Research Project

RUINS

Risk, Uncertainty and Insurance under Climate Change.
Coastal Land Management on the German North Sea

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Summary

The impacts of climate change as well as the consequences of adaptations are uncertain. These uncertainties may be deeper than "risk", where one knows at least the probabilities of potential future outcomes. In particular, there may be "Knightian uncertainty", where one knows the potential outcomes but not their probabilities.

In this inter- and transdisciplinary project, we study both risk and Knightian uncertainty of climate change impacts and adaptation options for the case of coastal land management on the German North Sea, where people benefit from a suite of ecosystem services which are subject to climate change and to alternative land management options. In this case, both risk and uncertainty are relevant for decision-making about local adaptations to climate change. We combine economics with landscape ecology through modelling, and we include local stakeholders in the process of analysis and conclusion.

Our project has three aims: (1) To develop concepts for the economic valuation of adaptation options and concepts of (natural or financial) insurance under Knightian uncertainty. (2) To develop a procedure to assess and communicate combined risk-and-uncertainty throughout the full chain of analysis and implementation – from basic science all the way to practical solution. (3) To identify – in exchange with stakeholders – which potential land management option is their preferred way of addressing the risks and uncertainties of (adapting to) climate change. This includes identifying stakeholders' risk-and-uncertainty preferences as well as potential synergies, conflicts and trade-offs between ecosystem services and between stakeholder groups.

These aims are achieved through a work program that comprises the following work packages: (1) Conceptualization and theoretical foundation of preferences, valuation and insurance under Knightian uncertainty; (2) Environmental modelling of ecosystem services at the landscape level for different land management options, and uncertainty analysis; (3) Empirical elicitation of risk and uncertainty preferences of stakeholders; (4) Project management, integration of research results, organization of stakeholder relations, knowledge transfer.

Our project produces (1) an economic valuation of the land management options currently discussed in the case study region, including an identification of potential conflicts; (2) a transfer of results to stakeholders, through workshops and a policy brief for decision-makers; (3) 6-7 publications in academic journals, 18 presentations at international conferences; (4) 2 contributions to the international *Summer School on Sustainability Economics* and 6 Bachelor or Master theses.

1. Topic, aims, and contribution of the project

1.1 Topic

The impacts of climate change on natural and socio-economic systems, as well as the consequences of implementing adaptation options to these impacts, are characterized by various and deep uncertainties. In academic analyses, they arise in different instances – empirical data, model structures and parameter values, upscaling from local and short-term scales to global and long-term scales, etc. For evaluating adaptation options and decision-making, these uncertainties mean that one does not know the future consequences of present actions for certain. This uncertainty can be classified into different types (Faber et al. 1992). The type studied most widely in economics is “risk”: one knows the potential future states of the world and the objective probabilities of these states. A deeper form of not-knowing-the-future-for-sure than risk is “Knightian uncertainty” (Keynes 1921, Knight 1921): one knows the potential future states of the world, but not the probabilities at which they turn out.

For analyses of climate change, and the evaluation of adaptation options, both risk and Knightian uncertainty matter. Some impacts and consequences of policies are risky, that is, we know the potential outcomes and also the probabilities of potential outcomes. Other impacts and consequences of adaptation options are uncertain: while we know the potential outcomes, there are no objective probabilities – for example, because the system may be too complex, or the time horizon may be too long. Examples include the climate sensitivity of the Earth’s atmosphere (Meinshausen et al. 2009). In its most recent version, the IPCC report (2013: 16) therefore raises serious doubts on the reliability of probabilities to characterize potential future developments.

This raises some big and important questions, which are both at the current front of academic research and critically relevant for practical solutions: how to deal with different types of uncertainty – risk and Knightian uncertainty – in scientific analyses? How to “aggregate” uncertain effects if both risk and Knightian uncertainty are involved? How to measure, assess and evaluate the “overall uncertainty”? In particular: how to put an economic value on, and how to take into account in decision-making, future outcomes that are uncertain in a deeper way than risk? How to insure against Knightian uncertainty, that is, when probabilities are not known?

A practically relevant case is coastal land management along the German North Sea, which is our case study. Here, we build on previous work from the BMBF project COMTESS – *Sustainable coastal land management: Trade-offs in ecosystem services* (grant no. 01LL0911A-G). COMTESS has studied ecosystem services in two study sites, amongst others, at Greetsiel (1,760 ha) and at Freepsum (1,607 ha) in the municipality of Krummhörn, Aurich county, Lower Saxony (Figure 1).

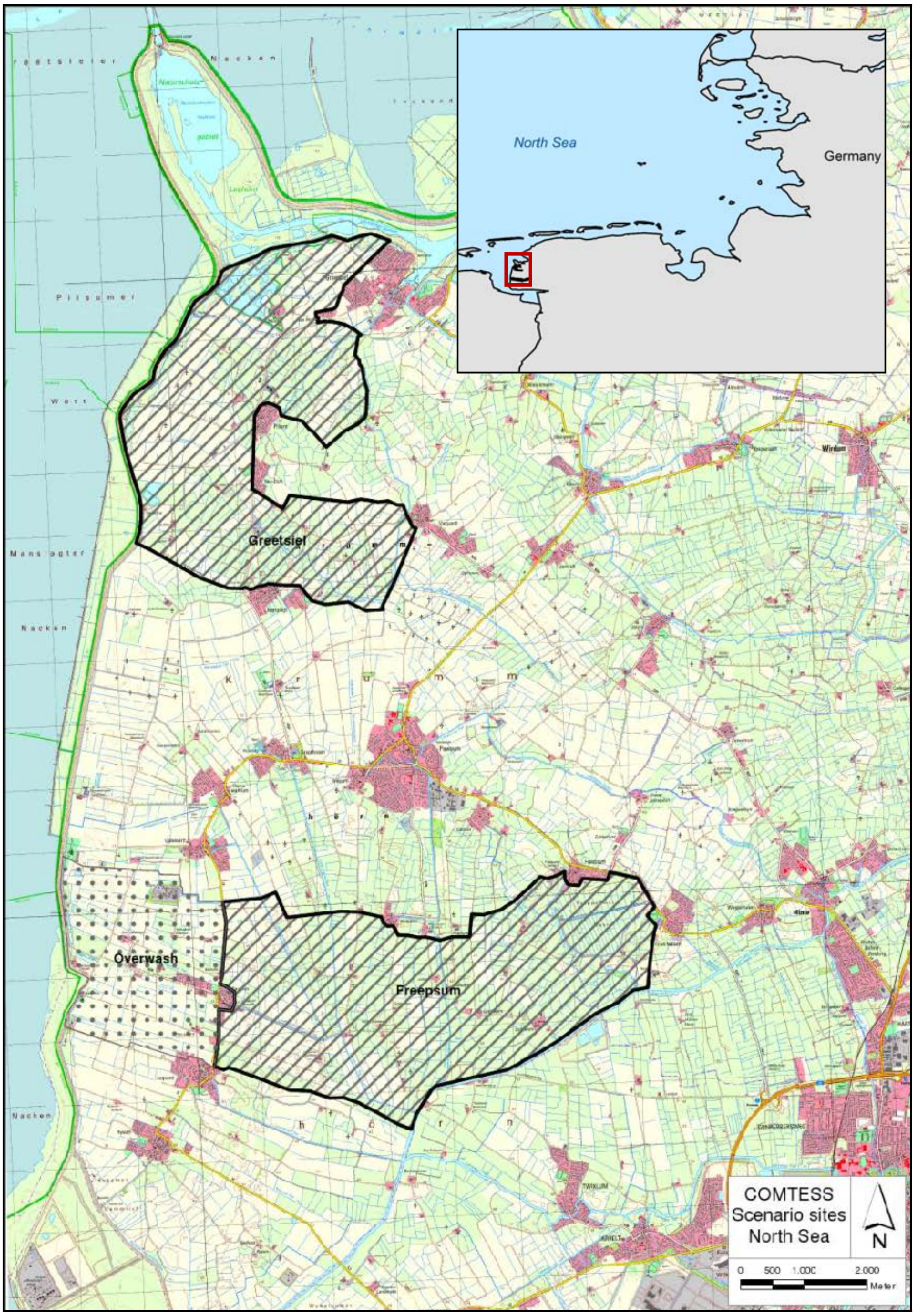

Figure 1: Study sites on the North Sea at Greetsiel and Freepsum, in the municipality of Krummhörn (Aurich county, Lower Saxony, Germany)

People living in this region derive well-being from, amongst others, a number of ecosystem services (Karrasch et al. 2014): agricultural crop and forage produce, fresh-water provision, bioenergy and raw material production, carbon sequestration, water retention, existence of endangered species, attractiveness for recreation and tourism, a sense of belonging to the land, and feeling of safety from flooding. Several options to manage the coastal land in view of climate change are currently discussed in the region and have been studied by COMTESS (Karrasch, Kleyer, **Schibalski** et al. 2017): maintain land use patterns as current (trend), develop polders that serve as sinks for water to cope with increased winter rainfall and mitigate summer droughts (water management), remodel dyke lines and create brackish zones in which reed is grown for bioenergy and biomass production (carbon management), or a stakeholder-defined mix of these (Figure 2).

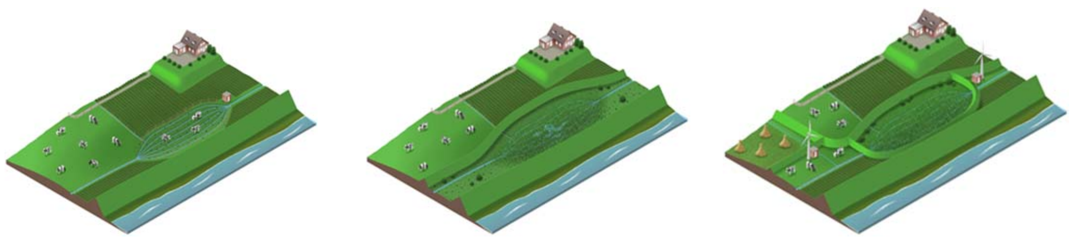

Figure 2: Land management options under study (developed in COMTESS)

Climate change affects the different ecosystem services and, thus, human well-being. Which climate change scenario – in terms of temperature, sea level, and precipitation – will actually unfold is a matter of Knightian uncertainty. For each climate change scenario, the level of ecosystem services obtained can be scientifically predicted through probability distributions, i.e. it is a matter of risk. Climate change impacts on natural and socio-economic systems, as well as the consequences of implementing one or the other adaptation option, are thus a combined matter of both risk and uncertainty.

1.2 Aims

Against this backdrop, our project has the following aims. **The first aim** is to develop basic and general concepts for the economic valuation of adaptation options where the outcomes are Knightian uncertain, that is, without relying on probabilities. This includes developing a concept of (natural or financial) insurance against Knightian uncertainty.

The second aim is to develop an encompassing and coherent scientific procedure to assess and communicate combined risk-and-uncertainty throughout the full chain of analysis and implementation – from collecting primary data on natural and socio-economic systems in the field or lab, through processing this data by a suite of linked ecological-economic models, all the way to suggesting practical solutions.

The third aim is to identify – in exchange with stakeholders – which potential land management option is their preferred way of addressing the risks and uncertainties of climate change, taking into account the best available predictions from natural science about the provision of ecosystem services under different climate change scenarios. This includes identifying stakeholders' risk-and-uncertainty preferences as well as potential synergies, conflicts and trade-offs between ecosystem services and between stakeholder groups.

1.3 Contribution to the call's objectives and to the focus theme "climate risks"

The project contributes to the call's focus theme "3. Managing climate risks / b.) How to evaluate, compare and implement potential adaptation options and models?" In particular, we develop, test and practically implement new concepts for the analysis, economic valuation, and decision-oriented communication of the uncertainties of different options for the adaptation to climate change, so that these adaptation options can be systematically compared even under deeper forms of uncertainty than risk.

Our project specifically contributes to the overall call's objectives by achieving:

(1) disciplinary scientific excellence, by developing innovative and cutting-edge concepts and methods for the analysis and economic valuation of Knightian uncertainty and of combined risk-and-uncertainty;

(2) interdisciplinarity, through the cooperation of academic partners from economics and landscape ecology, both with a reputation of disciplinary excellence and a rich experience in inter- and transdisciplinary cooperation;

(3) practical relevance and application, through a case study of coastal land management along the German North Sea;

(4) transdisciplinarity, through the cooperation with local stakeholders and the use of target-group-specific formats and products, in particular with innovative formats for the communication and visualization of risks and uncertainties of coastal land-management under climate change;

(5) improved political decision-making, through mutually linked cutting-edge research, societal relevance, and solution-oriented implementation process;

(6) international visibility, through regular presentations at international conferences and workshops, and publications in international academic journals;
(7) capacity building and community development, by supporting students in their project-related Bachelor-, Master- and PhD-theses, and by contributing to the bi-annual international *Summer School on Sustainability Economics*.

2. State of research and relevant own previous contributions

Coastal land management under climate change has been widely studied before, also for the German North Sea – e.g. by some of the KLIMZUG projects (BMBF 2008-2014) or the COMTESS project ("Sustainable coastal land management: Trade-offs in ecosystem services", 2011–2016, BMBF grant number: 01LL0911). Our innovation over these projects is that we systematically assess and evaluate not just the risks but also the deeper (Knightian) uncertainties of climate change adaptation.

The **empirical data collected** and expertise gained within the COMTESS project will be the starting point for modelling in our project. COMTESS investigated the impact of climate change, sea level rise, and different land management options on the provision of ecosystem services at the German Baltic and North Sea coast. To this end, we developed **a chain of hydrological, vegetation, and socio-economic models** resulting in quantitative, spatio-temporally explicit predictions of the regional hydrology, vegetation distribution, and ten ecosystem services (**Schibalski** et al. 2016). COMTESS was unique in quantitatively tracking the effect of climate change through hydrological and ecological processes, ultimately affecting ecosystem service provision. Here, we will build on this model chain and assess different sources of uncertainty within the chain as well as the accumulation of errors along the chain. Linking models in the way described above affects the uncertainty of the predicted outcome. Uncertainty analyses have been done for separate sources of uncertainty, e.g. (climate) input data (Stoklosa, et al. 2015) or model types (Gritti, et al. 2013). There are convenient tools available to perform uncertainty analyses of single (complex) models (Wang, et al. 2016). Global sensitivity and uncertainty analysis is an approach accounting for various sources of uncertainty at once, which can be applied to a model chain (Convertino, et al. 2014, Perz, et al. 2013, Zajac, et al. 2015). In our model chain, species distribution models play a central role in linking predicted environmental changes to ecosystem services. One of the PIs has systematically analyzed uncertainty in species distribution modelling in several studies (Dormann, **Schröder** et al. 2008; Zurell, **Schröder** et al. 2012a; Zurell, **Schröder** et al. 2012b).

As for **economic valuation and insurance under risk**, the von Neumann-Morgenstern expected-utility framework is standard and has been widely applied. With this framework, we have clarified the economic value of public environmental goods under uncertainty and under unequal income distribution (**Baumgärtner** et al. 2016, 2017). We have developed and applied the concept of insurance value of biodiversity and ecosystem resilience: nature can provide insurance to risk-averse users of ecosystem services (**Baumgärtner** 2007, **Baumgärtner** and Strunz 2014). Such real insurance is a substitute for financial insurance. It may therefore be driven out by the latter, depending on relative (shadow) prices (Quaas and **Baumgärtner** 2008). If ecosystem services have the character of public goods, or if risk is a public characteristic, there may be risk externalities and moral hazard among the various risk-averse users of the system, leading to welfare losses which may be even aggravated through the availability of financial insurance (Quaas and **Baumgärtner** 2008; Müller, **Baumgärtner** et al. 2011, **Baumgärtner** and Fianu 2016).

As for **decision under Knightian uncertainty**, existing decision criteria are either non-probabilistic (Niehans 1948, Wald 1949, Savage 1954, Arrow and Hurwicz 1977) or probabilistic (Gilboa and Schmeidler 1989, Klibanoff et al. 2005, Maccheroni et al. 2006). While the probabilistic criteria build on some surrogate probabilities (the plausibility of which is questionable for a very long-term and complex problem such as climate change), the non-probabilistic ones either do not use all available information on payoffs in all potential states (e.g. maximin or maximax) or lack an explicit concept of uncertainty aversion (e.g. minimum regret). We have axiomatically characterized an entropic preference-function under Knightian uncertainty that is non-probabilistic, takes into account all available information on payoff in all potential states, and captures non-satiation as well as uncertainty aversion (**Baumgärtner** and Engler 2017). In the same paper, we have also suggested a concrete one-parameter functional form of the preference function, based on Rényi's (1961) generalized entropy function, and demonstrated that the parameter parameterizes the decision-maker's degree of uncertainty aversion.

3. Approach, methods and work program

3.1 Work program

The work program comprises four work packages (WP), with several tasks (T) in each. There are Milestones (M) on the way, and some tasks produce Deliverables (D) for other Work Packages within the project or for external use. Work packages 1 and 3 are carried out within subproject 1 at the University of Freiburg; Work Package 2 is carried out within subproject 2 at Technische Universität Braunschweig. Work package 4 is lead by University of Freiburg within subproject 1, and involves substantial input from both partners.

Work Package WP1. Conceptualizing preferences, valuation and insurance under Knightian uncertainty (University of Freiburg)

This work package is at the conceptual and theoretical level and develops the decision-theoretic basis of the project.

Task T1.1 (9 months). We classify different types of uncertainty aversion and for each, define the degree of uncertainty aversion. For this task, we start from the usual classifications under risk (absolute or decreasing, constant or relative risk aversion, downside risk aversion) and develop Knightian analogues. One important special case will be the one-parameter entropic preference function under Knightian uncertainty developed by Baumgärtner and Engler (2016), because it has a clear axiomatic characterization and a well-studied functional form. It is already known that its parameter parameterizes the degree of risk aversion. We will clarify what type of risk aversion this is.

Milestone M1.1 (in month 9): We have classified uncertainty preferences in general for different types and degrees of uncertainty aversion, and we have some illustrative examples based on concrete functions.

Deliverable D1.1 (in month 9; for use in T2.2, T3.1): Manuscript with classification of uncertainty preferences in terms of the type and degree of uncertainty aversion.

Task T1.2 (6 months). For uncertainty preferences in general – that is, assuming a generic uncertainty preference function – we derive different measures of the economic value of an uncertain income stream. We will start with the certainty equivalent of the uncertain income stream, and from that derive the equivalent and the compensating variation, as well as the uncertainty premium of switching from an uncertain income stream to its certainty equivalent. We will do this in analogy to the risk-case. We will specify these measures for the concrete uncertainty preference functions derived in Task T1.1.

Milestone M1.2 (in month 15): For uncertainty preferences in general, we have derived different measures of the economic value of an uncertain income stream, and we have specified these for some concrete uncertainty preference functions.
Deliverable D1.2 (in month 15; for use in T2.4, T3.5): Manuscript with an analytical concept of the insurance value of all land management options under study.

Task T1.3 (6 months). We clarify the notion of (real or financial) insurance under Knightian uncertainty. A preliminary definition would be: insurance is an action or payment scheme that decreases the uncertainty premium of an uncertain income situation. Here, we build on the concept of uncertainty premium from Task T1.2. We interpret the land management options as (potential) real insurance against Knightian uncertainty.
Milestone M1.3 (in month 21): We have defined the notion of (real or financial) insurance under Knightian uncertainty, and we have interpreted the land management options as (potential) real insurance against Knightian uncertainty

Task T1.4 (6 months). Transferring the idea of Baumgärtner (2007) from risk to uncertainty and using previous results from this WP, we define the insurance value of a real insurance against Knightian uncertainty such as a land management option.
Milestone M1.4 (in month 27): We have analytically derived the insurance value of a real insurance against Knightian uncertainy, such as a land management option.

Task T1.5 (joint task with T2.4, T3.5) (9 months). We quantitatively estimate the insurance value of all land management options under study, using the empirical data from other work packages. This task brings together previous results from Work Packages 1, 2 and 3. In particular, it builds on the concepts of uncertainty aversion and the economic value, and insurance value, of an uncertain income situation (Deliverables D1.1 and D1.2 from Work Package 1), the uncertain distribution of ecosystem services (Deliverables D2.1 and D2.2 from Work Package 2), and the empirical estimate of stakeholders' uncertainty aversion (Deliverable D3.1 from Work Package 3). This task is carried out jointly between the three work packages 1, 2 and 3.
Milestone M1.5 (in month 36): We have quantitatively estimated the insurance value of all land management options under study

External deliverables from this Work Package:

D1.3 (in month 36): 1 PhD thesis

D1.4 (in month 36): 3 manuscripts for academic journals (of which 1 is joint with WP2 and WP3)

D1.5 (throughout): 6 contributions to international conferences

Work Package WP2. Environmental modelling and uncertainty analysis (Technische Universität Braunschweig)

This work package provides the empirical data for ecosystem services at the landscape level, through model-based upscaling of plot-level field data gathered in the COMTESS project.

Task T2.1 (15 months). Based on different sources of uncertainty (see **T2.2**), produce alternative probabilistic predictions of ecosystem service provision. The hydrological response to climate change and sea level rise is driving our chain of environmental models. We will obtain hydrological modelling results from an external contractor (i.e. the previous hydrological modeler in COMTESS, Dr. Thomas Graeff). Species distribution models and species traits-to-ecosystem service relationships developed in the COMTESS project will be applied to predict ecosystem service provision for multiple scenario combinations.

Milestones:

M2.1 (in month 7): Preliminary hydrological modelling received and tested for compatibility

M2.2 (in month 13): Final hydrological modelling received and tested for compatibility

M2.3 (in month 15): Ecosystem service prediction finished

Deliverable D2.1 (in month 15; for use in T1.5, T2.2, T2.4, T3.5): Probabilistic distribution of ecosystem service provision

Task T2.2 (30 months). For the environmental modeling, analyze the following sources of uncertainties: climate and sea level rise scenarios, climate models (different global circulation models with different regionalization) and species distribution model types (BRTs, GLMs, GAMs), hydrological model parameterization and missing process (salinization).

To incorporate *uncertain future conditions*, we assume different combinations of (i) emission scenarios (RCP4.5, RCP8.5) and (ii) sea level rise scenarios (0, 80, 150 cm).

To capture the *uncertainty in climate modelling* (for each combination of scenarios, i.e. climate × sea level rise), we will compare different climate model realizations. Therefore, we will use data from four global circulation models (ECHAM6, CNRM-CM5, IPSLCM5, GFDL-CM3, HadGEM2-CC), downscaled with three regionalization methods (REMO, WETTREG, XDS). To assess the *uncertainty in the hydrological model*, external modeller Dr. Thomas Graeff will conduct a partial sensitivity analysis, focusing on processes and parameters affected by land management (contract work). As with the climate model uncertainty, we will carry on this model uncertainty as alternative predictions of hydrological variables (minimum, mean and maximum), thus multiplying the number of alternative ecosystem service predictions for any given scenario.

As an example for *uncertainty due to lack of process knowledge*, we will investigate the effect of salinization. We know that salinization is an important, potentially damaging process at the coast that is projected to increase under climate change (Essink, et al. 2010) and that can lead to a reduction in, e.g., forage production or freshwater provision. However, we only have very limited data on the distribution of potential salt water intrusion sites (due to disturbances in the underlying clay layers that permit saline water to infiltrate the soil from below). Hence, we lack information on the extent of salinization today as well as its development in the future. As a result, we omitted salinization as a process in COMTESS, assuming low salinization levels which do not increase. In order to assess how this lack of knowledge might affect the resulting ecosystem service predictions, we will run three different salinization scenarios with varying rates and spatial extents of salinization. This way, we will learn how sensitive our predictions of ESS provision are to salinization and how much uncertainty is introduced by ignoring it.

Dormann et al. (2008) found model type and data uncertainty to be the most important sources of variation in predicted species occurrences. Whereas we used only one model type (Boosted Regression Trees, i.e. a machine learning algorithm, cf. Elith, et al. 2008) to predict plant species distributions in COMTESS, we will apply two additional techniques (GLMs and GAMs, i.e. parametric and semi-parametric statistical approaches with information-theoretic model selection) in **RUINS** to account for the effect of different modelling approaches. For *data uncertainty* in the vegetation modelling process, we will study the effect the detail of environmental input data (measured metric vs. derived categorical predictors) has on the performance and predictions of the resulting models.

Milestone M2.4 (in month 33): Uncertainty analysis finished

Deliverable D2.2 (in month 33; for use in T1.5, T2.4, T3.5): Quantification and ranking of uncertainties in the chain of environmental models

Task T2.3 (15 months). Building on Bonneau et al. (2014) and Brodlie et al. (2011), investigate ways of visualizing these different types of uncertainty to the scientific community. Taking advantage of the stakeholder network required for experiments in WP3, we will test these uncertainty visualization techniques within different stakeholder groups. To this end we will benefit from the expertise of an external contractor (Dr. **Christoph Stasch** and Dr. **Benedikt Gräler**, 52°North GmbH) in uncertainty representation, communication and visualization (Bastin et al. 2013, Gerharz et al. 2011). 52°North will develop a web application to visualize uncertainties which we can use to survey the suitability and acceptance of our proposed visualization techniques with stakeholders. We, thus, directly involve stakeholders in the development of visualization techniques, thereby enhancing the transdiciplinarity of the project as requested by reviewers.
Milestone M2.5 (in month 36). Visualization finished
Deliverable D2.3 (in month 36). Concept of visualizing uncertainty in model predictions

Task T2.4 (joint task with T1.5, T3.5) (9 months). We quantitatively estimate the insurance value of all land management options under study, using the empirical data from other work packages. This task brings together previous results from Work Packages 1, 2 and 3. In particular, it builds on the concepts of uncertainty aversion and the economic value, and insurance value, of an uncertain income situation (Deliverables D1.1 and D1.2 from Work Package 1), the uncertain distribution of ecosystem services (Deliverables D2.1 and D2.2 from Work Package 2), and the empirical estimate of stakeholders' uncertainty aversion (Deliverable D3.1 from Work Package 3). This task is carried out jointly between the three work packages 1, 2 and 3.
Milestone M2.6 (in month 36): We have quantitatively estimated the insurance value of all land management options under study

External deliverables from this Work Package:
D2.4 (throughout): 6 thesis topics for bachelor or master theses
D2.5 (in month 36): 3 manuscripts for academic journals (of which 1 is joint with WP1 and WP3)
D2.6 (throughout): 6 contributions to international conferences

Work Package WP3. Empirical measurement of stakeholder preferences (University of Freiburg)

The outcome of this WP will be empirical data on the type of risk-and-uncertainty preferences, and the degree of risk aversion and uncertainty aversion, of different stakeholder groups as well as society at large.

Task T3.1 (12 months). We develop a case-study-contextual laboratory experiment and a survey – based on the Laury-Holt method for risk aversion, and something analogous for uncertainty aversion, and incentivized through a risky/uncertain payout in real money – to measure individuals' type of risk-and-uncertainty preference, and their degree of risk aversion and uncertainty aversion. As for risk aversion, we build on the usual classification of von-Neumann-Morgenstern-type of preferences. As for uncertainty aversion, we build on the classification of uncertainty preferences in terms of the type and degree of uncertainty aversion developed in Work Package 1 (Deliverable D1.1).

Milestone M3.1 (in month 12): We have developed a case-study-contextual laboratory experiment and a survey to measure individuals' type of risk-and-uncertainty preference, and their degree of risk aversion and uncertainty aversion.

Task T3.2 (6 months). We carry out the survey and the laboratory experiment with stakeholders, by visiting them in person and in the case study region.

Milestone M3.2 (in month 18): We have carried out the laboratory experiment and the survey with stakeholders.

Task T3.3 (3 months). We run the web-based online survey with ideally the full population of stakeholders in the study region. As it will not be possible to make everyone participate in the survey, we will employ criteria of representativeness, so that we can gather a representative subsample from the sample of all survey respondents.

Milestone M3.3 (in month 18): We have run the web-based online survey with a random sample of people from the study region.

Task T3.4 (9 months). We analyze the results of laboratory experiments and online survey in terms of the types and degrees of risk aversion and uncertainty aversion. We will empirically determine the type and degree of risk aversion and uncertainty aversion, as well as their socio-demographic determinants. We will also study the

relation between risk aversion and uncertainty aversion. We will carry out these analyses for the total sample of respondents, as well as for separate stakeholder groups.
Milestone M3.4 (in month 27): We have analyzed the results of the laboratory experiments and the online survey.
Deliverable D3.1 (in month 27; for use in T1.5, T2.2, T2.4): Manuscript with an empirical estimation of stakeholders' risk and uncertainty preferences

Task T3.5 (joint task with T1.5, T2.4) (9 months). We quantitatively estimate the insurance value of all land management options under study, using the empirical data from other work packages. This task brings together previous results from Work Packages 1, 2 and 3. In particular, it builds on the concepts of uncertainty aversion and the economic value, and insurance value, of an uncertain income situation (Deliverables D1.1 and D1.2 from Work Package 1), the uncertain distribution of ecosystem services (Deliverables D2.1 and D2.2 from Work Package 2), and the empirical estimate of stakeholders' uncertainty aversion (Deliverable D3.1 from Work Package 3). This task is carried out jointly between the three work packages 1, 2 and 3.
Milestone M3.5 (in month 36): We have quantitatively estimated the insurance value of all land management options under study

External deliverables from this Work Package:
D3.2 (in month 36): 1 PhD thesis
D3.3 (in month 36): 2 manuscripts for academic journals (of which 1 is joint with WP1 and WP2)
D3.4 (throughout): 6 contributions to international conferences

Work Package WP4. Project management, integration of results, and knowledge transfer (lead: University of Freiburg, with substantial input from Technische Universität Braunschweig)

This Work Package includes project management, integration of results, and knowledge transfer. It establishes coherence within the project, and external impact.

Task T4.1 (throughout the entire project period). We will hold two workshops per year with all scientific partners, to ensure exchange, coherence, progress towards the aims, and good scientific practice throughout the project. These workshops will normally have a 24-to-48-hours format. They will be held at Freiburg and Braunschweig, in an alternating manner, or as side-events to BMBF events or scientific conferences that all scientific partners attend anyway.

Task T4.2 (in year 1, year 2, and year 3) We will hold one annual stakeholder workshop in the study region, to gain input from, communicate with, and advise stakeholders. All workshops will be moderated by a professional moderator. The first-year workshop will be held early on in the project, and will serve as a scoping workshop. Together with stakeholders, we will gather and synthesize project-relevant concepts and ideas of risk and uncertainty as they pertain to land management in the study region.
Milestone M4.1 (in month 5): We have carried out a scoping-workshop with stakeholders, and gathered their input for our planned research

The second-year stakeholder workshop will be held half-way in the project, to discuss intermediate results with stakeholders, and to allow for adjustments in the research design and communications which may be necessary in view of stakeholders' interests or research conditions.

The third-year stakeholder workshop will be held towards the end of the project. It serves to discuss near final results – prepared by us as a draft version of the Summary for Stakeholders before the workshop. Results of the discussion at the workshop will be taken into consideration when finalizing, after the workshop, this Summary.
Milestone M4.2 (in month 35): We have carried out a final workshop with stakeholders and discussed the stakeholder-oriented summary of results.
Deliverable D4.1 (in month 36): Summary for stakeholders

Task T4.3 (throughout the entire project period). Integration of research results from WPs 1 through 3 in view of case-study-applicability. We will organize and manage the process of exchanging (intermediate) results and data between Work Packages, and we will ensure that results and exchange are such that they are targeted toward reaching the overall project aims. Mostly, this exchange will happen during the internal project workshops (Task 4.1), which we will prepare and post-organize accordingly. Beyond this twice-per-year interaction, we will facilitate direct interactions between work packages, and in particular between the two subprojects at Uni Freiburg and TU Braunschweig, through short-term research visits of individual researchers at the other institution.

Task T4.4 (in year 1 and year 3). We will act as co-organizers of the bi-annual international *Summer School on Sustainability Economics* in 2018 and in 2020. The specific topics of these two summer schools will be “Deep uncertainties in decision-making for sustainability” and “Responsibility in managing the global commons” (working titles). In both years, we will make a teaching contribution (lecture, feedback to students) of preliminary project results to the summer school. This will ensure a transfer of fundamental as well as cutting-edge research results on the project’s topic and methods to junior researchers worldwide.

The summer school has been initiated by the Sustainability Economics Group at Leuphana University of Lüneburg, and has been operated bi-annually for some ten years with varying, specific topics. It targets junior researchers (doctoral or post-doctoral level) with a research focus on the summer school’s theme, who want to engage with experts in the field in a highly interactive manner. It brings together a small group of approximately 25 participants, including about ten eminent speakers and ten to fifteen junior researchers. The format will be that of a research-oriented workshop. While invited speakers provide keynote lectures on the topic with ample room for discussion, junior researchers present their research in shorter sessions. Junior researchers can apply for participation by responding to an open call.

Deliverable D4.2 (in month 10): teaching contribution (lecture, feedback to students) of preliminary results to international *Summer School on Sustainability Economics* in 2018

Deliverable D4.3 (in month 33): teaching contribution (lecture, feedback to students) of preliminary results to international *Summer School on Sustainability Economics* in 2020

Task T4.5 (throughout the entire project period). We will make contributions to accompanying activities of the BMBF program *Climate Change Economics*, such as e.g. participating in status conferences and contributing to network and outreach activities initiated by the program coordinators.

Overview of Milestones and Deliverables by Work Packages

Work Package	Month	Milestone	Deliverables
WP1 (Uni Freiburg)	9	M1.1	D1.1
	15	M1.2	D1.2
	21	M1.3	
	27	M1.4	
	36	M1.5	
			D1.3, D1.4, D1.5
WP2 (TU Braunschweig)	7	M2.1	
	13	M2.2	
	15	M2.3	D2.1
	33	M2.4	D2.2
	36	M2.5	D2.3
	36	M2.6	
			D2.4, D2.5, D2.6
WP3 (Uni Freiburg)	12	M3.1	
	18	M3.2	
	18	M3.3	
	27	M3.4	D3.1
	36	M3.5	
			D3.2, D3.3, D3.4
WP4 (Uni Freiburg with TU Braunschweig)	5	M4.1	
	10		D4.1
	35	M4.3	
	33		D4.2
	36		D4.3

Overview of deliverables from one task (row) to another (column)

from \ to		**WP 1 (Uni Freiburg)**					**WP 2 (TU Braunschweig)**				**WP 3 (Uni Freiburg)**					**WP 4 (both partners)**					**External**
		T 1.1	T 1.2	T 1.3	T 1.4	T 1.5	T 2.1	T 2.2	T 2.3	T 2.4	T 3.1	T 3.2	T 3.3	T 3.4	T 3.5	T 4.1	T 4.2	T 4.3	T 4.4	T 4.5	
WP 1 (Uni Frei-burg)	T 1.1							D1.1			D1.1										
	T 1.2																				
	T 1.3																				D1.3, D1.4, D1.5
	T 1.4									D1.2					D1.2						
	T 1.5																				
WP 2 (TU Braun-schweig)	T 2.1					D2.1		D2.1		D2.1					D2.1						
	T 2.2					D2.2				D2.2					D2.2						D2.4, D2.5, D2.6
	T 2.3					D2.3															
	T 2.4																				
WP 3 (Uni Frei-burg)	T 3.1																				
	T 3.2																				
	T 3.3																				D3.2, D3.3, D3.4
	T 3.4																				
	T 3.5					D3.1		D3.1		D3.1											
WP 4 (both partners)	T 4.1																				
	T 4.2																				D4.1
	T 4.3																				D4.4, D4.5, D4.6
	T 4.4																				D4.2, D4.3
	T 4.5																				

Schedule of work packages, tasks and milestones

	Year 1												Year 2												Year 3											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
WP 1	27 person months: 1 PhD student employed at 75% of regular work time over 36 months																																			
T 1.1									M																											
T 1.2															M																					
T 1.3																					M															
T 1.4																											M									
T 1.5																																				M
WP 2	36 person months: 1 PostDoc employed at 100% of regular work time over 36 months																																			
T 2.1							M						M		M																					
T 2.2																																	M			
T 2.3																																				M
T 2.4																																				M
WP 3	27 person months: 1 PhD student employed at 75% of regular work time over 36 months																																			
T 3.1												M																								
T 3.2																		M																		
T 3.3																		M																		
T 3.4																											M									
T 3.5																																				M
WP 4	9 person months: 1 PhD student employed at 25% of regular work time over 36 months																																			
T 4.1																																				
T 4.2					M																														M	
T 4.3																																				
T 4.4																																				
T 4.5																																				

explanation: personnel employed (person months, qualification, work time), duration of task, M – milestone

3.2 Time schedule and milestones

The project is scheduled to run over 36 months, from 01.09.2018 until 31.08.2021. The three substantive WPs 1 through 3 run in parallel over the full project period.

3.3 Resource needs and cost estimate

[omitted from this version]

4. Expected results and exploitation of results

Our project will produce the following tangible products.

For **stakeholders and policy-makers in the case-study region**: **(1)** We will produce an economic valuation of the land management options currently discussed in the case study region. This includes an identification of potential conflicts between different stakeholder groups, taking into account the different distributions of ecosystem services under different land management options and the groups' different uncertainty preferences. (jointly by Uni Freiburg and TU Braunschweig) **(2)** We will bring these results to the stakeholders, through workshops in the region and a policy brief for decision-makers (jointly by Uni Freiburg and TU Braunschweig).

For the **scientific community**: **(3)** The project produces a better scientific understanding of how to model, evaluate and academically communicate the various risks and uncertainties of potential adaptation options to climate change. This scientific output will be reported in 3 (Uni Freiburg) + 2 (TU Braunschweig) + 1-2 (joint) manuscripts for academic journals and 12 (Uni Freiburg) + 6 (TU Braunschweig) contributions to international conferences. **(4)** To transfer scientific expertise in climate economics to junior researchers, we will contribute to the biannual international *Summer School on Sustainability Economics* targeting graduate students and junior researchers (Uni Freiburg). In addition, we will offer 2 RUINS-derived topics per project year for bachelor or master theses (TU Braunschweig). **(5)** To make the developed methodology available to other researchers, we will produce a framework for uncertainty analysis in model chains, including visualization options.

For the **business sector and the economy at large**: our project will not immediately yield any products of commercial usefulness. But it will provide a basis on which such products may be developed (see next point).

Beyond this project and after its successful completion, our project will yield a number of perspectives for follow-up research, development, and implementation. In particular, we expect to be able **(6)** to develop follow-up research-and-development projects on the basis of this project and its expected results. For example, one follow-up project could, together with a practice partner from the insurance industry, turn the idea of insurance against Knightian uncertainty, to be developed at the conceptual level in this project, into a marketable product (Uni Freiburg). Other follow-up projects could apply the methodology, to be developed in this project, about how to comprehensively and systematically take into account different types of risk and uncertainty throughout the full chain of analysis, communication, and recommendation, to other land-management contexts (TU Braunschweig).

5. Division of labor, and cooperation with scientific and practice partners

The project is an *interdisciplinary* cooperation of two scientific partners (PIs): WPs 1, 3 and 4 are carried out at the **University of Freiburg** (PI: Prof. Dr. Stefan Baumgärtner); WP2 is carried out at the **Technische Universität Braunschweig** (PI: Prof. Dr. Boris Schröder-Esselbach). **Stefan Baumgärtner** (coordinator and PI of WPs 1, 3, 4) holds the Chair of Environmental Economics and Resource Management at the University of Freiburg. His expertise is on theory and conceptual foundation, amongst others of risk, resilience and insurance in ecological-economic systems. **Boris Schröder-Esselbach** (PI WP 2) holds the Chair for Landscape Ecology and Environmental Systems Analysis at the Technische Universität Braunschweig. As an expert in statistical and process-based modelling with expertise in inter- and transdisciplinary research, he focuses on the understanding of the relationships between patterns, processes, and functions in dynamic landscapes. In his group, **Anett Schibalski** (contributor WP 2) carried out the environmental and ecosystem service modelling within the COMTESS project (2011-2016). She is, thus, familiar with the coastal ecosystem under study and especially the data collected and models developed in COMTESS.

We cooperate with the **Carl-von-Ossietzky-University of Oldenburg** (Prof. Dr. Michael Kleyer and Dr. Leena Karrasch), where the COMTESS project had been coordinated. They will not perform any resource-requiring tasks for this project, but serve as a reference and host of information when it comes to COMTESS procedures and results. As we will continue working with the stakeholders already involved in COMTESS, Oldenburg will support us in making contact with these stakeholders and building up trust with them.

In a *transdisciplinary* manner, we will cooperate with a number of **stakeholders** in coastal land management in the study region. Some of them have already been involved in the COMTESS project, so that good working relations already exist:

- Entwässerungsverband Emden
- Deichacht Krummhörn
- Landwirtschaftskammer Niedersachsen
- Landwirtschaftlicher Hauptverein Ostfriesland e.V.
- a number of individual farmers
- Nationalparkverwaltung Niedersächsisches Wattenmeer
- Landkreis Aurich (Untere Naturschutzbehörde, Regionalplanungsbehörde)
- NABU
- Gemeinde Krummhörn
- Tourismusverband Ostfriesland
- Touristik GmbH Krummhörn–Greetsiel.

Prof. Dr. Michael Kleyer and Dr. Leena Karrasch (COMTESS), who continue working with these stakeholders in a separate project, will establish contact for us. Beyond this group with already established contact, we will extend the stakeholder network to include representatives of the insurance industry.

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