BOOK OF ABSTRACTS

I. SESSION DESCRIPTION

ID: T1a

Operationalizing the IPBES framework in place based socio-ecological systems research

Hosts:

	Name	Organisation	E-mail
Host:	Neema Robert Kinabo	Senckenberg Biodiversity and Climate Research Center	neema-robert.kinabo@senckenberg.de
Co-host(s):	Peter Manning	University of Bergen	peter.manning@uib.no

Abstract:

Addressing global challenges of sustainable land use and biodiversity loss requires a knowledge base that integrates the major components of social-ecological systems, as attempted in the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES) conceptual framework. This framework describes links between direct drivers of biodiversity change (e.g., land use and management), Nature's Contributions to People (NCP) provision (broadly equivalent to ecosystem services), stakeholder demand for NCPs, the link between NCPs and human well-being, and the governance and societal factors influencing biodiversity change and NCPs. However, the IPBES framework was developed for the science-policy interface, and operationalizing it in research projects presents numerous challenges that necessitate new research approaches. This posits an opportunity for interdisciplinary social-ecological research, which is of significant fundamental research interest and also an essential basis for transformation towards a sustainable relationship between nature and people.

Goals and objectives of the session:

This proposed session will showcase place-based social-ecological systems research that aims to operationalize the IPBES framework in a detailed but integrated fashion. Such detailed characterization of social-ecological systems is a crucial first step to identifying the many leverage points for transformation that may exist within them. The objectives for this session are to demonstrate approaches and share findings from interdisciplinary research studies that characterize the many components of the IPBES framework, and that generate knowledge that bridges the natural and social sciences interface. By doing this, we will show how such work can help identify potential leverage points within social-ecological systems for achieving transformative change. The focus of our session will be on the large-scale Kilimanjaro Social-Ecological Systems-KiliSES project (https://kili-ses.senckenberg.de/), which explicitly aims to operationalize the IPBES framework, and we will also welcome contributions from other projects with similar aims.

Planned output / Deliverables:

Characterization and mapping of social-ecological systems for identifying levers of transformative change.

II. SESSION PROGRAM

Room: Expert Street 2

Date of session: 19th of November 2024

Time of session: 11:00-15:30

Timetable speakers

Time	First name	Surname	Organization	Title of presentation
11:00-11:13	Peter	Manning	University of Bergen, Norway	Operationalizing the entire IPBES framework on Mount Kilimanjaro
11:13-11:26	Dickson	Mauki	Senckenberg Biodiversity and Climate Research Center, Germany	Plant functional composition drives climate regulation across a tropical climatic gradient
11:26-11:39	Fabia	Codalli	Justus Liebig University Giessen, Germany	Water quality indices for drinking and irrigation water on the southern slopes of Mt. Kilimanjaro
11:39-11:52	Frank Paul	Shagega	Justus Liebig University Giessen, Germany	Influence of land cover types on preferential flow dynamics on southern slopes of Mt. Kilimanjaro, Tanzania

Time	First name	Surname	Organization	Title of presentation
11:52–12:05	Koggani	D. Koggani	Senckenberg Biodiversity and Climate Research Center, Germany	The importance of biodiversity facets differs among wood supply products across tropical montane ecosystems
12:05–12:18	Maria Eugenia	Degano	Senckenberg Biodiversity and Climate Research Center, Germany	Using soundscapes to reveal the role of biodiversity in non-material Natures' Contributions to People at Mount Kilimanjaro., Tanzania
12:18–12:31	John	Sanya	Leuphana University of Lüneburg, Lüneburg, Germany	Heterogeneity of demands for Nature's Contributions to People and Nature's values by farmers: insights from the Kilimanjaro social-ecological System
14:01–14:14	Neema Robert	Kinabo	Senckenberg Biodiversity and Climate Research Center, Germany	Land use and elevation shape NCP multifunctionality for diverse stakeholder groups in the Kilimanjaro Social-Ecological System
14:14–14:27	Netra	Bhandari	University of Marburg, Germany	Exploring synergies and trade-offs between the potential supply of Nature's contributions to people in the southern slopes of Mt. Kilimanjaro, Tanzania
14:40–14:53	Agnes	Vari	McGill University, Montreal, Canada	How is the IPBES conceptual framework useful for place-based research? Analyzing case studies across Canada
14:53–15:06	Sophie	Peter	Institute for Social-Ecological Research, Germany	Transformative Change in Social-Ecological Systems: Analyzing Indirect Societal Drivers and Shaping Future Cultural Landscapes in Germany
15:06–15:19	Victoria	Grießmeier	Senckenberg Biodiversity and Climate Research Center, Frankfurt am Main, Germany	Insights on place based on the causes and consequences of biodiversity change from the from the Biodiversity Exploratories Project
15:19–15:30	Peter	Manning	University of Bergen, Norway	Open discussion and closing remarks

III. ABSTRACTS

The first author is the presenting author unless indicated otherwise.

1. Exploring synergies and trade-offs between the potential supply of Nature's contributions to people in the southern slopes of Mt. Kilimanjaro, Tanzania

First authors(s): Netra Bhandari

Other author(s): Neema Robert Kinabo, Dominic A. Martin, Andrea Larissa Boesing, Margot Neyret, Markus Fischer, Peter Manning, Dirk Zeuss

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Mountain socio-ecological systems are biodiversity hotspots and provide various nature's contributions to people (NCP), which can vary with elevation and land use. Furthermore, diverse demands from stakeholders make it crucial to assess synergies and trade-offs in NCP supply at management-relevant scales. In this study, we reviewed literature and consulted experts from natural and social sciences to identify suitable indicators for NCP specific to the Kilimanjaro socio-ecological system. We underpinned each indicator with data from across a large interdisciplinary project, covering 65 plots belonging to 13 ecosystems along Mount Kilimanjaro's elevational gradient and collected between 2010 and 2023. Complementing these locally measured indicators, we compiled remote sensing data covering indicators best assessed at landscape scales. We trained a random forest model to upscale indicators collected from plots using suitable remote sensing proxy data, while some indicators were downscaled from pre-existing remote sensing data. Overall, the 49 indicators represent the potential supply of 18 NCP. We also addressed the problem of spatial autocorrelation using a 10-fold spatial cross-validation method. We then conducted an area of applicability assessment to define where the predictions are valid and invalid. We further standardized the scaled-up maps of landscape-level potential NCP supply to calculate synergies and trade-offs across the landscape. Results indicate that high supply of material NCP is associated with lower biodiversity and a trade-off with regulating and non-material NCP, which correlate with higher biodiversity. Regulating NCP are primarily governed by Kilimanjaro's climatic gradient, with land use and biodiversity explaining significant variation within climatic zones. Areas at higher elevation and conserved by the national park show higher supply of regulating and non-material NCP and low material NCP. These comprehensive results, especially when combined with stakeholder demand, will provide a holistic understanding of the socio-ecological system

and identify governance and management options to mitigate trade-offs and improve NCP supply.

Keywords: NCP indicators, Kilimanjaro, social-ecological system, upscaling, remote sensing

2. Water quality indices for drinking and irrigation water on the southern slope of Mt. Kilimanjaro

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The southern slopes of Mount Kilimanjaro in Tanzania act as a water tower, providing the Nature's Contributions to People (NCP) regulation of water supply and quality for the densely populated slopes, the adjacent lowlands and the Pangani River Basin. The fertile soils have been home to the indigenous Chagga people, who have shaped the slopes with their small-scale "homegardens" and locally managed canal systems. Further down, the lowlands are characterised by intensive agriculture and settlements, particularly around the town of Moshi. Given the high water demand for drinking and agricultural use in the study area, this study aims to evaluate the NCP of regulation of water quality by assessing the suitability of eight different water types (streams in natural condition, streams, irrigation canals, domestic water, springs, lake, groundwater and rainfall) for drinking and irrigation. Fifty-one samples were collected in a snapshot sampling campaign over 10 days in February 2023 during the dry season. Initially, four physical water quality parameters, thirteen chemical and one microbiological parameter were analysed and compared with Tanzanian and international water quality guidelines. All parameters were within the guidelines except for faecal contamination and turbidity for drinking water and pH for irrigation water. Then, the same parameters were used to calculate the drinking (DWQI) and irrigation water quality indices (IWQI, Kelley's Index, Soluble Sodium Percentage, Permeability Index, Residual Sodium Bicarbonate and Magnesium Ratio). The DWQI classified 77% of the samples as unsuitable, 4% as poor or very poor and 19% as good or excellent for drinking. The poor drinking water quality was exclusively due to faecal contamination, highlighting the need to identify the sources and remediate them before distribution. The IWQI showed no restrictions in use. However, three of the other five suitability indicators revealed that high concentrations of sodium and magnesium made 20-30% of water sources unsuitable for irrigation

Keywords: water quality, irrigation, drinking, water quality index, Kilimanjaro

3. Using soundscapes to reveal the role of biodiversity in non-material Nature's Contributions to People at Mount Kilimanjaro, Tanzania

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Soundscapes, comprising biological, biophysical, and anthropogenic sounds, hold significant cultural and emotional value for people. However, the differences and drivers of soundscape preferences and associated non-material Nature's Contributions to People (NCPs) across diverse cultural backgrounds and natural areas are relatively unknown. To address this gap, we collected acoustic recordings from seven habitat types across Mount Kilimanjaro (Tanzania) during dusk and dawn, and characterized them using eight acoustic indices. In a comparative approach, we played recordings to international tourists and local residents to assess their soundscape preferences and associated non-material NCPs. We ranked the recordings based on stakeholder group preferences and used generalized linear mixed models to identify drivers of non-material NCP association. We found a general preference for dawn recordings over dusk recordings, given the dominance and variability of birds' vocalizations over the louder, insect-dominated soundscapes of dusk. Local residents preferred and attributed more NCPs to natural sounds from montane habitats, followed by those from human-dominated areas such as coffee plantations and maize fields. In contrast, international tourists valued soundscapes from natural habitats such as grassland and subalpine habitats more highly. Furthermore, local residents and international tourists attributed different non-material NCPs to soundscapes. International tourists experienced greater restorative effects, particularly from natural sounds free of anthropogenic interference and with stable sound intensity, whereas local residents attributed cultural heritage to soundscapes associated with a high diversity of sounds, including both natural and human-generated sounds. This analysis highlights the differing perceptions of soundscapes and suggests pathways to link social perceptions with ecological data. Integrating these insights into management decisions could foster conservation strategies that consider the pluralistic perspectives of nature.

Keywords: non-material Nature's Contributions to People, cultural ecosystem services, soundscapes, pluralistic perspectives, acoustic indices

4. Insights on place-based research on the causes and consequences of biodiversity change from the Biodiversity Exploratories

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Since 2006, the Biodiversity Exploratories program (BE; www.biodiversity-exploratories.de) is focusing on long-term, large-scale investigations of the relations between land-use, biodiversity and ecosystem processes and services, using 150 grassland and 150 forest sites as model systems. More recently, the program is also addressing the indirect drivers of land-use change and the consequences of changing ecosystem service supply for various stakeholders.

To study these issues, three study regions, the so-called “Exploratories” were established along the North-East South-West axis of Germany, encompassing the following areas: Schorfheide-Chorin, Hainich-Dün, and Schwäbische Alb. In the current funding phase (2023-2026), 41 projects are involved, including several social-ecological ones.

We present results on land-use effects on various facets of biodiversity, on how biodiversity change affects ecosystem service supply, on how far this supply meets stakeholder demands, and on underlying cultural, socio-cultural, and socio-demographic factors. In addition, we highlight important lessons learned from place-based research into the ecological and socio-ecological causes and consequences of biodiversity change.

Keywords: Biodiversity, Interdisciplinarity, Research Platform, Ecosystem Services, Social-ecological Research

5. Heterogeneity of demands for Nature's Contributions to People and Nature's values by farmers: insights from the Kilimanjaro social-ecological System

First authors(s): John Sanya Julius

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Farmers are not a homogeneous stakeholder group, particularly regarding their demands for Nature's Contributions to People (NCP) and how they value nature. Overlooking the inherent heterogeneity of farmers may prevent the implementation of inclusive nature conservation and agricultural policy that aligns with their needs and interests. We aimed to explore the inherent heterogeneity of the NCP demands and values of nature expressed by farmers, considering their socio-demographic characteristics, pro-environmental behavior, and geographical context. Additionally, we sought to understand how perceptions of NCP supply trends over the last decade affect demand for NCP. Using a socio-cultural valuation approach, we applied 364 face-to-face surveys in 14 villages residing on the southern slope of Mount Kilimanjaro, Tanzania. Based on the descriptive and redundancy analyses (RDA), we found that farmers primarily preferred material and regulating NCP: food, feed, and regulation of freshwater quality, whose supply is perceived as decreasing -i.e., 'critical' NCP-.Regarding values of nature, we found the highest share of agreement for statements representing intrinsic value (97.1% of respondents who agreed or strongly agreed), relational values (94.8%), and instrumental values (94.1%), although the pattern for individual value statements varied slightly. The RDA findings indicated that while altitudinal and latitudinal gradient, the number of generations living at Kilimanjaro and engagement in conservation activities strongly influenced NCP demand and nature's values. Values of nature were also influenced by age, education, and being a member of any association. Moreover, we found seven bundles of NCP demand that represent distinct ways farmers use and appreciate nature. These findings deepen the understanding of the interlinkages between NCP demands, perceived NCP supply trends, and the valuation of nature according to the inherent heterogeneity of farmers, which is essential to elaborate evidence-based strategies for nature conservation that align with their interests and needs.

Keywords: ecosystem services, interwoven NCP approach, mountain ecosystem, plural valuation, social preferences.

6. Land use and elevation shape NCP multifunctionality for diverse stakeholder groups in the Kilimanjaro Social-Ecological System

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Environmental changes can affect the balance between the supply of Nature's Contributions to People (NCP) and the demands of diverse stakeholders, especially in mountain social-ecological systems (SES). Balancing supply and demand require understanding how SES can provide the NCP demanded by diverse stakeholder groups. Here, we aimed to assess how multiple habitat types within the Kilimanjaro SES can provide multiple NCP simultaneously and how well this supply meets the demands of five stakeholder groups—farmers, conservationists, tourists, tour operators, and industry. Using the Ecosystem service multifunctionality (ESM) approach and data from across the Kili-SES project, we combined data on the supply of 25 context-specific NCP at the plot level with NCP demand social survey data of the five stakeholder groups. We found a significant difference ($p<0.001$) between the demands of stakeholders, where tourists demanded non-material NCP, e.g., new and unique experiences, while others demanded material NCP like food. We also found that the supply of material NCP decreased while non-material and regulating NCP increased with increasing elevation and decreasing disturbance. Stakeholder groups with the highest average multifunctionality values were conservationists and tourists, suggesting favorable ecological conditions of the Kilimanjaro SES, as these groups prioritized regulating and non-material NCP, respectively. Furthermore, results showed that the smallholder agriculture system of homegardens had a high potential to provide both non-material NCP, e.g., aesthetic enjoyment, for tourists, and specific material NCP, e.g., provision of building materials, similar to the habitats under protection where these NCP are high. Our study identifies the ecosystems that best meet the demands of different stakeholder groups and why while highlighting those with potential for NCP provision beyond what is currently utilized. These results can form the basis for landscape multifunctionality measures to provide a landscape-level synthesis for conservation in the Kilimanjaro social-ecological system.

Keywords: Ecosystem Service Multifunctionality, stakeholder demand, NCP indicators, Kilimanjaro, social-ecological system

7. The importance of biodiversity facets differs among wood supply products across tropical montane ecosystems

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Biodiversity can strongly influence forest productivity, yet this does not necessarily translate to a higher supply of wood-based Nature's Contributions to People (NCP), as only selected fractions of tree biomass are used. This study utilized forest survey data from Mt. Kilimanjaro, plant trait databases, and information from the local socio-economic system to investigate how the role of functional biodiversity in driving NCP supply varied among several wood-based NCP: timber, charcoal, fuelwood, and for comparison, total tree above-ground biomass (AGB), while also incorporating climate and land use intensity (LUI) as direct drivers within a structural equation framework. The highest supplies of tree biomass, timber, charcoal, and firewood were at intermediate elevations and moderate LUI, specifically in lower montane, Ocotea, and Podocarpus forests, while supplies were zero at the highest and lowest elevations dominated by Helichrysum, Erica, grass, and maize fields. The role of biodiversity varied significantly among biomass and different NCP. Timber supply was greatest in areas with high species richness, whereas charcoal and fuelwood supplies were unaffected by species richness but were influenced by the community abundance -weighted mean (CWM) of tree height. Elevation did not directly impact the supply of timber, charcoal, or firewood; its effect was mediated through LUI, CWM tree height, and species richness. LUI negatively impacted tree AGB both directly and indirectly by reducing species richness and CWM tree height, which positively influenced AGB. Timber supply was indirectly affected by elevation and LUI via their negative effects on species richness, while fuelwood supply was directly and indirectly negatively affected by LUI through its reduction of CWM tree height. Our results indicate that the relationships between biodiversity and NCP differ from that linking biodiversity to ecosystem functioning because of selective human use. This has implications for the transferability of biodiversity-ecosystem functioning research, management of biodiversity and NCP.

Keywords: material Nature's Contributions to People, Kilimanjaro, Social-Ecological System, selective human use, functional biodiversity

8. Operationalizing the entire IPBES framework on Mount Kilimanjaro

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Addressing interlinked societal and ecological challenges requires interdisciplinary approaches, such as those promoted by the Intergovernmental Panel for Biodiversity and Ecosystem Services (IPBES) framework. Yet, because of the conceptual and methodological challenges posed by interdisciplinary work, applications of the framework have been mostly qualitative, or conducted in fragmented studies of sub-components of it. In this talk I will give an overview of the IPBES framework, describe the need to operationalize it and discuss the present challenges in doing so. I will then describe an approach taken to overcoming these challenges, and how it has been applied within the Kilimanjaro Social Ecological System (Kili-SES) project. The Kili-SES project is a large research consortium in which all major components of the IPBES framework are measured within multiple sub-projects in a single study region. The linked nature of these projects allows for detailed synthesis and whole systems level understanding. In turn this will enable identification of pathways to transformation. This talk will lay the foundation for later talks in this session which focus on conceptually linked sub-sections and synthesis of the system, and broader discussion of how we operationalize the IPBES framework in place-based social-ecological systems research.

Keywords: IPBES framework, social-ecological system, Kilimanjaro

9. Plant functional composition drive climate regulation across a tropical climatic gradient

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Plant functional composition play an important role in shaping plant ecological responses to environmental conditions and influencing ecosystem functioning. However, how whole-plant functional strategies aggregate at the whole community level to influence carbon storage across climatic gradients remains poorly understood. Across the broad climatic gradient of Mt

Kilimanjaro, Tanzania, we measured the variation in whole-plant strategies at the community level using both aboveground and belowground plant traits. With Structural Equation Models, we further assessed the joint effects of climate and plant functional strategies on carbon storage in trees and soil. Our results revealed two main axes of functional composition variation at the community level; namely slow-fast and woody-grassy axes, driven by climatic variability. Both axes of functional composition strongly drive variation in carbon storage, which was highest in "fast" and "woody" communities. Climate influenced carbon storage both directly and indirectly through variations in plant community strategies. There is an overall positive correlation between annual precipitation and carbon storage, while mean annual temperature tends to be negatively correlated with carbon storage. We demonstrated that major plant strategy axes manifest at the community level along climatic gradients and explain variation in carbon storage. Also, we show the climate can directly and indirectly influence carbon storage via plant functional strategies. In particular, communities with fast-growing woody plants show greater carbon storage potential.

Keywords: climatic gradient, plant functional composition, above-ground carbon, soil carbon storage

10. Transformative Change in Social-Ecological Systems: Analyzing Indirect Societal Drivers and Shaping Future Cultural Landscapes in Germany

First authors(s): Sophie Peter

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Global biodiversity continues to decline, with unsustainable land use identified as a major direct driver, according to IPBES. To better understand this driving force, it is crucial to gain insights into indirect societal trends and their influence on the relation-ship between society and nature.

The DFG-funded project 'Socio-cultural Dynamics of German Cultural Landscapes – A Future-oriented Perspective' (SoCuLa) is part of the infrastructure priority program Biodiversity Exploratories and gain deeper insights into the social-ecological system of three German study regions. Therefore, our research takes a holistic perspective, focusing on indirect societal drivers of transformative change. By analyzing trends such as demographic change, health,

mobility, digitalization, societal transformation and changing values, we aim to understand their impact on biodiversity and ecosys-tem services. Our research focuses on identifying these indirect drivers and explor-ing sustainable approaches to shaping future cultural landscapes in Germany.

In my presentation, I will highlight three specific objectives of the project: (1) to investigate indirect societal drivers in Germany and more specifically in the study regions, (2) to participatively develop future social-ecological scenarios, and (3) to combine social science data with natural science research to create an interdiscipli-nary understanding of nature and society.

With the interdisciplinary approach of the SoCuLa project, we aim to combine social and natural science research to contribute to sustainable land use practices and the management of our cultural landscape in the future.

Keywords: Cultural Landscape, Indirect Societal Drivers, Participatory Scenario Development, Sustainable Land Use, Social-Ecological Research

11. Influence of land cover types on preferential flow dynamics on southern slopes of Mt. Kilimanjaro, Tanzania

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The southern slopes of Mount Kilimanjaro, Tanzania, feature a diverse range of land covers, from natural forests to agricultural lands. This diversity significantly impacts soil hydrological processes, particularly preferential flow (PF), and plays an important role in the provisioning of Nature's Contribution to People regulation of water supply. PF refers to the rapid movement of water through macropores, root channels, or fractures, bypassing the general vertical flow through the soil matrix. Understanding the influence of land cover on PF is essential for effective water resource management (e.g., groundwater recharge) and soil conservation (e.g., reduction of surface runoff) in this ecologically sensitive region. However, despite its importance, the quantification of PF in tropical regions, particularly in Sub-Saharan Africa, remains scarce. In this study, we assessed the influence of land cover on PF occurrence across

eight ecosystem types on Mount Kilimanjaro's southern slopes. We analyzed continuous soil moisture data measured in three soil depths and rainfall data at 1-h resolution from January 2022 to August 2023. After separating and clustering rainfall events, we assessed the dynamics of soil moisture responses. The order of soil moisture changes and response times in different soil depths informed us about the occurrence of PF versus sequential (matrix) flow. Our results also indicated frequent PF occurrence in upper mountain ecosystem types: Erica forest (81.6%), Ocotea forest (30.1%), and montane forest (26.4%), suggesting rapid subsurface water movement and potential groundwater recharge. Conversely, disturbed Ocotea forest, grassland, and maize fields indicated more uniform flow dynamics, which may lead to increased surface runoff and soil erosion. We also found that rainfall depth, duration, intensity, and initial soil moisture levels (optimal between 35 to 45%) significantly influenced PF occurrence. These findings are crucial for understanding subsurface water movements, soil conservation strategies, and managing the vital water resources of both the natural and disturbed ecosystems of Mount Kilimanjaro.

Keywords: rainfall events, soil moisture, soil moisture metrics, preferential flow, Mount Kilimanjaro

12. How is the IPBES conceptual framework useful for place-based research? Analyzing case studies across Canada.

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Conceptual frameworks in general are deemed to be important for multiple reasons: for synthesizing knowledge, for stepping from the specific to the general, for serving communication. The IPBES conceptual framework is one of the most acknowledged frameworks for social-ecological research. However, experience from place-based research points at a mixed engagement with this framework. In our comparative study, we wanted to know how far and for what the IPBES conceptual framework can be useful to place-based research. We analyzed six different landscape level case studies across Canada participating in the NSERC ResNet project. In our analysis we tested where the visual and textual representations of these case studies deviate or differ from the IPBES conceptual framework, and how these reflect their regional land management issues. We found that big-picture conceptual frameworks like the IPBES one are actually less used to guide local research then expected. The land-use management issues targeted by our case-studies could be often seen as conflicts within some

components of the IPBES conceptual framework (e.g. between different institutions, or as trade-offs between different ecosystem services). The process of developing own frameworks to represent more specific (local) social-ecological issues was often seen as more beneficial than the use of any pre-existing framework. Nevertheless, the use of well-known frameworks can help to translate between local actors (as a boundary object) or point out biases in stakeholders perceptions. They are also essential for communicating local processes and structures to external viewers.

Keywords: conceptual frameworks, place-based research, social-ecological systems, IPBES