context of the current literature analysis (especially referring to literature category C). These articles are diverse as they come from meteorological research (e.g. Morss *et al.* (2010), geography (e.g. Patt and Dessai (2005)), environmental sciences (e.g. de Boer *et al.* (2010)), anthropology (e.g. Hulme *et al.* (2009)), and especially from psychology (e.g. Marx *et al.* (2007) or Whitmarsh (2011)). They deal with issues related to communicating and mentally processing probability statements, as well as to user-oriented information conditioning and framing. The more non-experts use such information the more relevant his type of research becomes. Some decision-makers may use relatively poor information from secondary information providers while others might use good quality information, but use it in a wrong context due to a lack of interpretation competency.

In addition, from an economic point of view, future research has to address the challenge of potential users in search for reliable information. These customers will ask for an independent "meta-judgement" regarding the reliability of the information and / or the "best available" information. Therefore, institutionalized quality assurance issues will become crucial in addition to communicating uncertainties. For example, insurers call for such quality assurance as they have already experienced that they are not seen as independent contributors to a climate information value chain. As they often fear accusations of being alarmist or of lobbying when raising awareness of climate risks, they are keenly interested in quality assurance. Possibly, independent public institutions will be needed in the future that provide some sort of certification for the scientific quality of information.

In this context, institutional questions arise regarding the organization of such quality assurance as well as the efforts and costs required. Information and institutional economic theory can help to define roles and to find feasible organizational structures for such institutions.

4.3 Governance Oriented Research

Development of roadmaps

Based on a combination of demand and supply side oriented research, a more sophisticated gap analysis with respect to potentials, limitations, economic benefits and further implications can be conducted. This would form the basis for roadmaps that would further develop services and necessary (information) infrastructure.

Such roadmaps that can serve as inputs for national and international climate information policies and for the implementation of the "Global Framework for Climate Services" (GFCS) and other purposes, should be accomplished through research on different roles of policy, private actors, service providers and the scientific community.

Governance options and PPPs

Some processing steps and types of information should be considered public goods, and therefore need to be treated as public tasks. Further investigation on the type of weather and climate information that should be publicly available worldwide is of high economic relevance for building resilient economies. The differences between national legal frameworks for public information duties and the differences regarding the availability of basic (meteorological) data and weather and climate predictions are an indication of the need for further international clarification. In addition, institutional rules should be developed about how publicly funded weather and climate service centers should co-operate and / or compete with each other.

In addition, due to the multitude of climate and sector-related competencies and needs of public and private actors, as well as a spectrum of diverse public-private responsibilities, role allocations at different value-added steps and governance options are imaginable with respect to regulation, cooperation and competition. For instance, some private actors (e.g. insurers) are not only customers of such services but can also contribute as suppliers of highly relevant data (e.g. statistics on damages). An analysis of different types of partnerships, examinations of practices with PPPs as well as examinations of business models, should provide insight regarding the efficiency and efficacy of institutional designs. Such research is directed not only towards the setup of climate information "services", but rather towards climate information "systems", including institutional settings of service providers and rules of interaction with different involved partners and customers.

4.4 Final Remarks

Given the high relevance of climate information and the enormous economical, institutional, and scientific challenges reflected above, there is a strong need

- for public and private capacities and national and international cooperation between public and private actors to face these challenges
- of developing and fostering dialogue, research, and development-related processes on these subjects in order to reduce transaction costs and increase efficiency of institutional arrangements, climate risk management and public and private adaptation to climate change and variablity.

As all efforts related to building up networks and necessary competencies at the different institutions involved require enormous amounts of time exposure, the subject of available climate information services may also become a matter of urgency. Today, for many potential users climate risks may only have the relevance of "emerging risks". But, if a concrete information service is supposed to be available at a certain time in the future, it needs to be taken into account that the lead time for its development may amount to several years.

Therefore, awareness-raising regarding the potential value of climate information should be an ongoing process of mutual learning from both the demand and supply sides.

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APPENDIX A: ASSIGNMENT OF ARTICLES TO LITERATURE CATEGORIES

Information Needs (A)			
(Jagtap & Chan 2000)	(Munang *et al.* 2010)	(Rogers *et al.* 2010)	
(Scott & Lemieux 2010)	(C J Stigter *et al.* 2000)	(Tribbia & Moser 2008)	

Information Supply (B)			
(Beukes *et al.* 2008)	(Bonazountas *et al.* 2007)	(Jagtap *et al.* 2002)	(Laughlin *et al.* 2007)
(Montesinos *et al.* 2001)	(Pavan *et al.* 2011)	(Roberts *et al.* 2009)	

Reconciliation (C)			
(Ahchong & Dodds 2012)	(Boykoff & Boykoff 2007)	(Burandt & Barth 2010)	(Cash & Moser 2000)
(Davey & Brookshaw 2011)	(de Boer *et al.* 2010)	(Doulton & Brown 2009)	(Gawith *et al.* 2009)
(Hammer *et al.* 2001)	(Hulme *et al.* 2009)	(Lemos & Morehouse 2005)	(Marx *et al.* 2007)
(McNie 2007)	(Morss *et al.* 2010)	(Moser 2005)	(Moser 2009)
(Olufayo *et al.* 1998)	(Patt 2007)	(Patt & Dessai 2005)	(Pyke *et al.* 2007)
(Regnier 2008)	(Sarewitz & Pielke Jr. 2007)	(Sivakumar 2006)	(Stone & Meinke 2006)
(Spence & Pidgeon 2010)	(Stigter 2008)	(Troccoli 2010)	(Vogel *et al.* 2007)
(von Storch 2009)	(Whitmarsh 2011)		

Impact Studies (D)			
(Agnew & Thornes 1995)	(Amsalu *et al.* 2007)	(Badjeck *et al.* 2010)	(Bakker *et al.* 2005)
(Basumatary *et al.* 2009)	(Behzad *et al.* 2009)	(Belliveau *et al.* 2006)	(Bornn & Zidek 2012)
(Bullough 2012)	(Changnon & Changnon 2005)	(Chhetri 2010)	(Chipanshi *et al.* 1997)
(Chipanshi *et al.* 1999)	(Denstadli *et al.* 2011)	(Dockerty *et al.* 2006)	(Falk 2009)
(Falloon & Betts 2009)	(Field *et al.* 2006)	(Francisco & Guise 1988)	(Fraser *et al.* 2008)
(Hein *et al.* 2009)	(Holt & Punt 2009)	(Johnson *et al.* 2011)	(Kang *et al.* 2009)
(Kogan 1986)	(Kumar & Parikh 2001)	(Lemke *et al.* 2011)	(Lin & Matzarakis 2011)
(Liu & Cui 2009)	(Lorenzoni *et al.* 2000)	(Lourdes *et al.* 2011)	(Malone & Yohe 1992)
(Martens *et al.* 2010)	(Mestre-Sanchis & Feijóo-Bello 2009)	(Miller *et al.* 2010)	(O'Brien *et al.* 2009)
(Oberthür *et al.* 2011)	(Odgaard *et al.* 2011)	(Ploner & Brandenburg 2003)	(Polsky & Easterling III 2001)
(Reilly *et al.* 1994)	(Roudier *et al.* 2012)	(Ruane *et al.* 2011)	(Scott *et al.* 2007)
(Sosa *et al.* 2011)	(Southworth *et al.* 2000)	(Stuart *et al.* 2011)	(Thornton *et al.* 2009)
(Tibbo *et al.* 2003)	(Turner *et al.* 2009)	(Wang *et al.* 2008)	(Zi Y. Zhang *et al.* 2012)

Adaptation Studies (E)			
(Abel *et al.* 2011)	(Adger *et al.* 2005)	(Beyazıt & Koc 2010)	(Biesbroek *et al.* 2010)
(Bryan *et al.* 2009)	(Buzinde *et al.* 2009)	(Cai *et al.* 2009)	(Challinor 2009)
(Conway & Schipper 2011)	(Crane *et al.* 2011)	(Deboudt 2012)	(Deressa *et al.* 2009)
(Doswell III 2003)	(Falaleeva *et al.* 2011)	(Frank *et al.* 2011)	(Gabrielsson & Ramasar 2012)
(Gössling *et al.* 2012)	(Griess *et al.* 2012)	(Gürlük & Ward 2009)	(Hallegatte 2009)
(Hamilton 2007)	(Hisali *et al.* 2011)	(Hobson & Niemeyer 2011)	(Jewson & Caballero 2003)
(Jones & Boyd 2011)	(Leblois & Quirion 2011)	(Li *et al.* 2010)	(Meze-Hausken *et al.* 2009)
(Moors *et al.* 2011)	(Mortreux & Barnett 2009)	(Patt & Schröter 2008)	(Patt *et al.* 2010)
(Picketts *et al.* 2012)	(Pollard *et al.* 2008)	(Robledo *et al.* 2011)	(Rodima-Taylor *et al.* 2012)
(Salinger *et al.* 2000)	(Simoes *et al.* 2010)	(Sivakumar *et al.* 2000)	(Sovacool *et al.* 2012)
(Tompkins 2005)	(Tompkins & Eakin 2012)	(Tompkins *et al.* 2010)	(Trotman *et al.* 2009)
(Tschakert 2007)	(Vermeulen *et al.* 2012)		

Observational Data (F)			
(Hills 1981)	(Karl *et al.* 2010)	(Malone *et al.* 2010)	(Manton *et al.* 2010)
(Morrissey 1993)	(Sah 1979)	(Viglione *et al.* 2010b)	

Value of Climate and Weather Information (G)			
(Ackerman 1994)	(Anaman & Lellyett 1996a)	(Anaman & Lellyett 1996b)	(Anaman *et al.* 1995)
(Anaman *et al.* 1997)	(Asseng *et al.* 2012)	(Ballentine 1994)	(Bert *et al.* 2006)
(Casati *et al.* 2008)	(Easterling & Mjelde 1987)	(Fox *et al.* 1999)	(Freebairn & Zillman 2002a)
(Frei 2010)	(Frei *et al.* 2012)	(Gunasekera 2010)	(Hansen 2002)
(Harrison 1981)	(Herdan 1994)	(Hill *et al.* 2000)	(Jones *et al.* 2000)
(Kaiser & Pulsipher 2004)	(Kar *et al.* 2006)	(Kite-Powell & Solow 1994)	(Kumar 2010)
(Lee & Lee 2007)	(Leigh 1995)	(Leviäkangas 2009)	(Luseno *et al.* 2003)
(Mazzocco *et al.* 1992)	(Meza & Wilks 2004)	(Meza *et al.* 2003)	(Millner & Washington 2011)
(Mjelde & Hill 1999)	(Mjelde *et al.* 1997)	(Moeller *et al.* 2008)	(Mylne 2002)
(Phillips *et al.* 2002)	(Rollins & Shaykewich 2003)	(Ruth 2010)	(Sherrick *et al.* 2000)
(Stein 2011)	(Vizard *et al.* 2005)	(Walker 2000)	(Wilks 2001)
(Wilks *et al.* 1993)			

Market (Development) for Met Services (H)			
(Freebairn & Zillman 2002b)	(Pettifer 2008)		

Value of Climate and Weather Information (G)			
(Beniston 2002)	(Changnon & Changnon 1996)	(Colander 2010)	(Cox *et al.* 1991)
(Georgakakos & Carpenter 2006)	(Hearn *et al.* 2011)	(James *et al.* 2010)	(Jameson *et al.* 2002)
(Kalabokidis *et al.* 2008)	(Mjelde & Hollinger 1989)	(Murtugudde 2009)	(Patenaude 2011)
(Pielke Jr 2000)	(Potter 1986)	(Quinlan & Scogings 2004)	(Rossa *et al.* 2011)
(Robinson *et al.* 2011)	(Scruggs & Benegal 2012)	(Stephen R. J. Shepperd *et al.* 2011)	(Vicente-Serrano *et al.* 2012)
(Xiuying Zhang *et al.* 2012)			

APPENDIX B: JOURNAL DATABASE

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environmental Science
Accounting Forum		X		
Accounting, Management and Information Technologies		X		
Accounting, Organizations and Society		X		
Acta Agronomica Sinica	X			
Acta Ecologica Sinica	X			X
Acta Oecologica	X			X
Advances in Accounting		X	X	
Advances in Agronomy	X			
Advances in Botanical Research	X			
Advances in Comparative International Management		X		
Advances in Ecological Research	X			X
Advances in Environmental Research				X
Advances in Food and Nutrition Research	X			
Advances in Food Research	X			
Advances in Insect Physiology	X			
Advances in International Accounting		X		
Advances in Marine Biology	X			
Advances in Plant Biochemistry and Molecular Biology	X			
Advances in Plant Pathology	X			
Agricultural Administration	X			
Agricultural Administration and Extension	X			
Agricultural and Forest Meteorology	X			
Agricultural Economics	X		X	
Agricultural Meteorology	X			
Agricultural Sciences in China	X			
Agricultural Systems	X			
Agricultural Wastes	X			X
Agricultural Water Management	X			
Agriculture and Agricultural Science Procedia	X			
Agriculture and Environment	X			X
Agriculture, Ecosystems & Environment	X			X
Agro-Ecosystems	X			X
Algal Research	X			
Alkaloids: Chemical and Biological Perspectives	X			
Analytica Chimica Acta				X

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Animal Behaviour	X			
Animal Feed Science and Technology	X			
Animal Reproduction Science	X			
Annales des Sciences Naturelles - Zoologie et Biologie Animale	X			
Annals of Agricultural Sciences	X			
Annals of Botany	X			
Annals of Nuclear Energy				X
Annals of Tourism Research		X		
Annual Review of Fish Diseases	X			
Appetite	X			
Applied Animal Behaviour Science	X			
Applied Animal Ethology	X			
Applied Behavioral Science Review	X			
Applied Geography	X			X
Applied Soil Ecology	X			X
Aquacultural Engineering	X			
Aquaculture	X			
Aquatic Botany	X			
Aquatic Ecosystem Health and Management	X			
Aquatic Living Resources	X			
Aquatic Toxicology	X			
Archiv für Protistenkunde	X			
Archives des Maladies Professionnelles et de l'Environnement				X
Arthropod Structure & Development	X			
Asia-Australia Marketing Journal		X		
Atmospheric Environment				X
Atmospheric Environment (1967)				X
Atmospheric Environment. Part A. General Topics				X
Atmospheric Environment. Part B. Urban Atmosphere				X
Atmospheric Research				X
Australasian Marketing Journal (AMJ)		X		
Basic and Applied Ecology	X			X
Behavioural Processes	X			
Biocatalysis and Agricultural Biotechnology	X			
Biochemical Systematics and Ecology	X			

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Biochemie und Physiologie der Pflanzen	X			
Biochemistry and Molecular Biology of Fishes	X			
Biochimica et Biophysica Acta (BBA) - Bioenergetics	X			
Biofutur	X			
Biological Conservation	X			X
Biological Control	X			
Biological Journal of the Linnean Society	X			
Biological Wastes	X			
Biological Wastes				X
Biomass	X			
Biomass and Bioenergy	X			
Bioresource Technology	X			
Bioresource Technology				X
Biosystems	X			
Biosystems Engineering	X			
Botanical Journal of the Linnean Society	X			
Building and Environment				X
Building Science				X
Bulletin of Mathematical Biology	X			
Bulletin of the British Mycological Society	X			
Business Horizons		X		
Carbohydrate Polymers	X			
Carnegie-Rochester Conference Series on Public Policy			X	
CATENA	X			
Cerevisia	X			
Cheese: Chemistry, Physics and Microbiology	X			
Chemical Engineering Journal				X
Chemico-Biological Interactions				X
Chemie der Erde - Geochemistry	X			X
Chemistry and Physics of Lipids	X			
Chemosphere				X
Chemosphere - Global Change Science				X
China Economic Review			X	
China Journal of Accounting Research		X		
China Population, Resources and Environment				X

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Cities		X		
City, Culture and Society			X	
Cladistics	X			
Climate Policy				X
Coastal Engineering				X
Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology				X
Comparative Immunology, Microbiology and Infectious Diseases	X			
Composites Business Analyst		X		
Comptes Rendus Biologies	X			
Comptes Rendus de l'Académie des Sciences - Series III - Sciences de la Vie	X			
Comptes Rendus Geoscience				X
Computers and Electronics in Agriculture	X			
Computers, Environment and Urban Systems				X
Conservation & Recycling				X
Continental Shelf Research	X			
Corporate Environmental Strategy		X		X
Critical Perspectives on Accounting		X	X	
Crop Protection	X			
Cryobiology	X			
Cryptogamie Algologie	X			
Cryptogamie Bryologie	X			
Cryptogamie Mycologie	X			
Cuadernos de Economía			X	
Cuadernos de Economía y Dirección de la Empresa		X		
Current Biology	X			
Current Opinion in Environmental Sustainability				X
Current Opinion in Plant Biology	X			
Decision Support Systems		X		
Deep Sea Research (1953)	X			
Deep Sea Research and Oceanographic Abstracts	X			
Deep Sea Research Part A. Oceanographic Research Papers	X			
Deep Sea Research Part B. Oceanographic Literature Review	X			

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Deep Sea Research Part I: Oceanographic Research Papers	X			
Deep Sea Research Part II: Topical Studies in Oceanography	X			
Dendrochronologia	X			X
Der Zoologische Garten	X			X
Desalination				X
Developments in Agricultural Economics	X		X	
Developments in Agricultural Engineering	X			X
Developments in Aquaculture and Fisheries Science	X			X
Developments in Atmospheric Science				X
Developments in Crop Science	X			X
Developments in Earth and Environmental Sciences				X
Developments in Environmental Economics				X
Developments in Environmental Modelling				X
Developments in Environmental Science				X
Developments in Food Science	X			
Developments in Integrated Environmental Assessment				X
Developments in Marine Biology	X			
Developments in Mineral Processing				X
Developments in Plant Genetics and Breeding	X			
Developments in Soil Science	X			X
Developments in Water Science				X
Digital Investigation		X		
DNA Repair				
Domestic Animal Endocrinology	X			
Ecological Complexity	X			X
Ecological Economics	X		X	X
Ecological Engineering	X			X
Ecological Indicators	X			X
Ecological Informatics	X			X
Ecological Modelling	X			X
Economic Modelling			X	
Economic Systems			X	
Economics & Human Biology	X		X	

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Economics Letters			X	
Economics of Education Review			X	
Ecotoxicology and Environmental Safety				X
Electronic Commerce Research and Applications		X		
Emerging Markets Review		X	X	
Energy and Buildings				X
Energy Economics			X	
Energy in Agriculture	X			
Energy Policy				X
Energy Strategy Reviews		X		X
Engineering Costs and Production Economics			X	
Engineering Management International		X		
Environment International				X
Environmental and Experimental Botany	X			
Environmental Development				
Environmental Forensics				X
Environmental Hazards				
Environmental Impact Assessment Review				X
Environmental Innovation and Societal Transitions			X	X
Environmental Modelling & Software				X
Environmental Policy and Law				X
Environmental Policy in an International Context				X
Environmental Pollution				X
Environmental Pollution (1970)				X
Environmental Pollution Series A, Ecological and Biological				X
Environmental Pollution Series B, Chemical and Physical				X
Environmental Research				X
Environmental Science & Policy				X
Environmental Software				X
Environmental Toxicology and Pharmacology	X			X
Epidemics				
Estuarine and Coastal Marine Science				
Estuarine, Coastal and Shelf Science				
Ethics and the Environment				X

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Ethology and Sociobiology	X			
European Economic Review			X	
European Journal of Agronomy	X			
European Journal of Cell Biology	X			
European Journal of Political Economy			X	
European Journal of Protistology	X			
European Journal of Purchasing & Supply Management		X		
European Journal of Soil Biology	X			X
European Management Journal		X		
Evaluation and Program Planning		X		
Evolution and Human Behavior	X			
Experimental and Toxicologic Pathology	X			
Experimental Pathology	X			
Experimentelle Pathologie	X			
Expert Systems with Applications		X		
Explorations in Economic History			X	
FEBS Letters	X			
FEMS Microbiology Ecology				X
Field Crops Research	X			
Field Mycology	X			
Finance Research Letters			X	
Financial Services Review			X	
Fish & Shellfish Immunology	X			
Fish Physiology	X			
Fisheries Research	X			
Flora - Morphology, Distribution, Functional Ecology of Plants	X			X
Food and Bioproducts Processing	X			
Food and Chemical Toxicology	X			X
Food Chemistry	X			
Food Control	X			
Food Hydrocolloids	X			
Food Microbiology	X			
Food Policy	X		X	
Food Quality and Preference	X			
Food Research International	X			
Forest Ecology and Management	X			X
Forest Policy and Economics	X			X

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Fungal Biology	X			
Fungal Biology Reviews	X			
Fungal Ecology	X			
Futures		X		
Games and Economic Behavior			X	
Geoderma	X			
Geoforum			X	
Global and Planetary Change				X
Global Environmental Change				X
Global Environmental Change Part B: Environmental Hazards				X
Global Finance Journal			X	
Government Information Quarterly		X		
Harmful Algae	X			
Healthcare Management Forum		X		
HOMO - Journal of Comparative Human Biology	X			
Human Resource Management Review		X		
IIMB Management Review		X		
Industrial Crops and Products	X			
Industrial Marketing Management		X		
Infection, Genetics and Evolution	X			
Information & Management		X		
Information and Organization		X		
Information Economics and Policy			X	
Information Systems		X		
Infosecurity		X		
Infosecurity Today		X		
Innovative Food Science & Emerging Technologies	X			
Insect Biochemistry	X			
Insect Biochemistry and Molecular Biology	X			
Insurance: Mathematics and Economics			X	
International Biodeterioration & Biodegradation				X
International Business Review		X	X	
International Dairy Journal	X			
International Journal for Parasitology: Drugs and Drug Resistance	X			
International Journal of Accounting Information Systems		X		

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
International Journal of Applied Earth Observation and Geoinformation				X
International Journal of Applied Quality Management		X		
International Journal of Aromatherapy	X			
International Journal of Disaster Risk Reduction				X
International Journal of Food Microbiology	X			
International Journal of Forecasting		X	X	
International Journal of Gastronomy and Food Science	X			
International Journal of Greenhouse Gas Control				X
International Journal of Hospitality Management		X		
International Journal of Hygiene and Environmental Health				X
International Journal of Industrial Organization			X	
International Journal of Information Management		X		
International Journal of Insect Morphology and Embryology	X			
International Journal of Intercultural Relations		X		
International Journal of Management Education		X	X	
International Journal of Production Economics			X	
International Journal of Project Management		X		
International Journal of Refrigeration	X			
International Journal of Research in Marketing		X		
International Journal of Tourism Management		X		
International Journal of Transport Management		X		
International Public Management Journal		X		
International Review of Economics & Finance			X	
International Review of Financial Analysis			X	
International Review of Law and Economics			X	
Investigaciones de Historia Económica			X	
Japan and the World Economy			X	
Journal for Nature Conservation	X			

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Journal for Nature Conservation				X
Journal of Accounting and Economics		X		
Journal of Accounting and Economics			X	
Journal of Accounting and Public Policy		X		
Journal of Accounting Education		X		
Journal of Aerosol Science				X
Journal of Agricultural Engineering Research	X			
Journal of Air Transport Management		X		
Journal of Applied Economics			X	
Journal of Arid Environments				
Journal of Arid Environments				X
Journal of Asian Economics			X	
Journal of Asia-Pacific Entomology	X			
Journal of Banking & Finance			X	
Journal of Behavioral Economics			X	
Journal of Business Research		X		
Journal of Business Venturing		X		
Journal of Cereal Science	X			
Journal of Cleaner Production				X
Journal of Comparative Economics			X	
Journal of Comparative Pathology	X			
Journal of Consumer Psychology		X		
Journal of Contemporary Accounting & Economics		X	X	
Journal of Corporate Finance		X	X	
Journal of Dairy Science	X			
Journal of Development Economics			X	
Journal of Direct Marketing		X		
Journal of Econometrics			X	
Journal of Economic Behavior & Organization		X	X	
Journal of Economic Dynamics and Control			X	
Journal of Economic Psychology		X	X	
Journal of Economic Theory			X	
Journal of Economics and Business		X	X	
Journal of Empirical Finance			X	
Journal of Energy Finance & Development			X	
Journal of Engineering and Technology Management		X		

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Journal of Environmental Economics and Management			X	
Journal of Environmental Management				X
Journal of Environmental Radioactivity				X
Journal of Environmental Sciences				X
Journal of Equine Veterinary Science	X			
Journal of Exotic Pet Medicine	X			
Journal of Experimental Animal Science	X			
Journal of Experimental Marine Biology and Ecology	X			X
Journal of Family Business Strategy		X		
Journal of Feline Medicine & Surgery	X			
Journal of Financial Economics		X	X	
Journal of Financial Intermediation			X	
Journal of Financial Markets			X	
Journal of Financial Stability			X	
Journal of Fluorine Chemistry				X
Journal of Food Composition and Analysis	X			
Journal of Food Engineering	X			
Journal of Forest Economics	X		X	X
Journal of Functional Foods	X			
Journal of Geochemical Exploration				X
Journal of Great Lakes Research				X
Journal of Hazardous Materials				X
Journal of Health Economics			X	
Journal of Hospitality, Leisure, Sport & Tourism Education		X		
Journal of Housing Economics			X	
Journal of Human Evolution	X			
Journal of Hydro-environment Research	X			
Journal of Hydrology	X			
Journal of Income Distribution			X	
Journal of Insect Physiology	X			
Journal of Integrative Agriculture	X			
Journal of Interactive Marketing		X		
Journal of International Accounting, Auditing and Taxation		X	X	
Journal of International Economics			X	
Journal of International Financial Markets, Institutions and Money			X	
Journal of International Management		X		

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Journal of International Money and Finance			X	
Journal of Invertebrate Pathology	X			
Journal of Macroeconomics			X	
Journal of Management		X		
Journal of Marine Systems	X			
Journal of Mathematical Economics			X	
Journal of Monetary Economics			X	
Journal of Multinational Financial Management			X	
Journal of Nutrition Education	X			
Journal of Nutrition Education and Behavior	X			
Journal of Operations Management		X		
Journal of Photochemistry and Photobiology B: Biology	X			
Journal of Plant Physiology	X			
Journal of Policy Modeling			X	
Journal of Product Innovation Management		X		
Journal of Public Economics			X	
Journal of Purchasing and Supply Management		X		
Journal of Quality Management		X		
Journal of Rail Transport Planning & Management		X	X	
Journal of Retailing		X		
Journal of Retailing and Consumer Services		X		
Journal of Rural Studies	X			X
Journal of Sea Research	X			
Journal of Stored Products Research	X			
Journal of the Academy of Nutrition and Dietetics	X			
Journal of the American Dietetic Association	X			
Journal of the Association of Arab Universities for Basic and Applied Sciences	X			
Journal of the Japanese and International Economies			X	
Journal of the Saudi Society of Agricultural Sciences	X			
Journal of Theoretical Biology	X			
Journal of Thermal Biology	X			X

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Journal of Trace Elements in Medicine and Biology				X
Journal of Transport Geography				X
Journal of Urban Economics			X	
Journal of Veterinary Behavior: Clinical Applications and Research	X			
Journal of Veterinary Cardiology	X			
Journal of Vocational Behavior		X		
Journal of World Business		X	X	
Labour Economics			X	
Land Use Policy	X			X
Landscape and Urban Planning	X			X
Landscape Planning	X			X
L'Année Biologique	X			
Large Marine Ecosystems	X			X
Limnologica - Ecology and Management of Inland Waters	X			X
Livestock Production Science	X			
Livestock Science	X			
Long Range Planning		X		
LWT - Food Science and Technology	X			
Mammalian Biology - Zeitschrift für Säugetierkunde	X			X
Management Accounting Research		X	X	
Marine Environmental Research	X			
Marine Genomics	X			
Marine Models	X			X
Marine Policy	X			X
Marine Pollution Bulletin	X			
Mathematical Biosciences	X			
Mathematical Social Sciences				
Meat Science			X	
Meteorological Applications	- Not Part of ScienceDirect -			
Molecular Phylogenetics and Evolution	X			
Museum Management and Curatorship		X		
Mutation Research/DNA Repair				X
Mutation Research/DNA Repair Reports				X
Mutation Research/DNAging				X
Mutation Research/Environmental Mutagenesis and Related Subjects				X

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis				X
Mutation Research/Genetic Toxicology and Environmental Mutagenesis				X
Mutation Research/Reviews in Genetic Toxicology				X
Mutation Research/Reviews in Mutation Research				X
Mycological Research	X			
Mycologist	X			
Netherlands Journal of Sea Research	X			
NeuroToxicology				X
Neurotoxicology and Teratology				X
New Scientist	X	X		X
NJAS - Wageningen Journal of Life Sciences	X			
North American Review of Economics and Finance			X	
Nuclear and Chemical Waste Management				X
Ocean & Coastal Management				X
Ocean and Shoreline Management				X
Ocean Engineering				X
Ocean Management				X
Oceanologica Acta	X			
Oil and Chemical Pollution				X
Oil and Petrochemical Pollution				X
Omega		X		
Organisms Diversity & Evolution	X			X
Organizational Behavior and Human Decision Processes		X		
Organizational Behavior and Human Performance		X		
Organizational Dynamics		X		
Pacific-Basin Finance Journal			X	
Palaeogeography, Palaeoclimatology, Palaeoecology				X
Pedobiologia	X			X
Pedosphere	X			
Perspectives in Plant Ecology, Evolution and Systematics	X			X
Pesticide Biochemistry and Physiology	X			
Physica A: Statistical Mechanics and its Applications			X	
Physiological and Molecular Plant Pathology	X			

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Resources Policy			X	X
Resources, Conservation and Recycling				X
Review of Development Finance			X	
Review of Economic Dynamics			X	
Review of Financial Economics			X	
Review of Radical Political Economics			X	
Revista Española de Nutrición Humana y Dietética	X			
Rice Science	X			
Ricerche Economiche			X	
Safety Science		X		
Saudi Journal of Biological Sciences				X
Scandinavian International Business Review		X		
Scandinavian Journal of Management		X		
Scandinavian Journal of Management Studies		X		
Science of The Total Environment				X
Scientia Horticulturae	X			
Small Ruminant Research	X			
Socio-Economic Planning Sciences		X	X	
Soil and Tillage Research	X			
Soil Biology and Biochemistry	X			X
Soil Technology	X			
South African Journal of Botany	X			
Special Topics in Primatology	X			
Spill Science & Technology Bulletin				X
Sport Management Review		X		
Structural Change and Economic Dynamics			X	
Studies in Environmental Science				X
Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences	X			
Studies in Plant Science	X			
Sugar Series	X			
Sustainable Cities and Society				X
Swarm and Evolutionary Computation	X			
Systematic and Applied Microbiology	X			X
Technological Forecasting		X		
Technological Forecasting and Social Change		X		

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Technology in Society			X	X
Technovation				X
Telecommunications Policy			X	
Terrestrial Ecology			X	
The American Journal of Evaluation			X	
The British Accounting Review			X	
The British Journal of Animal Behaviour	X			
The Columbia Journal of World Business	X			
The Cornell Hotel and Restaurant Administration Quarterly			X	
The Electricity Journal		X		
The Environmentalist				X
The Geochemical Society Special Publications		X		
The International Food and Agribusiness Management Review		X		
The International Journal of Accounting		X		
The Journal of High Technology Management Research				X
The Journal of Socio-Economics	X			
The Journal of Strategic Information Systems	X			
The Leadership Quarterly		X	X	
The Lichenologist	X			
The North American Journal of Economics and Finance	X			X
The Quarterly Review of Economics and Finance	X			
The Spanish Review of Financial Economics	X			
The Veterinary Journal	X			
Theoretical Ecology Series				X
Theoretical Population Biology		X		
Theory in Biosciences			X	
Theriogenology				X
Ticks and Tick-borne Diseases	X			
Tissue and Cell	X			
Topics in Companion Animal Medicine	X			
Tourism Management				X
Tourism Management Perspectives	X			
Toxicology	X			X
Toxicology and Applied Pharmacology		X		
Toxicology in Vitro		X		

	Agricultural and Biological Sciences	Business, Management and Accounting	Economics, Econometrics and Finance	Environ-mental Science
Toxicology Letters				X
Toxicon				X
Trace Metals and other Contaminants in the Environment				X
Trace Metals in the Environment				X
Transactions of the British Mycological Society	X			
Transportation Research Part D: Transport and Environment				X
Transportation Research Part E: Logistics and Transportation Review		X		
Trends in Ecology & Evolution	X			X
Trends in Food Science & Technology	X			
Trends in Plant Science	X			
Urban Ecology				X
Urban Forestry & Urban Greening	X			X
Urban Water				X
Utilities Policy		X		
Value in Health			X	
Veterinary Immunology and Immunopathology	X			
Veterinary Microbiology	X			
Veterinary Parasitology	X			
Waste Management				X
Waste Management & Research				X
Waste Management Series				X
Water Policy				X
Water Research				X
Water Science and Technology				X
World Crop Pests	X			
World Development			X	
World Patent Information		X		
World Survey of Climatology				X
Zeitschrift für Pflanzenphysiologie	X			
Zentralblatt für Hygiene und Umweltmedizin				X
Zoological Journal of the Linnean Society	X			
Zoologischer Anzeiger - A Journal of Comparative Zoology	X			X
Zoology	X			X

IMPRESSUM

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