Research Ideas and Outcomes 6: e53608
doi: 10.3897/rio.6.e53608

Grant Proposal

Drivers and value tradeoffs of regional-scale adaptation in rural landscapes of central Europe

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Reviewable v1

Received: 24 Apr 2020 | Published: 28 Apr 2020

Citation: Mattsson BJ, Toth W, Penker M, Kieninger P, Vacik H (2020) Drivers and value tradeoffs of regional-scale adaptation in rural landscapes of central Europe. Research Ideas and Outcomes 6: e53608. https://doi.org/10.3897/rio.6.e53608

Abstract

Coupled human and natural systems exhibit complex interactions (e.g. feedback-loops) that are often poorly understood. Decision-makers from regional (e.g., state or provincial) scale environmental stewardship programs to international policy makers are often faced with uncertainties about future climatic and sociopolitical conditions (henceforth, system change) when supporting livelihoods and ecosystem services derived from lands and waters they oversee. Understanding how these system changes interact with adaptive decision-making processes toward stewardship of ecosystem services represents a considerable gap in knowledge. Adaptation, or iterative adjustment of management practices in response to or anticipation of system change, has been forwarded as a means of effective ecosystem stewardship. Furthermore, lack of clarity about value tradeoffs among competing program objectives (e.g., economics and aesthetics) often precludes development and implementation of adaptation. Although there have been several qualitative studies on regional to national adaptation, lacking is an empirical understanding of how the drivers and value tradeoffs associated with adaptation differ among regions and between related sectors spanning multiple countries. Diverse cultural heritages and

political structures among regions of central Europe offer great opportunities for examining spatial patterns of limitations to regional-scale adaptation in forest and agricultural sectors. This project will develop a quantitative index of adaptation for examining hypotheses about patterns of rural adaptation within regions of nine countries in central Europe. Alternative hypotheses describe contrasting assumptions regarding geographic variation in the relative importance among drivers and objectives associated with adaptation. Predictions derived from these hypotheses will be examined through a survey instrument that gathers information from programs focused on rural stewardship. Survey data will be analyzed using a hierarchical Bayesian approach that accounts for biases and missing information often resulting from surveys. Interviews will be used to validate survey responses and receive feedback on inferences made from the analysis of the survey data. Placing findings within the context of existing adaptation literature and evaluating subtler patterns that emerge from the survey data will generate new hypotheses to be examined through future research. The research will be conducted at University of Natural Resources and Life Sciences (BOKU) in Vienna. The applicant Harald Vacik from the Institute of Silviculture at the Department of Forest and Soil Sciences has proven his expertise on the evaluation of natural resource management in the context of sustainability, biodiversity and climate change. The post docs Brady Mattsson, Pia Kieninger and the PhD student Werner Toth contribute with their experience in developing climate adaptation decision support systems and providing uncertainty analysis in environmental decision-making. The proposed study will be an important step in advancing knowledge about adaptation and the interplay between humans and nature in maintaining a sustainable supply of ecosystem goods and services. This novel research integrates multiple scientific disciplines (e.g., ecology, sociology, decision theory, statistics) and to generate an integrated index of adaptation.

Keywords

agriculture, Bayesian hierarchical analysis, Central Europe, climate change adaptation, coupled human and natural systems, decision-making, ecosystem services, forestry, natural resource management, value trade-offs

State of the art and related research questions

Planning and implementation of adaptation

Coupled human and natural systems exhibit complex feedbacks, thresholds, and tipping points (Liu et al. 2007). Decision-makers are often challenged to ensure sustainability of livelihoods and ecosystem services derived from the natural conditions of the lands and waters they oversee (Millennium Ecosystem Assessment 2005, Nichols et al. 2011, Smit and Skinner 2002). Broad-scale system changes resulting from a shifting climate and increasing resource demands by humans have motivated resource managers to ensure resilient systems that buffer ecosystem services from local to regional scales (Chapin et al. 2010, Tsiafouli et al. 2013). Adaptation, the adjustment of management actions in response to and anticipation of system changes, has been forwarded as a particular means by which

to achieve sustainable management in the face of uncertainty about system changes. Within the environmental sciences adaptation is often considered in the context of climate change, but it also applies more generally to management adjustments according to any system change (e.g., increasing resource demand by humans). A general research question is to understand how adaptation varies with respect to multiple dimensions, including political borders, economic sectors within these borders, and affected ecosystem services and human benefits. Examining this complex field of research requires approaches that span disciplines of mathematics, ecology, geography, sociology, psychology, and economics (Adger et al. 2007). Although there have been qualitative studies of adaptation (e.g., Doria et al. 2009, Swart et al. 2009, European Environment Agency 2015), lacking is a quantitative measure to compare the status of adaptation by individuals, organizations, and governments. Such a quantitative index would enable addressing scientific questions regarding adaptation in a robust manner allowing comparisons within and across studies and sampling units within them. Drivers of adaptation have been explored initially at local (e.g., individual households and municipalities) to national levels, with the most in-depth investigations occurring at the national level. Studies range from investigations of drivers at all levels of government across the globe (Berrang-Ford et al. 2011) or within a single country (Tompkins et al. 2010) to a single governmental level for one or more continents (Bauer et al. 2012, Hanger et al. 2013, Ribeiro et al. 2009, Swart et al. 2009). On-ground adaptation (e.g., changing farm-level cropping practices), although guided by organizations working at a national scale, is primarily coordinated and conducted by organizations operating at regional (state/province/territory) and local (municipality to individual household) levels (Berkhout 2012). Further, adaptations at the local level are often closely tied to decisions and guidance made within the corresponding region (Adger et al. 2005, Smit and Skinner 2002). Regional-scale adaptation is therefore a critical lynchpin for linking local-scale adaptation actions to objectives at national to international scales; such vertical integration is a stated goal of international and national policies related to adaptation (Biesbroek et al. 2010). The only study that has included some explicit focus on drivers of regional adaptation raised perhaps more questions than answers on the topic due to the reported early stages of regional adaptation (Ribeiro et al. 2009). Thus, little is known about drivers of adaptation by regional-scale rural stewardship programs (henceforth, programs) and it would be important for adaptation planning and implementation in regional-scale rural stewardship programs which are relevant, and how do they interact, if at all (Fig. 1)?

Hypothesized drivers of regional-scale rural adaptation can be derived from studies at regional to national scales (Bauer et al. 2012, Berrang-Ford et al. 2011, Hanger et al. 2013, Ribeiro et al. 2009, Swart et al. 2009). These identified drivers can be broadly classified under five categories operating at multiple scales (Fig. 1):

1. Scientific information (regional) – communicated projections of ecosystem services as a function of management interventions taking into account uncertainties about system change;

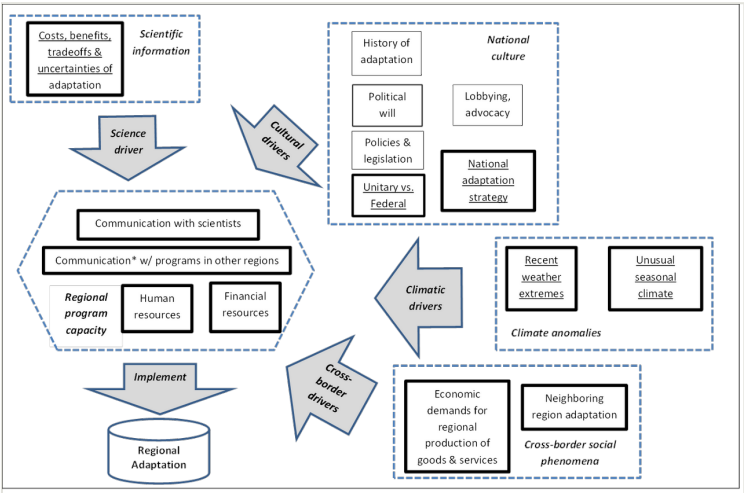

Figure 1. doi

Candidate drivers of adaptation by a program working at a regional scale, partially adapted from Figures 1.1 and 3.1 in Swart et al. (2009). This conceptual framework provides a basis for constructing hypotheses in this project. Each dashed border encapsulates a category of putative drivers. Neither relationships among individual drivers nor feedbacks between categories of drivers and adaptation actions are shown. Bolded boxes represent drivers that will be examined in this study. Underlined drivers can be at least partly informed from literature sources, whereas the remainder will be based solely on surveys and interviews with regional program administrators. (*Communication can also include coordination of adaptation planning/implementation in other regions).

2. Cultural attributes (national) – mode of governance (i.e., unitary vs. federal), flexibility of existing programs to adapt, lobbying/advocacy for or against adaptation, political will, and existence of adaptation policies and legislation;
3. Climatic anomalies (scales: regional to continental) – catastrophic weather events (e.g., floods, droughts, storms) and unusual annual variation in climatic variables;
4. Cross-border social phenomena (scales: interregional to international) – observed adaptation within neighboring regions, and shifting interregional economic demands; and
5. Regional capacity (program): communication or coordination with related decision makers, communication with scientists who can translate costs and benefits of adaptation, and available human or financial resources.

The drivers of these five categories can be hypothesized to work individually or interactively to influence the likelihood of achieving adaptation that yields benefits to ecosystem functions, services, and derived benefits to humans. Remaining unclear then is the relative importance of these drivers, ways they interact, and how they compare between particular economic sectors (e.g., forestry and agriculture) and among adjacent regions for a particular sector.

Central Europe as a test case for studying differences in regional adaption

Europe serves as an excellent focal continent for examining the challenges associated with regional-scale adaptation. Given a high level of cultural diversity along with demonstrated potential for cross-border cooperation and coordination (Perkmann 2003), studying spatial patterns among European countries can provide a model that could be compared with modes of regional adaptation in other parts of the world. Throughout Europe, projected system changes are expected to have spatially heterogeneous impacts on rural landscape condition and the resulting potential for deriving ecosystem goods and services (Alcamo et al. 2007). An example of a spatially heterogeneous impact is that water will become less available in regions experiencing more droughts due to climate change, elevated resource demands due to human population change and decision-making, or a combination of these two (Flörke et al. 2011). The European Union has responded by motivating international cooperation for system-change adaptation through a series of policy documents approved by the European Commission (2007), European Commission (2012a), European Commission (2013), and these have run parallel with developments of national climate strategies within Europe (Hanger et al. 2013). Given the recent international developments, little is known about how these potentially conflicting international policies are interpreted and applied in a region (Bauer et al. 2012, Swart et al. 2009). Many industrialized countries of central Europe have approved a national adaptation strategy going to be implemented on regional level (mostly considered as NUTS 2 regions - Nomenclature of Units for Territorial Statistics - Table 1) in particular.Those regions have their own network for international and interregional cooperation thanks in part to sharing their international borders and for the application of regional policies (European Commission 2020). This network of countries on the one hand exhibits diversity in culture with respect to democratic modes of governance and progress with adaptation that reflects some of the diversity seen across all of Europe (Bauer et al. 2012, Hanger et al. 2013). These central European countries, on the other hand, possess cultural similarities due to a shared history (Johnson 1996). By excluding some of the dimensions of European cultural diversity as a whole, focusing explicitly on central Europe enables a tractable test case of particular scientific challenges associated with regional adaptation.

Table 1.

Attributes of industrialized countries within central Europe. Geography is based on NUTS-2 regions included within Central Europe Programme (European Commission 2020) plus the nation of Switzerland, which was excluded from the CEP because of its non-EU member status although by many accounts it is part of central Europe (e.g., World Factbook; Encyclopedia Britannica; Brockhaus Enzyklopädie; Columbia Encyclopedia).

Country	Governance	National adaptation strategy approval year	Entire country in central Europe?	Num. NUTS-2 regions in central Europe
Austria	Federal	2012	Yes	9
Czech Republic	Unitary	2015	Yes	7
Germany	Federal	2008	No	8

Country	Governance	National adaptation strategy approval year	Entire country in central Europe?	Num. NUTS-2 regions in central Europe
Hungary	Unitary	2008	Yes	7
Italy	Unitary	2015	No	9
Poland	Unitary	2013	Yes	16
Slovakia	Unitary	2014	Yes	4
Slovenia	Unitary	-	Yes	12
Switzerland	Federal	2012	Yes	26

Management of ecosystem services in rural landscapes

Rural landscapes comprise >90% of the land area in Europe (Martino and Fritz 2008), and therefore they offer a particularly interesting opportunity for examining and comparing challenges of adaptation between sectors and regions spanning multiple countries. For the purpose of this study, rural landscapes are defined as terrestrial areas that are dominated by vegetative cover and are protected or managed through agriculture or forestry. Through such protection and management, these landscapes can provide diverse ecosystem services and associated benefits to humans (Maes et al. 2012, Schroter 2005). Within the rural landscape, two sectors are distinguished based on the dominant vegetation cover:

1. agriculture sector - dominated by herbaceous plants or shrub over story;
2. forest sector- dominated by trees.

Some landowners may conduct both agricultural and forestry practices on their properties, and so in this project we recognize this overlap while defining separate activities related to agriculture and forestry in our analytical framework. A particular focus of this work will be on forestry and agricultural activities, which are dominant even within so-called protected areas of Europe (Tsiafouli et al. 2013).

A general challenge in rural landscapes is balancing ecosystem services and human benefits derived from forested and agricultural lands (e.g., timber and crop production, carbon sequestration, recreation opportunities) while accounting for anticipated climatic and socioeconomic changes (Vos et al. 2008, West et al. 2009). Calls for improved ways to integrate understanding about adaptation in rural landscapes provide a clear impetus for cross-disciplinary research that considers potential for balancing several ecosystem services (Biesbroek et al. 2010, European Commission 2012b, European Commission 2012a). Focusing on nations of central Europe presents an opportunity to develop and integrate relevant knowledge about how drivers of rural adaptation vary in importance among regions and countries.

Forest management actions have already been augmented from individual-management-unit to landscape scales throughout much of Europe in anticipation of projected climate-induced changes to forest ecosystems and related services (Kolström et al. 2011). Frameworks exist for choosing among silvicultural (i.e., stand-level) adaptation techniques recognizing temporal dynamics of forests and tradeoffs among often competing ecosystem

services along with uncertainties about system change (Seidl and Lexer 2013). Indicator systems have also been developed representing multiple European forest ecosystem services (Seidl et al. 2010, Wolfslehner and Vacik 2011). Although there is some knowledge about variation in adaptive capacity in forests among multinational ecoregions within Europe (Lindner et al. 2010), lacking is an understanding of how factors limiting forest adaptation vary among and within individual countries.

Across rural landscapes of Europe, agricultural areas exhibit important contrasts with forested areas. Forests are usually designated as intensively managed for wood production across multiple decades, whereas usage of agricultural landscapes varies annually from intensive crop production to livestock grazing to arable fallows (Harrison et al. 2010). European agricultural lands are increasingly abandoned or managed for short-term profit, while many European forests are expanding and managed for long-term sustainability (Barbati et al. 2011, Stoate et al. 2009, Eurostat 2015). Further afforestation and intensification of remaining agricultural lands are expected to continue losses of European biodiversity (Fahrig et al. 2010). A particular challenge in sustaining agricultural ecosystem services at broad scales is that farms are privately owned, whereas substantial amounts of European forests are publicly owned and managed (Barbati et al. 2011). An expectation applying to both sectors, however, is that climate change will likely lead to elevated primary productivity in central Europe along with increased frequency and severity of droughts and storms that would induce physiological stress of the plants along with soil erosion (Flörke et al. 2011). Forest stands could face an additional threat of pest outbreaks resulting from droughts and storms (Lindner et al. 2010). Another pressure facing both rural sectors is increasing demand for agricultural and forest products (e.g., biofuels, wood, food), while at the same time there is a desire to mitigate intensive management practices to maintain rural landscapes supporting non-consumptive ecosystem services (Rounsevell et al. 2006, Schroter 2005). These salient comparisons between rural sectors give rise to the following question: how do drivers and tradeoffs of adaptation differ between the agriculture and forest sectors among regions within central Europe?

Value tradeoffs among ecosystem services

Although likely differing in magnitude, forests and agriculture provide similar types of ecosystem services including provisioning services (e.g., biofuels), regulating services (e.g., local climate regulation) and cultural services (e.g., outdoor recreation and tourism). The ways in which rural lands are managed will of course modify the levels of ecosystem services and derived benefits provided. Models of forests and of agricultural systems offer quantitative predictions about alternative management strategies, and in some cases climate scenarios (Happe et al. 2006, Lindner et al. 2005). These models can provide a basis for developing quantitative descriptions of scenarios for eliciting value tradeoffs from decision-makers (Task 1.3). We use the concept of a value tradeoff to capture how decision-makers engaged in stewardship of rural landscapes value ecosystem services. Here, a value tradeoff is defined as the value a decision-maker places on combinations of possible outcomes among categories of ecosystem services. This valuation reflects the satisfaction or desirability of the scenario by the decision-maker and can be quantified

using the concept of relative importance and hence can be used in multi-criteria decision analysis (Keeney and Raiffa 1993, Mendoza and Martins 2006). Understanding these value tradeoffs is crucial for making science-based policy and management recommendations that are transparent and likely to satisfy objectives of adaptation (Eakin et al. 2009, Nichols et al. 2011). Value tradeoffs among ecosystem services can vary across scales, for example a private rural landowner may place greater value on economic return than on aesthetics, whereas a regional stewardship program would want an outcome that somehow balances aesthetics with landowner profits. Indeed, European governments have subsidized private rural landowners for particular stewardship practices that promote cultural services to offset economic losses from these altered management practices, but none have assessed how decision makers value different combinations of ecosystem services. Some understanding exists regarding ways in which forest managers value tradeoffs among competing ecosystem services but only within a subset of regions of a single country (Wolfslehner and Vacik 2008, Seidl and Lexer 2013). An open question, therefore, is how do decision makers ("rural stewards") value possible outcomes of categories of ecosystem services derived from rural landscapes under system change, and how do these vary geographically?

Objectives

The overall goal of this project is **to identify the differences in adaptation within rural landscapes among geographies and between sectors within central Europe**. This will be followed by two sub-questions:

- Which drivers are important for adaptation planning and implementation within regional-scale rural stewardship programs, how do they interact, and how do they vary among regions or between sectors?
- How do decision-makers engaged in stewardship of rural landscapes perceive value tradeoffs among ecosystem services, how do these vary geographically, and how do they compare between forestry and agricultural sectors?

Methods - hypotheses and predictions regarding drivers and value tradeoffs of regional-scale adaptation

We form the groundwork for developing and examining subsequent questions and hypotheses about how decision-makers can account for drivers and value tradeoffs when stewarding rural ecosystem services. There are several studies in the literature examining such variation in adaptation from local to continental scales (Bauer et al. 2012, Berrang-Ford et al. 2011, Hanger et al. 2013, Ribeiro et al. 2009, Swart et al. 2009), but none have yet formally developed and examined hypotheses. Developing and evaluating multiple hypotheses is crucial for robust scientific inquiry (Chamberlin 1890), in this case regarding adaptation. Two classes of hypotheses can be developed to explore two corresponding elements of regional-scale rural adaptation:

1. variation in drivers, and
2. variation in importance of ecosystem services (i.e., value tradeoffs).

An important result from examining these hypotheses in this project will be a spatial representation of the degree to which adaptation has proceeded across central Europe.

Variation in drivers of rural adaptation

Three sets of hypotheses can explain variation in drivers of regional-scale rural adaptation with respect to three corresponding dimensions:

1. relative importance among **categories** of drivers,
2. **rural sectors** (forests and agriculture), and
3. **geography** (among regions).

An index representing the state of adaptation within each region will be used to evaluate these hypotheses (compare Tasks 1.1 and 3.2 in the Work Plan description – chapter 3). Example predictions are provided for each hypothesis to illustrate how a hypothesis could be supported by results from this study.

Driver-importance hypotheses H1-3 address the relative importance among **categories** of candidate drivers of adaptation (Fig. 1), which serves as a basis for examining variation in drivers among regions and between the rural sectors. We indicate this below under the **rural** and **geographic** sets of hypotheses.

H1. Unknown drivers: None of the examined drivers are important for explaining the adaptation process. *Example prediction*: There is no relationship between any of the putative drivers and a regional adaptation index (Fig. 2a). None of the drivers are important and may exhibit little variation among programs.

H2. Unlinked driver(s): One or more categories of drivers work independently to affect adaptation. *Example prediction*: Neighbor adaptation (cross-border driver) and national adaptation (cultural driver) increase with an index of regional adaptation (henceforth 'are important'; Fig. 2b and Fig. 3a), but these factors show no interaction and none of the other drivers are important. Cross-border and cultural drivers independently drive adaptation.

H3. Interacting drivers: Pairs of drivers from separate categories interact to affect adaptation. *Example prediction*: Adaptation of a focal regional program is only advanced when both national adaptation of the focal region and regional adaptation of neighboring regions are advanced (Fig. 3b). This hypothesis has support from existing adaptation literature (Bauer et al. 2012, Berrang-Ford et al. 2011, Hanger et al. 2013, Ribeiro et al. 2009, Swart et al. 2009).

Intersectoral-drivers hypotheses H4-5 compare importance of drivers between **rural sectors**. These hypotheses refer to the previous set of hypotheses regarding the relative importance of drivers (H1-3).

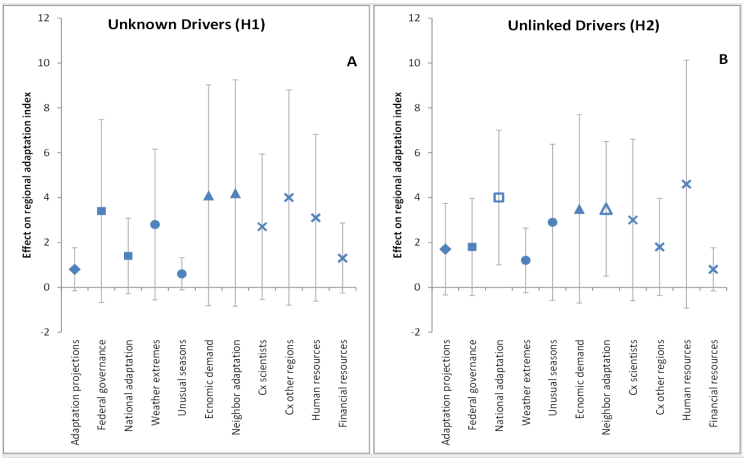

Figure 2. doi

Two hypotheses regarding drivers of adaptation, illustrated by simulated effects of individual drivers on an adaptation index (see below Tasks 1.1, 1.2, 3.2 in the Work Plan). Categories of drivers distinguished by symbols: diamond (u) = science; square (■) = culture; circle (●) = climate; triangle (▲) = cross-border; and × = regional program capacity. Whiskers represent 95% Bayesian credibility intervals; open symbols illustrate significant positive effects. Cx = communication.

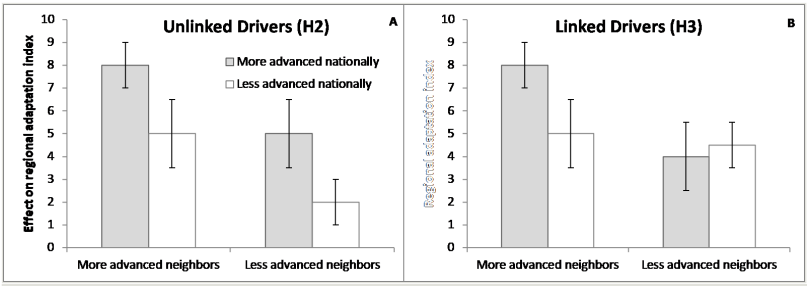

Figure 3. doi

Two hypotheses regarding drivers of adaptation, illustrated by simulated values representing absence (A) or presence (B) of interactions between effects on an adaptation index (see below Tasks 1.1, 1.2, 3.2 in Work Plan). Simulated effects include progress toward adaptation by countries of focal regions and by neighbors of these regions. Categories of progress toward adaptation defined as 'more advanced' (at or above median index value) or 'less advanced' (below median index value). Whiskers represent 95% Bayesian credibility intervals; non-overlapping whiskers illustrate statistically significant contrasts.

H4. Transferable drivers: Importance of drivers is similar between the forestry and agricultural sectors. *Example prediction*: Neighbor adaptation and national adaptation are important for both agriculture and forestry (Fig. 2b).

H5. Nontransferable drivers: Relative importance of drivers differs between sectors in that an important driver for one sector is not important for the other sector. *Example*

prediction: Only neighbor adaptation is important in the forestry sector, whereas only national adaptation is important in the agriculture sector.

Spatial-drivers hypotheses H6-10 address how drivers of regional adaptation may vary **geographically** among regions and countries. This set of hypotheses refers to the previous set of hypotheses regarding variation in the importance of drivers among categories of drivers (H1-3).

H6. Spatially homogenous drivers: Importance of drivers (H1-3) does not vary geographically. *Example prediction*: Only national culture is important across all of the examined regions.

H7. Spatially unpredictable drivers: Relative importance of drivers varies without any predictable spatial pattern. *Example prediction*: In randomly distributed regions only national adaptation is important, whereas in the remaining regions none of the drivers are important.

H8. Spatially clustered drivers: Relative importance of drivers aggregates geographically. *Example prediction*: As the importance of extreme weather for adaptation in neighboring regions increases, the importance of extreme weather for adaptation within the focal region increases.

Synergistic dimensions of drivers: Although the dimensions have been presented as independent, synergies among the three dimensions will be examined through the statistical analysis such that one hypothesis per set could be supported by the data (compare Task 3.2 in the Work Plan description – chapter 3). If it were found for example that in both rural sectors importance of national adaptation for a focal region increases with the importance of national adaptation for neighboring regions but none of the other drivers were important, then this would support three hypotheses: H2 “Unlinked driver(s)”, H4 “Transferable drivers”, and H8 “Spatially clustered drivers”.

Variation in value tradeoffs associated with rural adaptation

As with the class of hypotheses regarding drivers of adaptation, three sets of non-mutually exclusive hypotheses can explain the variation among value tradeoffs associated with regional-scale rural adaptation. Rather than focusing on the variation in drivers, the issue here is resolving variation in the relative values assigned by regional programs toward alternative ecosystem services that could be supported by adaptation. The three focal dimensions of value tradeoffs regarding adaptation correspond with the three categories of candidate drivers of adaptation: relative importance among categories of ecosystem services, rural sectors (forests and agriculture), and geography (among regions).

Objectives-importance hypotheses (H9-11) address the variation among programs regarding importance they place among three categories of ecosystem services and corresponding program objectives regarding rural adaptation (see Task 1.3 under Work Plan below). A set of importance weights summing to 100% across categories will be used to evaluate this set of hypotheses (Fig. 4). The importance weights reflect tradeoffs among

values placed on each category by regional programs and will be determined (compare Task 1.3 and 3.2 in the Work Plan description – chapter 3). It is possible that individual programs place 100% importance on a single objective and 0% on the remaining two objectives.

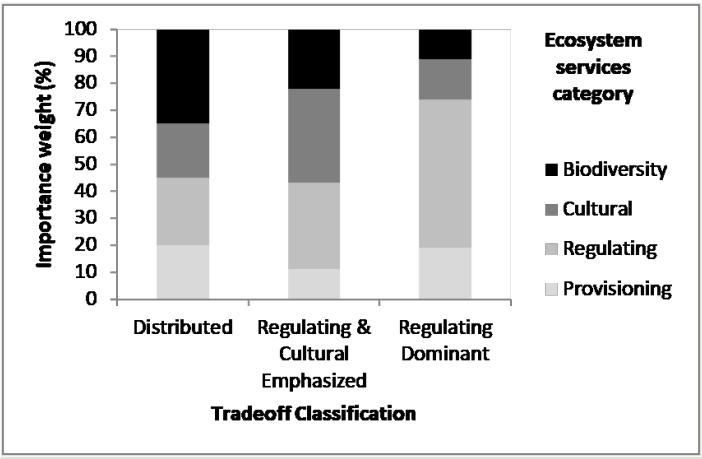

Figure 4. doi

Example classifications of tradeoffs from the perspective of regional stewardship programs: Distributed: each ecosystem service category is 20-30% (exclusive); Emphasized: ≥ 1 category is 30-50% (exclusive); Dominant: one categories is >50%.

H9. Indistinguishable value tradeoffs: Equal value of importance among categories of ecosystem services. *Prediction*: Likelihoods of dominance among classifications of value tradeoffs are indistinguishable.

H10. Dominant value tradeoffs: One category of services dominates the remainder. *Example prediction*: Likelihood of regulating services being dominant exceeds that of the other classifications.

H11.Diverse value tradeoffs: Multiple categories of services are consistently important. *Example prediction*: Likelihood of cultural and regulating services being emphasized exceeds that of the other classifications (Fig. 5).

Intersectoral-value tradeoffs hypotheses (H12-13) address comparisons in value tradeoffs between **rural sectors**. This set of hypotheses refers to the previous set of hypotheses regarding importance among categories of ecosystem services (i.e. value tradeoffs; H9-12).

H12. Transferable value tradeoffs: Value tradeoffs (H1-3) are similar between the forestry and agricultural sectors. *Example prediction*: Regulating and cultural services are emphasized by both agriculture and forestry.

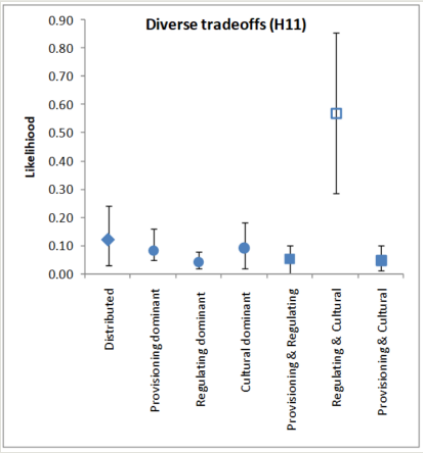

Figure 5. doi

Hypothetical result of an emphasis on regulating and cultural services consistent with the diverse value tradeoffs hypothesis. General classes of value tradeoffs distinguished by shapes: distributed (u), dominant (●) and double emphasis (■).Whiskers represent 95% Bayesian credibility intervals; open symbol illustrates a significant difference.

H13. Nontransferable value tradeoffs: Value tradeoffs differ between the forestry and agricultural sectors. *Example prediction*: Cultural services dominate in importance for agriculture, whereas regulating services dominate in the forestry sector.

Spatial-value tradeoffs hypotheses (H14-16) address how value tradeoffs associated with rural adaptation may vary **geographically** among regions and countries. This set of hypotheses refers to the previous set of hypotheses regarding importance among categories of ecosystem services (i.e. value tradeoffs; H9-12).

H14. Spatially homogenous value tradeoffs: Value tradeoffs do not vary geographically. *Example prediction*: For example regulating services dominate across all of the examined regions.

H15. Spatially unpredictable value tradeoffs: Value tradeoffs vary without any predictable spatial pattern. *Example prediction*: In randomly distributed regions regulating services dominate, whereas in the remaining regions relative importance among ecosystem services is similar.

H16. Spatially clustered value tradeoffs: Value tradeoffs aggregate geographically. *Example prediction*: When regulating services dominate in neighboring regions, the focal region has a high likelihood of this value tradeoff. In contrast, when ecosystem-service categories have similar importance in neighboring regions, then the focal region has a high likelihood of having such diverse interests.

Synergistic dimensions of value tradeoffs: As with the hypotheses regarding drivers of adaptation, synergies among the three dimensions will be examined through the statistical

analysis such that one hypothesis per set could be supported by the data. If it were found for example that for both sectors in randomly distributed regions regulating services dominate whereas in the remaining regions cultural services dominate, then this would support three hypotheses: H11 “Dominant services”, H13 “Transferable value tradeoffs”, and H15 “Spatially unpredictable value tradeoffs”.

Work plan and dissemination strategy

The project will be divided into 6 work packages (Fig. 6).

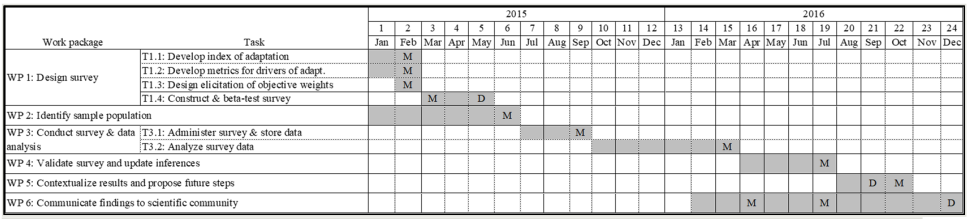

Figure 6. doi

Gantt chart showing tasks (T), milestones (M), and deliverables (D) as well as involvement of human resources according to the time plan – T, M and D are described in the text.

WP1: Survey design - The goal of the first work package is to design a survey beginning with **development of an initial prototype** to be **modified as needed following a review process**.WP1 is comprised of 4 tasks:

Task 1.1 is developing an initial prototype index of rural adaptation at regional scale (NUTS 2) (M1.1; Fig. 6), which will in turn be predicted by other metrics representing putative drivers (Fig. 1) that are developed under Task 1.2. This initial index of adaptation will be constructed using seven attributes, including:

1. awareness of potential changes and impacts,
2. engagement with relevant actors and stakeholders,
3. diversity of program objectives,
4. diversity of adaptation strategies,
5. understanding of consequences and uncertainties under alternative adaptation and system-change scenarios,
6. implementation of adaptation, and
7. documentation of planning and implementation.

These attributes are based on characteristics describing progress toward adaptation (Biesbroek et al. 2010, Nichols et al. 2011, Ribeiro et al. 2009).

For the initial index of adaptation, all **seven attributes** will be scored from 0 to 3 based on the survey responses, with a response of none always receiving a score of 0. The first attribute is **awareness**, which will be based on identified drivers of future alterations of rural ecosystem services within lands overseen by the respondent (scoring: changes in

climate = 1; changes in resource demands by humans = 2; or both types of changes = 3). The **engagement** attribute will be based on amount of communication/coordination with relevant actors and stakeholders involved with enacting local scale adaptation during the previous 12 months (1-3 days = 1; 4-5 days = 2; 6+ days = 3). The **diversity of program objectives** will be evaluated based on the distribution of importance weights among program objectives and corresponding ecosystem services (Dominant service = 1; Favored service[s] = 2; Diverse services = 3) (Task 3.2; Table 2). The **diversity of adaptation options** will be based on an existing typology for the agricultural sector comprised of strategies aimed at improving system resilience (i.e., continued provisioning of ecosystem services despite changes in climate or resource demand; Smit and Skinner 2002). This attribute will reflect how many categories of the following adaptation strategies are formally considered by a program:

Table 2.

Hypothetical result from a single survey respondent. Actual metrics and their units for corresponding program objectives will replace the words "RESILIENT" and "impacted" in the table for the survey.

	Scenario: resilience status from 2015 through 2040					
Ecosystem service	*Optimistic*	*Pessimistic*	Provisioning	Regulating	Cultural	Sum
Provisioning	*RESILIENT*	*impacted*	RESILIENT	impacted	impacted	-
Regulating	*RESILIENT*	*impacted*	impacted	RESILIENT	impacted	-
Cultural	*RESILIENT*	*impacted*	impacted	impacted	RESILIENT	-
Score	*(100)*	*(0)*	51	34	21	106
Weight (=score/sum)			0.48	0.32	0.20	1.00

1. crop innovations – develop new crop varieties for forest stands or crop fields;
2. resource management innovations – develop new approaches for managing forests or agricultural lands;
3. financial programs – modify programs involving insurance, income stabilization, subsidies, incentives, compensation, or assistance.

Understanding of consequences and uncertainties will be evaluated based on the existence and levels of agreement among predictive models linking adaptation options and system changes to outcomes in terms of program objectives (predictions exist but assume no system change= 1; predictions account for either climate change or social change = 2; predictions account for changes in climate and social systems = 3). **Implementation** will be evaluated based on progress of adjusting actions accounting for future system change in addition to a monitoring program that incorporates learning iteratively into the adaptation strategy (planned within next 5 years = 1; began within past 2years = 2; began >2 years ago = 3). **Documentation** will be assessed based on the availability and translations of reports or other publically available communications about the design and implementation of adaptation (only summary documentation in native language available and comprehensive documentation not available = 1, summary documentation and

comprehensive documentation in native language available = 2, summary documentation and comprehensive documentation in native language available and at least one of these two also in English available = 3). For every program, scores of each attribute will be summed to calculate the index of adaptation, ranging from 0 (no adaptation) to 21 (comprehensive adaptation) (Fig. 6).

Task 1.2 is developing an initial set of metrics for putative drivers of adaptation (M1.2), which will be used to predict the adaptation index when examining hypotheses under Task 3.2. Of the 11 metrics across the **four categories of drivers** (Fig. 1), 10 will be assessed in a survey (Task 1.4) using a 5-point Likert scale with 'none' as the minimum value and a maximum value given in parentheses below. The form of national governance has already been identified from existing literature (Table 1), so there is no need to include a survey question for this metric.

The **scientific driver** will be assessed using one metric regarding amount of information that is publically accessible and relevant at the scale of each sampled region quantifying uncertainties about system-change impacts and the costs and benefits of adaptation (maximum: sufficient amount of information at a regional scale that considers the adaptation actions, system drivers, program objectives, and value tradeoffs). Several aspects of national culture could independently or interactively influence the adaptation process, but for the purpose of this study **cultural drivers** will be evaluated using two metrics:

1. status of a national adaptation strategy or guidance (planned within next 5 years = 1; began within past 2 years = 2; began >2 years ago = 3), which should represent several relevant aspects of national culture;
2. type of national governance reflecting the relative ability of a nation to motivate adaptation efforts among regions (binary: unitary vs. federal).

Climatic drivers will be assessed using two metrics:

1. number of extreme weather events (e.g., flooding, drought, storms) that impacted ecosystem services within the past ten years (maximum: ≥3 extreme events), and
2. number of seasonal climate anomalies (e.g., unusual temperature ranges, levels of precipitation, timing of leaf out, growing degree days) relative to previous 10-year average experienced within the past three years (maximum: ≥3 anomalies).

Cross-border drivers will be measured using two metrics:

1. expected changes in economic demands for rural ecosystem services (market and non-market goods) to be exported from each region over next decade relative to current level (range: reduced by >10% to more than doubled);
2. number of neighboring regions known to be undergoing adaptation within a given rural sector (maximum: ≥3 neighbors).

Finally, **regional capacity** will be assessed from four metrics:

1. hours spent verbally communicating/coordinating with scientists regarding adaptation in the region during past 12 months (maximum:>40hr),
2. frequency of verbal communication/coordination with program administrators *in other regions* regarding adaptation within *those other* regions (maximum>40hr),
3. human resources to plan and carry out adaptation strategies in the region (maximum: more than sufficient for planning and implementation);
4. financial resources to carry out adaptation strategies in the region (maximum: more than sufficient for planning and implementation).

Task 1.3 is characterizing candidate program objectives with respect to their identity and developing a method for eliciting their relative importance by surveying regional program administrators (M1.3). The initial prototype selection of objectives is based partly on an indicator scheme for ecosystem services across Europe (Maes et al. 2012), and it is intended to capture the ultimate concerns expected to be important for regional programs while spanning the classes of ecosystem services (Millennium Ecosystem Assessment 2005) As such, the 3 **program objectives** and corresponding classes of ecosystem goods and services would include:

1. **provisioning services**: economic yield from food and wood production (Euros per ha) for agriculture and forestry, respectively;
2. **regulating services**: carbon storage representing regulating services for either sector (ton per ha) and
3. **cultural services**: recreation and tourism potential (5-point Likert scale from very low to very high) in either sector.

Supporting services are excluded, because as per definition they support the remaining services and would therefore likely not represent ultimate program objectives. Elicitation methods will include swing-weighting or the Analytic Hierarchy Process methodology (Saaty 1995). These methods quantify the relative importance among classes of ecosystem services. For example, a swing-weighting approach derives the relative importance values based on how decision-makers value the 'swing' from a very optimistic scenario to more pessimistic scenarios (see Table 2, Hammond et al. 2002). Scenarios will correspond with anticipated future outcomes regarding the three program objectives identified above averaged over three temporal horizons, accounting for climate change and demands for resources by society:

1. short (2017-2020), corresponding with the upcoming Common Agricultural Policy (European Commission 2012b);
2. medium (2017-2040), corresponding with the 25-year human generation time; and
3. long (2017-2100), corresponding with forest maturation time and with available climate-change predictions (Lasch and Lindner 1995, Pachauri and Reisinger 2008).

Under each scenario, the represented class of ecosystem services is predicted to be resilient to system change while the remaining ecosystem services are impacted severely (see Table 2). For each program objective, quantitative values derived from literature and expert consultations will be presented (e.g., Flörke et al. 2011, Happe et al. 2006, Maes et al. 2012).

Task 1.4 is constructing and beta-testing the survey (M1.4), which will be used to elicit from program administrators the metrics for adaptation and its drivers along with their value tradeoffs related to adaptation. The survey will consist of a glossary of terms and a brief justification for selection of the proxies for ecosystem service categories followed by 23 questions divided among four sections:

1. respondent identity – 5 questions, four of which asking the name, address, and affiliation of the respondent and one of which asking if they would like to remain anonymous in publications derived from this study;
2. adaptation index – 8 questions, of which seven ask about the corresponding seven attributes of adaptation (Task 1.1) and one asking whether implementation of adaptation has been documented and made available for at least those programs found in at least the neighboring regions (central European countries only) using the respective native languages;
3. adaptation drivers – 10 questions regarding the corresponding 10 metrics for the drivers (Task 1.2).

Additionally, the survey will include questions regarding the relative importance of the corresponding three classes of ecosystem services. A cover page will explain to each sampled program the importance of the survey, the mutual benefits of their participation, structure and content of the survey. Recommendations from literature on designing surveys will be followed for developing the survey (e.g., Dillman et al. 2009). The survey will be made available as an interactive web page. A draft version of the survey will be provided to the international cooperation partners of this project, colleagues at BOKU and the International Institute for Applied Systems Analysis (IIASA) for feedback. The revised survey will be translated into the respective languages of central European countries and then beta-tested with the national contacts identified through WP2. The survey will be revised again taking into account input from the national contacts, yielding a final version (D1.4) for administering under Task 3.1 below.

WP2: Identification of sample population - This work package will identify a sample population of programs engaged in regional (NUTS-2) stewardship of rural areas within industrialized regions of central Europe (M2). For the purpose of this study, a regional rural stewardship program is one that has articulated in its mission statement a desire to maintain the ecological and social benefits derived from forests and/or agricultural lands within a region of central Europe. With the support of the international cooperation partners of this project (listed below) the agricultural and forestry organizations providing such stewardship throughout Europe (e.g., Committee of Professional Agricultural Organizations, Forest Europe) will be contacted for developing a list of national and

regional contacts to be surveyed. Additionally the national and international cooperation partners will support:

- beta-testing the survey for Task 1.4;
- list of relevant regional programs and respective administrators within their country; and
- provide in-kind translation services for Tasks 1.4, 3.1, and WP4 if representing one of the 6 countries where the primary language is other than German or English.

The number of regional programs sampled will be maximized, and whenever possible at least one program administrator involved with forest stewardship and one with agricultural stewardship will be sampled within each region. The identified population for sampling would therefore include at least 196 programs across the 98 regions within the 9 central European countries. We assume a response rate of 50% and hence a sample size of 98. If multiple responses per program are received, only the one with the highest authority for that program will be considered for the analysis.

WP3: Survey and data analysis - The third work package is comprised of two tasks: Task 3.1 – administer survey and store data, and Task 3.2 – analyze survey data.

Task 3.1 is to administer the survey and store data within a relational database (M3.1). Recommendations from literature on conducting surveys will be used in administering the survey (e.g., Dillman et al. 2009), recognizing the sample population consists of professionals who use email as part of their daily work as opposed to the general public who may or may not use email regularly. Initially (Day 1), a notification letter will be sent to each sampled program from the national contact endorsing the survey to briefly describe its goals, benefits of participation, and date that it will be sent from the researcher via email. One week later (Day 7), a link to the web version including the survey will be mailed to each sampled program over email. Another week later (Day 14), each sampled program that has yet to respond will receive a reminder to complete the survey. Three weeks from the initial notification (Day 21) a final reminder will be sent to those who have not responded over email as was done on Day 14. A final database to be used for analysis under Task 3.2 will include responses received via the web.

Task 3.2 is to analyze the survey data (M3.2). As described in detail under Task 1.1, and if retained in its initial form, an index of adaptation will be calculated by summing individual scores (0-3) representing seven attributes of adaptation for each responding program yielding a total score ranging 0-21. Importance weights among program objectives will be derived using a swing-weighting elicitation (Task 1.3), yielding proportions between 0 and 1 (Table 2).

The first step in the analysis is to construct a generalized linear mixed model (GLMM, Kéry 2010) for each of the two classes of hypotheses and predictions posed above under ‘Project goals, hypotheses, and predictions’:

1. variation among drivers, and
2. variation in value tradeoffs.

In addition to the relevant predictors, each GLMM will contain a random intercept (henceforth, intercept) for the region of each sampled program to control for repeated samples within regions. To evaluate the first set of hypotheses regarding categories of drivers (H1-3; Fig. 1), the GLMM will have additive predictors for each driver along with interactions between program capacity metrics and the remaining drivers. Likewise, the GLMM for examining value tradeoffs will contain a predictor for each category of ecosystem services to evaluate the first set of hypotheses regarding categories of services (H11-13).

Otherwise, predictors for the two GLMMs will be the same for evaluating the remaining sets of hypotheses. A binary predictor for sector (forestry vs. agriculture) will be included in each GLMM for comparing the drivers and value tradeoffs between rural sectors (H4, 5, 14, 15). To examine the geographic hypotheses (H6-10 and 16-20), each GLMM will contain a fixed spatial effect for the proportion of neighboring regions exhibiting a focal trait regarding drivers and value tradeoffs, respectively. As an example, for the prediction under H8, the spatial effect will be calculated as the average of the regional adaptation index for the neighboring regions.

The GLMMs will be fitted to the survey data using Bayesian analysis, which not only accommodates missing data (i.e., unanswered survey questions or missing sector within a region, henceforth 'nonresponses') that may arise but also allows for readily fitting complex GLMMs (Kéry 2010). For each analysis representing a corresponding class of hypotheses there will be two specifications of the GLMM - one for the observation model and one for the process model. The observation model will be informed by the responses to the survey, whereas the process model will impute predictions for the non- responses based on the data from survey responses. This enables computing estimates regarding variation in drivers and value tradeoffs of adaptation across all sampled programs and regions rather than just those that provide responses. Because the adaptation index will be ordered, discrete, and bounded from 0 to 18, a binomial distribution will be assumed initially (Kéry 2010). An alternative discrete probability distribution (e.g., multinomial, negative binomial, Poisson) will be used instead if its goodness-of-fit exceeds that of the binomial. Value tradeoffs for each respondent will be classified according to the relative emphasis they place among categories of ecosystem services (Fig. 4) yielding 7 value tradeoff classes. For analyzing these categorical data, a multinomial distribution will be assumed. Because there are no known studies providing quantitative results to inform this analysis, uninformative prior distributions will be specified.

Statistical significance regarding drivers and value tradeoffs will be inferred from the posterior distributions of adaptation predictors (i.e., drivers) and objective weights, respectively. A slope will be considered significantly different if its odds ratio (i.e., for regression based on a logit link) is ≤0.5 or ≥2 and its 95% Bayesian Credibility Interval (BCI) excludes zero. Two means will be considered significantly different if they are ≥ 10% different and their BCIs exclude the opposing mean. As an example when examining relative importance among drivers of adaptation, if the BCI of the slope parameter for the binary variable representing existence of a national climate adaptation strategy excludes zero whereas none of the other drivers exhibit this effect then this would provide support

for the Unlinked Driver(s) Hypothesis (H2; Fig. 2b). In contrast when evaluating value tradeoffs, for example if the mean objective weight for regulating services exceeds 50% then this would support the Dominant Service Hypothesis (H13). The final set of results and inferences will be summarized for validation under WP4.

WP4: Validation of initial findings - The goal of WP4 is to account for sampling biases regarding the survey instrument along with any inconsistencies between the perspectives of selected respondents and inferences made from the initial analysis under Task 3.2 (M4). Sampling biases induced by inaccurate responses and nonresponses from surveys can be quite large, especially from the latter when questions ask about socially neutral to desirable behavior (Sakshaug et al. 2011). As such, one respondent and one non respondent from each of the 9 countries will be randomly selected within each of the following strata:

1. programs focused on stewardship of forests,
2. programs focused on stewardship of agriculture.

These 36 respondents will be contacted and requests will be made that they participate in a structured interview to discuss the initial inferences made from the analysis across all respondents. Interviews will be structured into two parts. The first part will focus on gathering or reviewing the responses to the survey for the original respondents and nonrespondents, respectively. Accuracy of the responses will also be discussed with regard to any existing documentation of program operations. Any skipped responses will also be discussed to reveal difficulties with completing the questions. The second part will consist of discussing the main findings from the analysis (Task 3.2) and checking whether they correspond with the perspectives of the selected respondents. Interviewees will be given an opportunity to revise or provide new responses for the final analysis.

For addressing measurement errors, this additional sample of 36 will be incorporated in the analysis from Task 3.2. In particular for each class of hypotheses, a binary variable for whether the sample was based on a structured interview and another binary variable will be added to the observation model to account for the non response bias and survey-measurement errors. The latent process model will remain the same as the original GLMM, but instead will be informed by not only the original survey responses but also the updated responses collected during interviews. The validation process will lead to updating inferences from the analysis, taking into account the measurement errors and insights gained from considering perspectives of selected respondents on the initial findings.

WP5: Contextualization of results - An important product from the analysis will be a map (D5), showing the geographic variation in the adaptation index among regions as an output from the GLMM. The map will enable additional inferences from the analysis, and the collective inferences will be compared with those reported in the literature for adaptation from local to national scales and across sectors. Any differences among scales and sectors will be noted along with any findings that contradict existing literature on regional rural adaptation. For example, drivers of regional-scale adaptation may be unimportant at other scales while drivers of rural adaptation may differ from those in other sectors. Comparisons between findings from this study and those in other parts of Europe (e.g., Mediterranean,

Scandinavia) will also be made. This synthesis will lead to not only new hypotheses (M5) but also recommendations for how this information could be incorporated into national and international policies on adaptation.

This study will yield a rich data set regarding the drivers and value tradeoffs of regional-scale adaptation in rural areas across 9 countries of central Europe. The a priori hypotheses and predictions (see above) capture the most salient patterns expected to emerge. More subtle patterns are also expected to emerge, which will generate new hypotheses about the drivers and value tradeoffs of regional rural adaptation to be examined through future research. Examples of such anticipated hypotheses and patterns include:

1. adaptation at international scales – adjacent regions sharing an international border exhibit similar drivers and/or value tradeoffs;
2. value tradeoffs and cultural drivers – variation in tradeoffs regarding regional-scale rural adaptation is linked to concomitant variation in cultural drivers of adaptation among regions; and
3. culture & science activation – regional capacity only becomes important when there is sufficient political will and access to information regarding costs and benefits of adaptation.

Directions for future research will not only propose means of investigating these emergent hypotheses but also ways of examining questions about how decision-makers and policy-makers could account for the discovered patterns of drivers and value tradeoffs of rural adaptation among regions in their decision making.

WP6: Dissemination – Communication of findings - Outcomes of the study will be published in international journals and also be presented at the annual European Climate Change Adaptation Conference (anticipated every spring) and the biennial Permanent European Conference for the Study of the Rural Landscape (occurs on even-numbered years, next in September 2018). Furthermore, in the final phase of the research project it is intended to organize a workshop at the University of Natural Resources and Life Sciences (BOKU) including all surveyed program officers to discuss the results, to foster mutual understanding and to stimulate potential collaborations (see Additional aspects).

Human Resources, Financial Aspects and International cooperation

The research will be conducted principally at the Institute of Silviculture at the Department of Forest and Soil Sciences within the University of Natural Resources and Life Sciences (BOKU) in Vienna. The Institute for Sustainable Economic Development at the Department of Economics and Social Sciences will be collaborating in the survey design and interpretation of the results. Beyond these two academic units, BOKU houses researchers with diverse expertise related to this interdisciplinary proposal including social sciences, economics, and natural resource policy.

Core team

The applicant **Harald Vacik (in-kind contribution)** has proven his expertise on the evaluation of natural resource management in the context of sustainability, biodiversity and climate change. Geographical information sciences and decision-support systems for multipurpose natural resource management are part of his research activities. For a period of almost 15 years he is actively involved in the development and application of criteria and indicators for evaluating sustainable forest management within national and international contexts. In this context he is providing expert advice in the implementation of scientifically based practical applications of multi-criteria decision making techniques in Europe and Asia. In collaboration with more than 65 co-authors all over the world including graduate students, Harald Vacik has published >200 articles, comprising an h-index of 12. Harald Vacik will use the project activities to intensify the existing collaboration with research institutions in Central Europe, contribute to the scientific output of the Institute of Silviculture and further develop the capacity of human resources regarding drivers and value tradeoffs of regional-scale adaptation:

The principal worker **Werner Toth** (the project embraces a PhD-program) will be supervised by the applicant Harald Vacik and the Post-Doc researcher Brady Mattsson. **Werner Toth** has a good knowledge of qualitative research methods, statistical analysis, and has shown his capability to analyze complex problems in his master studies. The project aims to support Werner Toth to further intensify research on decision-making associated with natural resource management.

The project will allow **Brady Mattsson** to further engage in natural resource management communities of central Europe, building upon his experience with developing climate adaptation decision support systems in North America. Currently he is providing decision support for sustainable forest management on cross-border national parks of central Europe, which will support the identification of important drivers for adaption.

Pia Kieninger and **Marianne Penker** (in-kind contribution) will be regularly involved in discussions regarding the project activities in WP1 and WP3. Pia Kieninger is currently a lecturer at BOKU. She was formerly a university assistant at the Institute of Integrative Nature Conservation Research and a post-doc at the University of Vienna. She was involved in several interdisciplinary research projects on sustainable land use. Marianne Penker is Associated Professor for Regional Development at BOKU and her current research focusses on collective management and sustainable use of rural resources (e.g. landscapes, local food products, biodiversity, traditional knowledge and skills) and the governance of socio-ecological systems (e.g. geographical indications, protected areas, agri-environmental schemes). This project will allow for intensive collaboration with forest scientists and work on joint publications.

The project is supported by two master-theses (N.N.), linked to the development of the index of adaptation (Task 1.1) and to the development of a set of metrics for drivers of adaptation (Task 1.2). This will support the master students in their scientific careers by providing contacts to European research groups and working on a highly innovative topic.

Additionally the continuing education program at BOKU comprises various courses and workshops that will be used to improve professional skills in project management. This will improve the impact of the outreach activities planned in course of the project.

International cooperation partners

Colleagues from the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria will be involved (as noted in Task 1.4, c), as a research emphasis at IIASA is investigating drivers of global transformations in response to emerging broad-scale stressors, especially climate change. Additionally, several international partners from central European countries have committed themselves to support the project regarding the identification of the sample population and reviewing the survey inWP2: Technical University in Zvolen (Slovakia), The Slovenian Forestry Institute, Global Change Research Centre, Academy of Sciences of the Czech Republic, Institute of Dendrology (Poland), Center for Development Research (ZEF) (Germany) and the Swiss Federal Institute for Forest, Snow and Landscape Research). More details on the partners are provided in the annex.

Financial aspects

DRIVER will be implemented with the contribution of one PhD (Werner Toth - 75%, 30 months), partly two post doc positions (Brady Mattsson, Pia Kieninger,10%, 30 months) and two short term contracts (GB) for the two master students (N.N. 6 months). A total amount of 135.299.60 € is needed to cover the staff costs for the activities described in the workplan (chapter 3). A total amount of 4.400 € is needed to cover the travel costs according to the consultation with the program officers in WP 2 (1 person travelling to 8 countries for 3 days each), the validation of the results (1 person travelling to 8 countries for 1-2 days each – see WP4) and the participation in scientific conferences. Additional short term service contracts will be made to cover the costs for the online survey and the translations services (3.350 €). The catering for the kick off and final workshop will require additional financial support (1.800 €) to cover the costs for the 30 participants at each workshop. This sums up to a total amount of 152.092,08 € (including the overheads) that are asked for funding. The full financial contribution is shown in a table in the annex.

Additional aspects

The research is novel, as it integrates multiple scientific disciplines (e.g., ecology, sociology, decision theory, and statistics) and fills gaps in knowledge about how human and natural systems interact. Questions about drivers of adaptation for stewardship of multiple rural ecosystem services under uncertainties about system change have primarily been investigated across all sectors, whereas this proposed project would address these questions comparatively between two particular rural sectors (i.e., forest and agriculture). Additionally, past investigations have used purely qualitative approaches (e.g., structured interviews) rather than incorporating quantitative approaches (i.e., modeling or statistics) to

address these questions. In particular this proposed work would generate for the first time an integrated index of adaptation that integrates the primary attributes of the adaptation process from awareness to implementation and learning (Task 1.1). Such a metric could be applied or modified for future scientific investigations of adaptation. Furthermore, this proposed work is innovative by examining and quantifying spatial patterns of drivers and value tradeoffs associated with adaptation among regions distributed across multiple countries. Finally, studies have focused primarily on adaptation with respect to climate change rather than also considering social changes (e.g., increasing resource demand by humans). Such interdisciplinary basic research can reveal novel insights about value tradeoffs and variation in drivers of regional-scale adaptation, which sets the stage for addressing these drivers and value tradeoffs when overcoming challenges for decision-makers faced with an uncertain future. More specifically, this research allows formulating region-specific recommendations to support regional stewardship of ecosystem services. The knowledge gained about drivers of adaption may help to develop regional stewardship programs that are accurately grounded on most influential factors. Clarity about particular trade-offs might help natural resource managers to more efficiently regulate the supply of ecosystem goods and services. Furthermore, practitioners might achieve additional learning affects through comparisons (e.g. on the quantitative adaptation index) with other regions or through collaborations with neighbor regions or other countries.

As the proposed project does not include experiments, potential ethical aspects, regulatory aspects and aspects associated with safety of potential experiment participants are seen as not relevant. Gathering surveyed data from program officers is considered to cause no impacts that would require us to further incorporate ethical aspects into the proposal.

Acknowledgements

Publication of this proposal was supported by BOKU Vienna's Open Access Publishing Fund.

Funding program

The proposal was rejected by the Austrian Science Foundation (FWF) as a Stand-Alone Project after a second submission and peer review in 2016.

Hosting institution

University of Natural Resources and Life Sciences, Vienna

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