ICIMOD Working Paper 2015/2

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Long-Term Environmental and Socio-ecological Monitoring in Transboundary Landscapes

An Interdisciplinary Implementation Framework

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About ICIMOD

The International Centre for Integrated Mountain Development, ICIMOD, is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalization and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

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ICIMOD Working Paper 2015/2

Long-Term Environmental and Socio-ecological Monitoring in Transboundary Landscapes

An Interdisciplinary Implementation Framework

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Foreword

Central to contemporary scientific and development discourse questions related to the services that society receives from ecosystems, how these services are impacted by the prevailing drivers of change, how they are perceived by local communities, and how behavioural changes affect ecosystem form and function are fundamental. Within this discourse, the need for research that integrates environmental, ecological, and social sciences has never been greater.

For over 30 years, the International Centre for Integrated Mountain Development (ICIMOD) has been working as an intergovernmental learning, knowledge sharing and enabling Centre in the Hindu Kush Himalayas (HKH). The long-term environmental and socio-ecological monitoring (LTESM) framework presented in this publication is an important step in establishing effective long-term environmental and socio-ecological monitoring in the region, which will support efforts by ICIMOD and its partners to fill critical data gaps in the Hindu Kush Himalayas.

The LTESM framework is a long-term transdisciplinary monitoring framework designed for implementation in ICIMOD's Transboundary Landscapes Regional Programme together with the Centre's partners in the region. It focuses on improving understanding of spatial and temporal changes to the biodiversity of the HKH, the drivers of these changes, and the consequences of these changes on human wellbeing in the region. By encouraging research institutions, organizations, and individual experts across disciplines to work together, it will support a more holistic understanding of the dynamic mountain ecosystems of the HKH and provide support for evidence-based decision making in the region. The approach also encourages experts to work on long-term collaborative programmes in line with rapidly growing international research networks such as Global Observation Research Initiative in Alpine Environments (GLORIA), International Long Term Environmental Research (ILTER), and Global Earth Observation Biodiversity Observation Network (GEO-BON).

On behalf of ICIMOD, I would like to thank everyone that contributed to and supported the development of this framework, which will be beneficial for ICIMOD and our partners. I am optimistic that it will also be of great help in the design and implementation of integrated and holistic research programmes and in increasing the socioeconomic resilience of people living in the Hindu Kush Himalayas.

David Molden, PhD
Director General

Acknowledgements

The authors would like to express their gratitude to Dr David Molden, Director General of ICIMOD, for his inspiration and support. We are also thankful to the Chengdu Institute of Biology of the Chinese Academy of Sciences and the Chinese Committee of ICIMOD for supporting the expert consultation workshop, which was instrumental for shaping the framework into its present form. Review and constructive comments from Dr Golam Rasul was useful for bringing additional values in the framework. The authors also recognize the support extended by the United Nations Environment Programme's World Conservation Monitoring Centre (UNEP-WCMC). The continuous support and commitment from ICIMOD's eight regional member countries is also acknowledged. The authors would also like to recognize the support of the Austrian Development Agency (ADA), the German Federal Ministry for Economic Cooperation and Development (BMZ) through its German Agency for International Cooperation (GIZ), and the Department of International Development (DFID), United Kingdom, which made this collaborative research possible.

Acronyms and Abbreviations

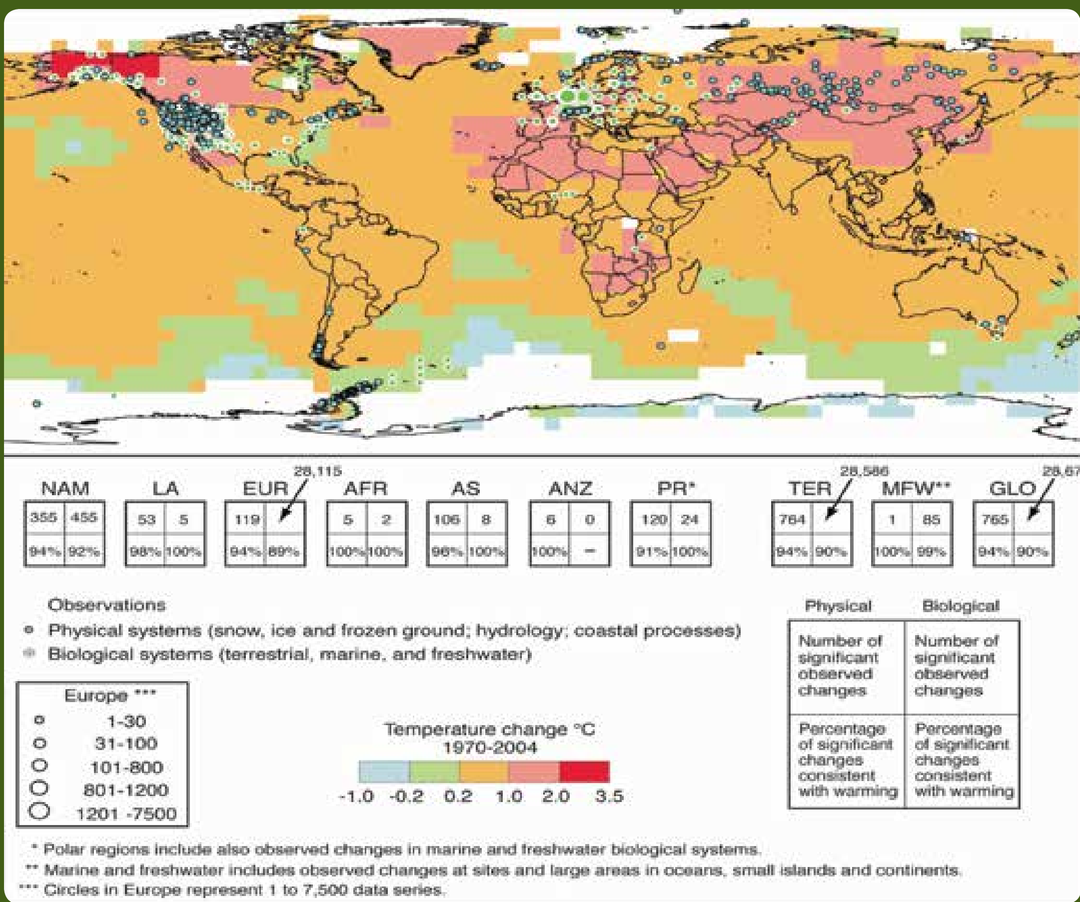
GLORIA	Global Observation Research Initiatives in Alpine Environments
HKH	Hindu Kush Himalayas
ICIMOD	International Centre for Integrated Mountain Development
LTER	Long-Term Ecological Research
LTESM	Long-Term Environmental and Socio-Ecological Monitoring
LTSER	Long-Term Socio-Ecological Research

1. Introduction

Why is long-term monitoring necessary in the Hindu Kush Himalayas?

The Hindu Kush Himalayan region (HKH) has been identified as one of the most biodiversity-rich areas world (Brooks et al. 2006). It is also culturally rich, serves as a water tower for the region, and is the source of a wide range of ecosystem goods and services of local, national, regional, and global significance (Xu et al. 2009). However, the region is facing socioeconomic, environmental, and ecological challenges with various drivers of change, including climate change (Schild and Sharma 2011). This is one of the poorest regions in the world. Poverty, livelihood insecurity, and food insecurity often force local communities to use resources to meet their needs for survival without considering the environment. Widespread poverty, along with the growing demand for resources and the strong profit motive of commercial enterprises, combined with inadequate incentives for sustainable management has led to the unsustainable use of resources and environmental degradation (Rasul 2014). In order to design appropriate policies and strategies to manage the environment in the long-term, data and information are needed. The Fourth Assessment Report of the IPCC (2007) explicitly identified the HKH as a data deficit area, with limited sources of socio-economic, environmental, physical and biological data for long-term analysis (Figure 1). The main reasons for this data deficit are the limited number of long-term research stations and systematic collection and archiving of socio-economic data in the region and the lack of a trusted platform and mechanism to share data among existing interested stakeholders. In addition, there are uncertainties about the consequences of various drivers of change due to a lack of long-term data, sporadic and scattered research, limited access to and the unreliability and incomparability of existing data.

Figure 1: **Distribution patterns of physical and biological monitoring stations considered for the IPCC Fourth Assessment Report**



What is long-term environmental and socio-ecological monitoring, and why it is important?

Monitoring can be defined as the process of repeatedly gathering information about variables (such as the income status of a local community, demographic change, the population size of a threatened species, species richness and composition, habitat condition, forest cover, or the distribution of an invasive pest) to assess the state of the system and draw inferences about changes over time (Yoccoz et al. 2001). Long-term ecological monitoring can also be interpreted as repeated field-based empirical measurements taken periodically and then analysed over the course of at least ten years (Lindenmeyer and Likens 2010). Understanding long-term ecological interactions at multiple spatial and temporal scales is difficult or, in some cases, impossible without a foundation of long-term observations. However, they are important for several reasons, including the following:

- Observations across many years can define the range of natural variability of socio-ecological systems and provide a baseline.
- Long-term observations on a comprehensive set of interacting physical, environmental, biological, and social variables allow for the assessment of relationships among components of socio-ecological systems.
- Experiments that are maintained for many years allow for the establish cause–effect relationships, especially for parameters that change over a longer timeframe. This enables for the prediction of future changes with respect to drivers of change and provides warnings to policy makers to inform appropriate action.
- Comparisons of long-term observations or experiments across multiple sites can lead to a more realistic understanding than that gained from individual sites alone.
- Long-term and integrated monitoring through interdisciplinary research could provide reliable data to develop nexus between social, environmental and ecological data for use in influencing policy and informing timely decision making holistic management and development interventions.

Jitendra Raj Bajracharya

What interdisciplinary monitoring systems are available and working?

Long-term research has been an integral part of sustainable development in human-dominated landscapes. Long-term research provides a reliable source of information and knowledge, leading to innovations, solutions to challenges, and more effective management of resources. Conservation and development communities have witnessed many innovative multidisciplinary research initiatives over the last three decades, including GLORIA (Global Observation Research Initiatives in Alpine Environment) (Pauli et al. 2004) and the bioDISCOVERY Science Plan of DIVERSITAS (Ash et al. 2009). However, these initiatives are limited in their scope. One of the most comprehensive and integrated monitoring systems was started in the Hubbard Brook Experimental Forest in the White Mountains of New Hampshire in 1963 which is one of the earliest experiments that threw light on the long term ecosystem changes and the actual use of such data to understand drivers of change (Likens 2013). In 1980, the Long-Term Ecological Research (LTER) Program was started in the United States of America (Redman et al. 2004), followed by China in 1988 (Fu et al. 2010). Since then, LTER expanded to a number of other Southeast Asian countries (Malaysia, Phillipines, and Japan), including regionally customized initiatives such as BIOTA-AFRICA (Jürgens et al 2012), Carribean Initiative (Rivera-Monroy et al. 2004), and the ALTER Net-Europe (Singh et al. 2013). More than 20 countries across the globe are under the umbrella of the International Long-Term Ecological Research (ILTER) network (Vihervaara et al. 2013). More importantly, after realizing the importance of social linkages, the concept of long-term ecological research (LTER) has been broadened to long-term socio-ecological research (LTSER) in many LTER sites (Haberl et al. 2006). Recognizing the linkages between drivers and impacts, the Drivers Pressures- Status- Impact- Response (DPSIR) framework is evolving (Niemeijer and de Groot 2008) into a promising approach for analysing environmental issues, especially in mountain ecosystems. However, many of these initiatives are driven by the objectives of individual programmes and have both advantages and limitations (Table 1). Some of the existing approaches still have narrow scope for integrated and systematic analysis with a long-term focus (Fischera et al. 2010). Although the importance for robust long-term research in the Hindu Kush Himalayas is increasingly realized with rising demand (Tripathi 2010, Khuroo et al. 2011; Rawat and Joshi 2014), there are few long-term research initiatives in the Hindu Kush Himalayas (Fu et al. 2010; Bajracharya et al. 2011; Krstić et al. 2012). Other countries in the Hindu Kush Himalayas are in the process of following in the footsteps of China and the global community (e.g., Sukumar et al. 1992; Houllier et al. 1997; Chawla et al. 2012). However, these initiatives are yet to be established with clear long-term goals.

Table 1: **Existing long-term monitoring programmes showing thematic focus and their comparative advantages and disadvantages at global, regional, and national levels**

Frameworks and manuals	Geographical focus	Thematic focus	Advantage	Limitation	References
International Long Term Ecological Research (ILTER)	Global	Biological and social sciences	• Site-based and research questions drive research and monitoring network • Wide spectrum of research with long-term data collection • Evolving from only ecological to also include social considerations • High-quality research with increasing network members • Well defined data sharing and data management practices	• Comparability of research from site to site is limited • Social science aspect is evolving	LTER 2007; Haberl et al. 2006 Gosz et al. 1996
Biodiscovery of Diversitas	Global	Biodiversity assessment, Improving observation and understanding of changes in biodiversity and improving biodiversity projections	• Robust integrated framework and conceptual clarity • Scope for trends and projections through modelling • Interdisciplinary science focusing on ecology, agro-biodiversity, and climate change • Strong global network	• No clear methodologies and indicators • Limited field demonstrations	Ash et al. 2009
Social and Biodiversity Impact Assessment (SBIA) Manual for REDD+ Projects	Global	Forest biomass	• Followed state-pressure-response framework • Strong focus on biomass and succession with robust methodologies • Includes the human dimension in the monitoring protocol	• Sees humans as a threat	Pitman 2011

Table 1, continued

Frameworks and manuals	Geographical focus	Thematic focus	Advantage	Disadvantage	References
Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems - Volume II	Global	Grassland, shrubland, and savanna	• Systematic description • Well-defined methodologies • Integrated approach in monitoring with wide spectrum, including soil	• Socio-economic parameters not used.	Herrick et al. 2005
Global Observation Research Initiative in Alpine Environments (GLORIA)	Global	Alpine ecosystems and climate change (population dynamics and migration)	• Well-defined methodology and protocols • Growing number of sites and network members with comparable data	• Limited to alpine ecosystems	Pauli et al. 2004 Grabherr, et al. 2000 Grabherr, et al. 2011
GLOCHAMORE (Global Change in Mountain Regions) Research Strategy	Global mountain area	Biological and social sciences	• Prepared through a rigorous, consultative process • Well-defined framework covering a wide spectrum of thematic focuses and indicators • Integrated approach with clear indicators for social and biological themes	• Limited to conceptual stage with limited practice and uptake	Price et al. 2006
BIOTA – Africa	Africa	Biodiversity complexity (genes, species and ecosystems) and dimension (composition, structure, function and evolution)	• Well-defined methodology and protocols • Covering complex biodiversity – abiotic (e.g., climate, soil characteristics) and biotic (e.g., land use, demography, biotic interactions) • Comparable data across Africa • Covers temporal and spatial scales	• Socio-economic parameters not used except consideration of demographic change as a driver	Jürgens et al. 2012
Hubbard Brook Experiment	US	Biochemistry, hydrology, forestry, nutrient dynamics, etc.	• One of the oldest long-term monitoring stations • Widely accepted and evolving methodologies and protocols • Widely accepted	• Limited faunal aspect covered • Socio-economic parameters not used.	Likens 2013 Federer et al. 1990
Framework for monitoring biodiversity change	Canada	Biodiversity change (species or species groups)	• Flexible option for flora and fauna • Follows standard protocols • Applied by many network members • Comparable at national and international levels	• Broad areas with less focus on habitat	Roberts-Pichette 1995
RAINFOR field manual for plot establishment and remeasurement	Amazonian ecosystems	Forests (biomass, structure, carbon dynamics, succession and soil)	• Well-represented in Amazonian basins • Develops protocols and is followed across the region • Well-maintained database	• Limited to biomass and structure • Biodiversity aspect missing • Mostly used for commercial purpose	Phillips et al. 2009
A Permanent Plot Method for Monitoring Indigenous Forests - Expanded Manual Version 4	New Zealand	Forest (carbon storage, invasive species, canopy dieback, modelling) and fauna	• Comprehensive process explained • Pictorial guides provided • Linked to indigenous people • Widely used as a network across New Zealand	• Socio-economic parameter is limited to indigenous forest without links to use patterns or benefits	Hurst and Allen 2007
Biodiversity Exploratories	Germany	Grassland and forest	• Systematic methodology • Functional traits and soil considered as important variables • Comparative analysis	• Limited ecosystems • Limited stations • Socio-economic parameters not used	Fischer et al. 2010
Chinese Ecological Research Network	China	Grassland, forest, wetlands	• One of the biggest networks of stations in Asia • Standardized methodologies and protocols • Wide spectrum of biophysical and environmental parameters (soil, nutrients, carbon, etc.) • Well-defined data access and management	• Socio-economic parameters not clearly defined	Fu et al. 2010 Huang et al. 1999

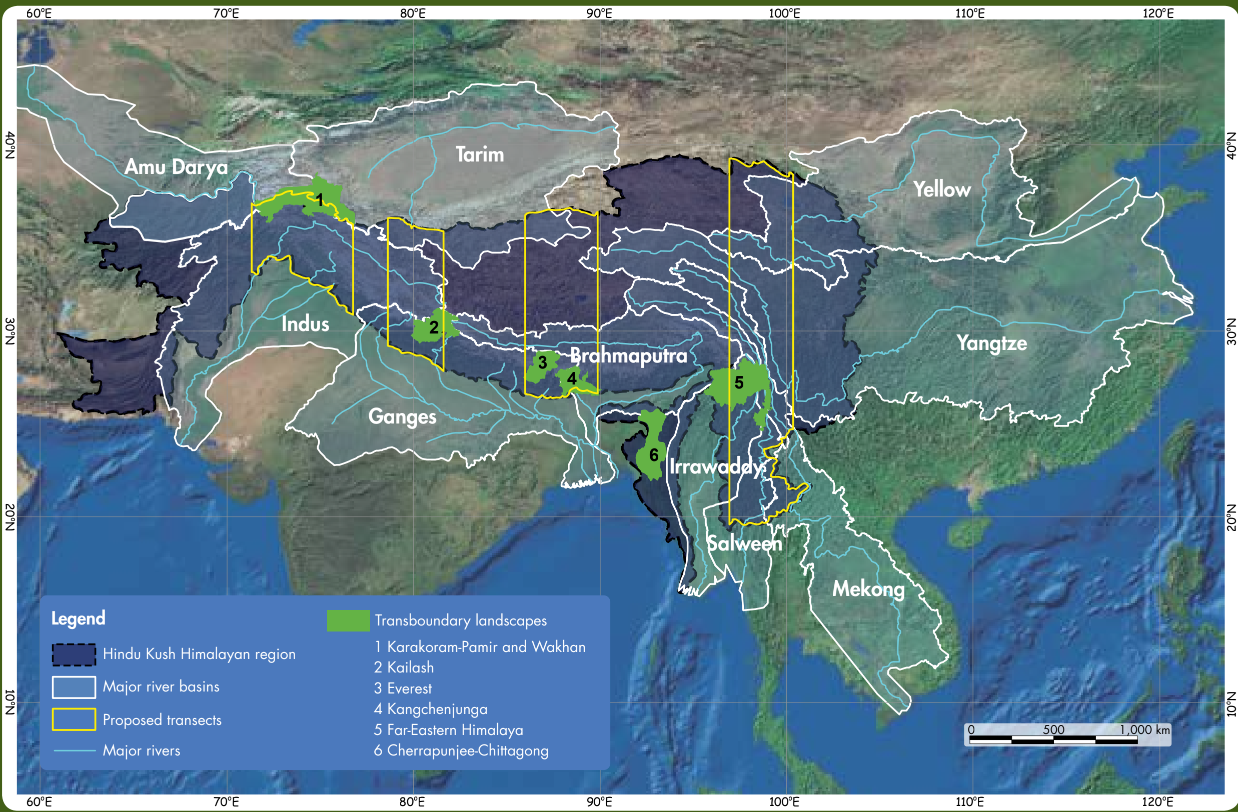
Why do we need an interdisciplinary framework?

In pursuit of a thorough scientific understanding of the world around us, ecologists, environmentalists, social scientists, and others have worked within their academic disciplines to develop a wide range of empirical studies, methods, and models to identify key drivers, processes, and controls that regulate human and ecosystem behaviour and interactions with the environment. However, most researchers have pursued answers to fundamental questions about patterns and processes in environmental, ecological, and human worlds from within the boundaries of one discipline or another, neglecting the relationships between them (Howe et al. 2013). In this context it may also be mentioned that the research from various disciplines not only provides essential data for interdisciplinary and integrative approaches, but is also increasingly at risk of being discontinued in many countries. Strengthening the nexus between the disciplines is one of the essential preconditions for successful inter- and transdisciplinary approaches. Thus, it is no longer tenable to study these systems in isolation from one another, as human beings are an integral part of virtually all ecosystems (MEA 2005). Almost all natural and human-induced activities have potential relevance to each other and the environment that we live in, and the resources surrounding us are the basis for our own wellbeing (Griggs 2013). Thus, there is an urgent need to strengthen integrative approaches equipped with a comprehensive framework, reinforcing multidisciplinary methods, and using high-quality complementary data for bringing together social, environmental, and economic perspectives in the planning and management of environmental resources.

What is ICIMOD doing to help address data deficits?

As an intergovernmental knowledge and enabling Centre, ICIMOD has been playing a pivotal role in generating and sharing knowledge on the Hindu Kush Himalayas over the last 30 years. ICIMOD believes that access to timely, relevant and high-quality data and information by its member countries and the wider regional and global

Figure 2: **Six transboundary landscapes and four transects across the Hindu Kush Himalayas**



community would inform, promote, and accelerate learning on the challenges faced by mountain ecosystems and their people; enable independent research and scientific enquiry; catalyse the development of knowledge products and innovations that improve the wellbeing and livelihoods of mountain communities; and empower critical and urgent decision making and efforts at times of emergency, disaster, and humanitarian crisis. With an objective to bridge, policy and practice gap', ICIMOD has initiated a Regional Database Initiative to promote open-access data sharing that complies with international and national laws, third party intellectual property rights, confidentiality obligations, and contractual terms and conditions of use imposed by the provider of the data (ICIMOD 2013). In addition, ICIMOD has also conceptualized a HKH transect framework (ICIMOD 2009a), with an objective to address data deficits across representative areas of arid, semi-arid, and wet landscapes and including altitudinal (low to high), longtitudinal (east to west), and latitudinal (south to north) gradients (ICIMOD 2009b). In 2010, ICIMOD established the HKH Conservation Portal (http://hkhconservationportal.icimod.org/Default.aspx), which is a dedicated open-access regional platform for sharing data in transboundary landscapes and encouraging collaboration among the countries sharing the six identified landscapes and four transects (Figure 2).

What are the goals and objectives of long-term environmental and socio-ecological monitoring?

Ecological dynamics and their linkages to different disciplines are complex, and the scope for long-term environmental and socio-ecological monitoring (LTESM) in the HKH is wide. However, based on the overall goal of ICIMOD's Transboundary Landscape Regional Programme and the strengths and opportunities available, the following objectives have been drawn:

Overall Goal

Establish and strengthen LTESM across the six identified landscapes to facilitate conservation and management decisions for sustaining ecosystem goods and services to improve livelihoods and gender inequality and enhance ecological integrity and socio-cultural resilience to environmental changes.

Objectives

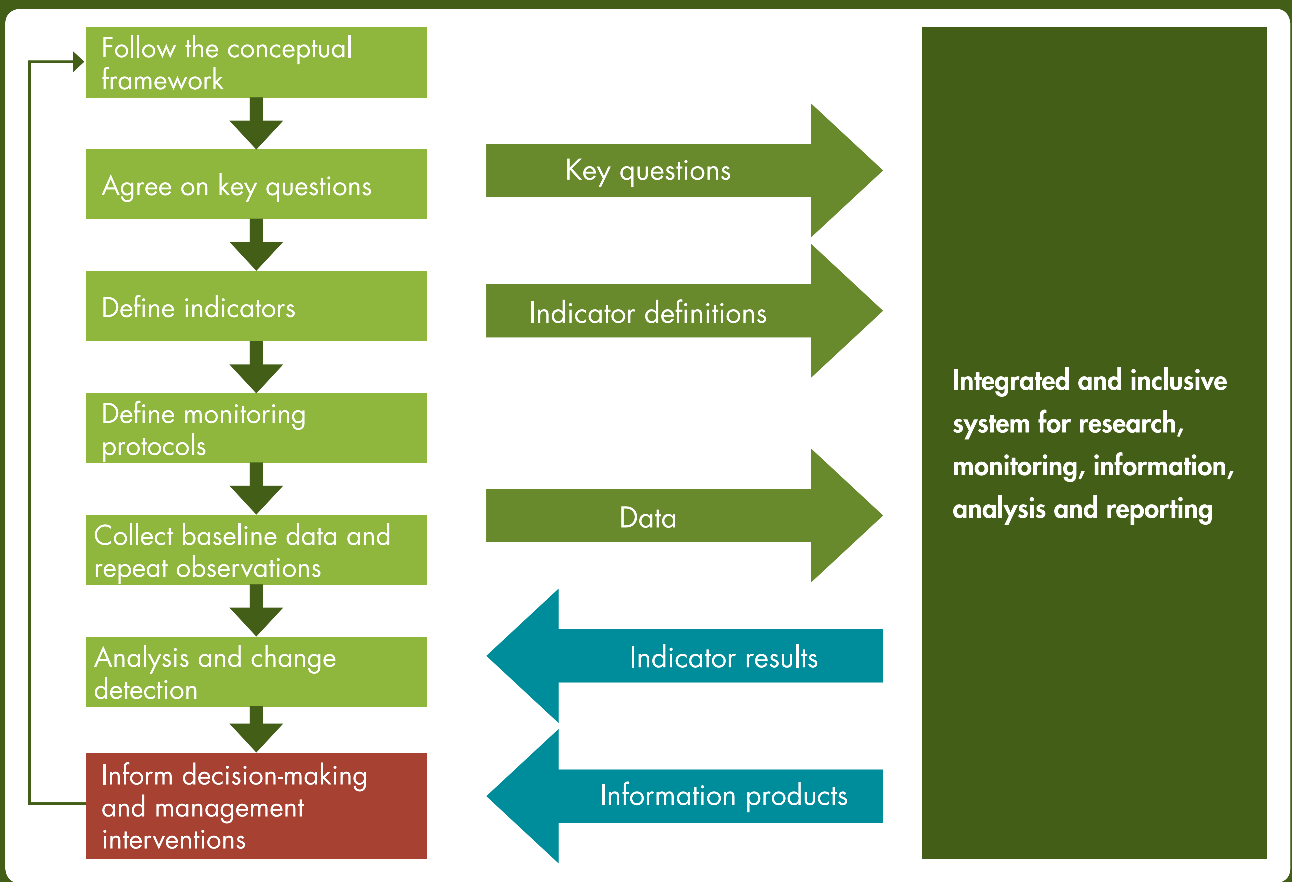
- Develop, agree, promote, and strengthen both disciplinary and interdisciplinary research frameworks and capacities and contribute to enhance knowledge for informed decision making.
- Enhance multidisciplinary and inclusive capacities and an environment of cross-learning by providing a common regional platform.
- Establish and enhance free, open, and reliable data use for conservation and development practitioners, researchers, and policy makers.
- Mainstream LTESM in transboundary landscapes for collaborative conservation and inclusive development actions at various scales.

2. A Framework for Long-Term Environmental and Socio-Ecological Monitoring

What are the elements of long-term environmental and socio-ecological monitoring?

With inputs from a consultation of more than 40 experts in Chengdu, People's Republic of China, in May 2014, ICIMOD proposed two broad steps, namely assessment and understanding of the socio-ecological system followed by informed and inclusive decision making (Figure 3). The process starts with defining the key themes and developing conceptual frameworks relevant for management and decision making, after which the key questions and indicators identified and discussed must be used and monitoring protocols must be determined, as is practised in the contemporary conservation arena (Sutherland et al. 2009). The LTESM framework also proposes to include a data management system that can enhance the quality of data for better analysis and results. Elaboration of some of the steps to be followed for implementation the framework are provided below:

Figure 3: **Steps to be followed for implementation of the LTESM Framework**



Steps to be followed for the implementation of the LTESM Framework

The Conceptual Framework

Long-term monitoring has been widely used in various scientific themes related to the cryosphere, biodiversity, ecosystems, and even in socioeconomic development fields. Because of the importance of the Hindu Kush Himalayas hold as the water towers of Asia, with the largest reserves of ice and snow outside of the polar regions, (Chettri et al. 2012) and as a home to several global biodiversity hotspots with higher dependency of people on the resources (Chettri et al. 2008), the cryosphere and biodiversity of the region are ideal candidates for LTESM. In addition, the state and dynamics of ecosystems and their interfaces are also considered convincing themes in terms of vegetation shifts, ecosystem degradation and the resulting effects on surrounding areas (ecotone), and the capacity to provide ecosystem services that are intricately linked to human wellbeing (Sharma et al. 2009). Based on recent experience during the development of the comprehensive environmental monitoring plans (CEMP) of Nepal, India, and China for the Kailash Sacred Landscape, thematic areas such as socioeconomic development, cryosphere, biodiversity (including agro-biodiversity), climate change, and ecosystem state and dynamics (rangeland, wetlands, etc.) featured prominently. These themes were identified as potential starting points for LTESM considering commonalities in terms of their relevance and usefulness across the HKH, their suitability as indicators, and other linkages and relationships, including to human wellbeing. The relationships between these themes need to be understood as elements of a socio-ecological system. The conceptual framework diagram helps to develop a common view of this socio-ecological system, including its themes and their relation to each other, among the participants and beneficiaries of LTESM. It also provides a guide for the design of activities to monitor and evaluate the process, analyse data, and communicate results. It helps support the formulation of theories and understanding of how the system works, and, in doing so, encourages participants to consider what responses might occur. The conceptual framework diagram also helps to ensure that all the relevant components have been considered.

Figure 4 is a generic conceptual diagram of a socio-ecological system for the landscapes of the HKH. This diagram can be used as a starting point for further definition and detailing of the themes that are common to the transboundary landscapes or to produce a framework diagram that is specific to the features of a particular landscape.

Figure 5 illustrates how the thematic areas for monitoring in the transboundary landscapes can be linked in terms of drivers, state, impacts, and responses for better decision making. However, these drivers could also be considered as consequences of other externalities such as markets, globalization, pollution, and economic developments.

Figure 4: **A broad schematic illustration of a socio-ecological system to guide the design of monitoring systems in support of transboundary landscape management in the Hindu Kush Himalayas**

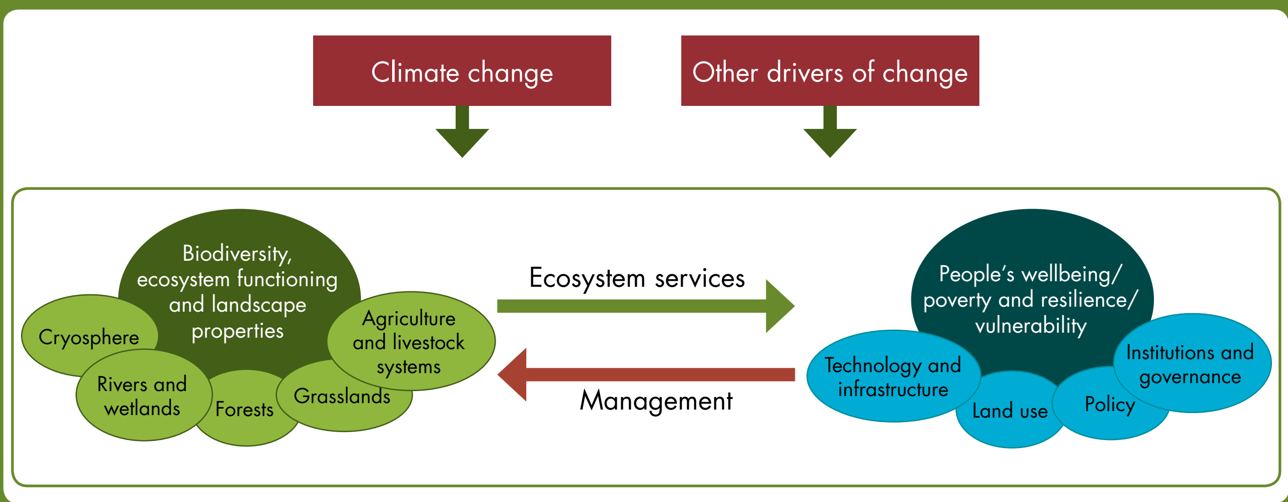
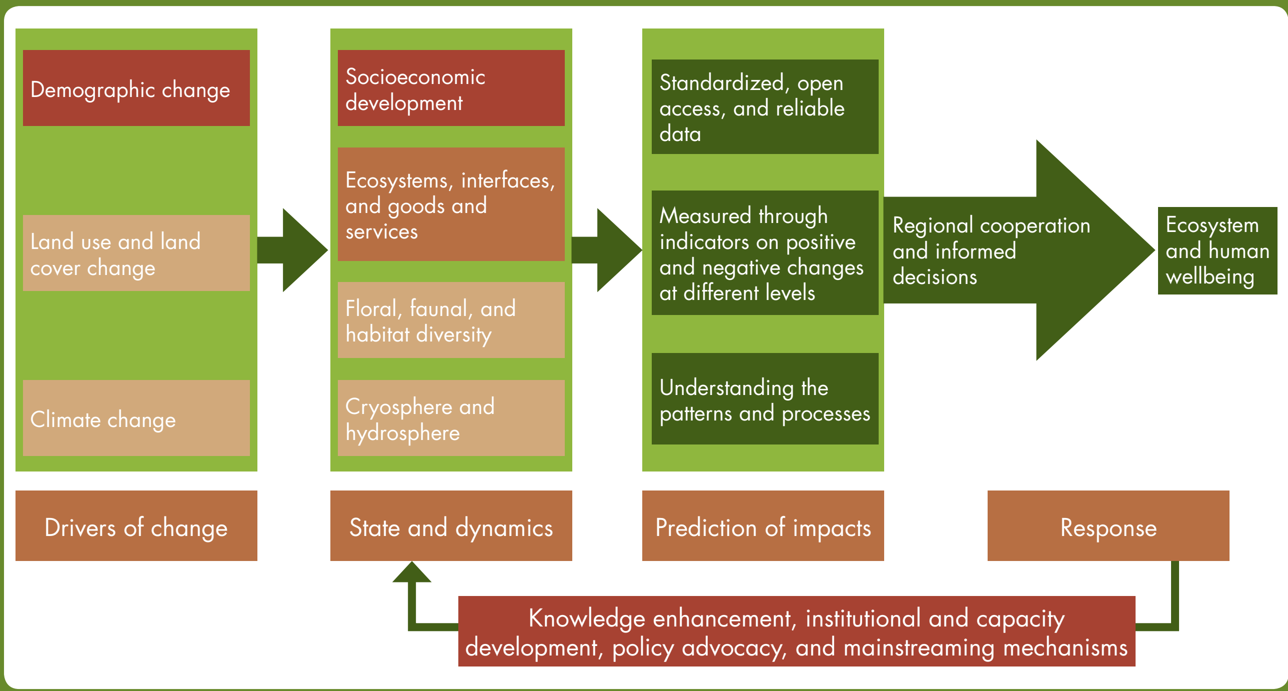


Figure 5: **Potential thematic areas and the linkages between drivers, state, impacts, and responses for better decision making in transboundary landscape management**



Adapted from Digout 2005

Agree on Key Questions

Good science is led by clear research questions (Sutherland et al. 2013) supported by strong conceptual clarity (Lindenmeyer and Likens 2010). The conceptual clarity serves as a guide to identify the key questions that the LTESM should address. There are likely to be key questions about the status and changes in the elements of the framework, and about how the elements influence each other. The monitoring activities in each transboundary landscape will use a common set of key questions identified, with the same indicators and data collection and analysis protocol, so that regional evidence and learning can be generated.

A table of the broader 'key questions' that the LTESM seek to help answer by providing data and analyses is provided in Table 2, along with the information parameters, indicators, methods, measurement frequency, and scale of measurement. The key questions can be further developed and focused based on the socio-ecological and environmental needs for each of the seven identified landscapes, with examples of such questions in Annex 1.

Define Indicators

Change detection with specified 'indicators' is widely practised in long-term research (Normander et al. 2012). It is necessary to have multiple indicators to understand the linkages and the dynamics at an ecosystem level or a landscape level (Vihervaara et al. 2013). Table 2 presents the information parameters or categories identified to help answer the key questions, as well as the specific indicators that will be measured. It is important to note that a specific measure, such as land use, only becomes an indicator when it is in relation to a key question. The same measure or dataset can potentially be used to indicate the status or functioning of more than one theme or subject. For example, the amount of vegetation litter on the ground can be an indicator of ecosystem structure, of ecosystem mineral cycle functioning, of harvesting pressure of forest products, and of fire occurrence in forests and grasslands. Some of the indicators in Table 2 require further definition to specify exactly what will be measured.

Define Monitoring Protocols

Long-term socio-ecological research has seen significant advancement with the standardization of monitoring protocols. However, the systematic approach for long-term monitoring, which has been widely used to guide interdisciplinary research, is still evolving (LTER 2007). A monitoring protocol is a document prepared for each indicator that specifies the monitoring objectives, responsible agency, monitoring method, sampling method, resource requirements, data analysis, data storage, reporting procedures, and references. It may also include data recording sheets. The definition of the monitoring protocols must consider the resources and costs for data collection under alternative methods in relation to the quality and quantity of resulting data and its importance for particular research and decision-making needs. This framework will be supported by a LTESM manual developed based on field learning and experimentation in later stages.

Collect data

High-quality data is needed for informed decision making. To make data from LTESM available, the framework outlines the need for data repository platforms both at the national level in each country in the Hindu Kush Himalayan region, as well as at the regional level, with ICIMOD as the host. A mechanism will be developed for the transmission of data from field sites and local communities to the data repository platforms. While collecting data, it is important to have sex desegregated data provision in the methodology for social science and other relevant data.

Analyse data

Good datasets and proper analysis can lead to good and useful results (Lindenmeyer and Likens 2010) both in social-ecological (Singh et al. 2013) and biophysical (Condit et al. 2014) contexts. Analysis through a gender lens would include an understanding of relationships between men and women of different categories and how these are shifting in response to new vulnerabilities and opportunities, but also shifting roles and preferences. Analyses and the resulting knowledge products developed will be designed to help answer the identified general key questions as well as specific questions that may arise to address particular decision making and management needs. During the analysis stage, data from transboundary landscapes will be processed to calculate the values of the indicators. These indicator sex and gender disaggregate results will then be interpreted as evidence to help answer the key questions, with guidance from the conceptual framework.

Inform decision making and management interventions

Periodically monitored data compatible at the regional scale is necessary to support informed decision making and effective management interventions. The collaborating partners working with ICIMOD in different transboundary landscapes of the HKH are required to use the resulting data and analyses for decision making and better management interventions. A logical flow between the process and the outputs will contribute to the desired outcomes and impacts (Campbell et al. 2015) (see Figure 6).

Figure 6: **Schematic flow chart describing the different steps of a monitoring system for better transboundary landscape management**

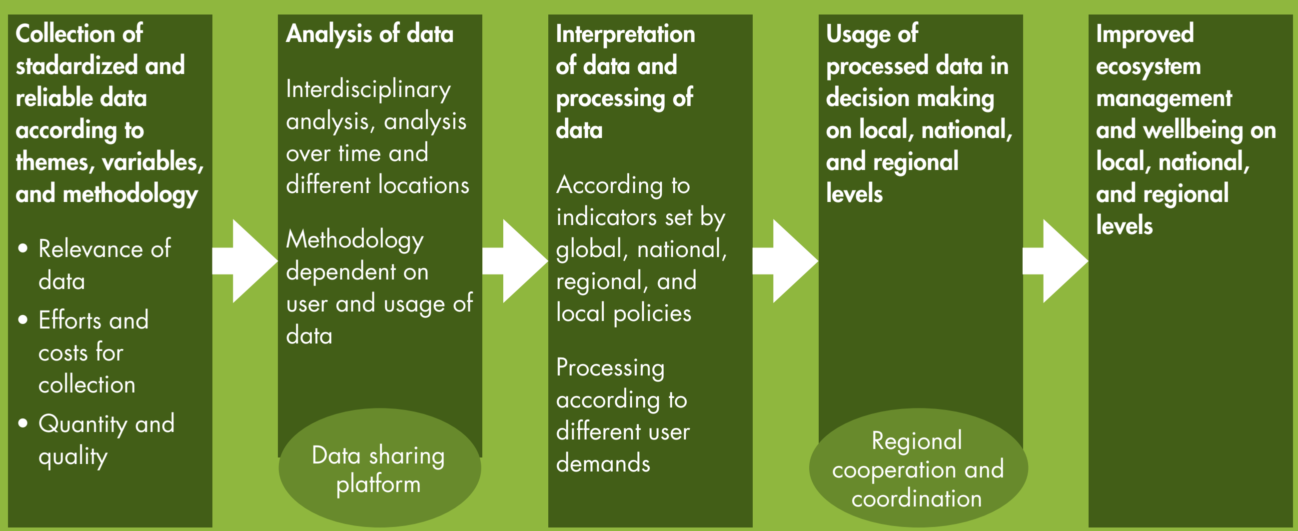


Table 2: **Matrix Showing The 'Key Questions' Based Monitoring Framework**

Key questions	Parameters	Indicators	Data collection methods	Frequency	Scale
Ecosystems					
What are the major stressors on ecosystems in an area?	Biomass extraction	Amount of biomass removed (fuelwood, timber, fodder, NTFP, leaf litter)	Household survey, transects, quadrats, field observation	3-5 years	Pilot areas
	Grazing pressure	Livestock stocking rate	Household survey, transects, quadrats	3-5 years	Pilot areas
	Alien Invasive species (AIS)	Unproductive land area due to alien invasive species. Decline in native species due to AIS.	Geospatial analysis, transects, quadrats	3-5 years	Pilot areas
	Climate change	Changes in climate variables	MET data from MET stations	Monthly/ Annual	Landscape
	Natural hazards	Incidence of droughts, floods and fire	Geospatial analysis and field observation	Annual	Landscape
	Land use and cover change, including habitat fragmentation	Change in land use and land cover, including infrastructure	Geospatial analysis and field observation	3-5 years	Landscape
	Illegal trade of high-value wild products	Populations of high-value wild products	Household survey, transects, quadrats	3-5 years	Landscape
Cryosphere and Water					
What is the impact of climate change on the cryosphere?	Cryosphere	Snow cover (thickness and duration), glacier area, melt water yield	Geospatial analysis and field observation	3-5 years	Landscape
How is water availability changing at the local level?	Water availability	Amount of water available for human use (including livestock & crops). Water quality. Water deficit for human use. Soil moisture deficit for plant growth.	Household survey, field observation	3-5 years	Landscape
Ecosystem services					
How are ecosystem services changing in the landscape?	Ecosystem services supply (provisioning, regulating, and cultural)	Status and change in quality and quantity.	Household survey focused group discussion, geospatial analysis and field observation	3-5 years	Landscape
Which ecosystems are used by the local communities?	Ecosystem services demand (provisioning, regulating, cultural)	Consumption of ES or benefits received from ES by local people and downstream beneficiaries	Household survey focused group discussion	3-5 years	Pilot areas
Is ecosystem service supply sufficient to meet demand?	Demand and supply ratio of ecosystem services	Demand and supply	Results of surveys of ES supply and demand	3-5 years	Pilot areas
Is ecosystem structure sufficient to supply desired ecosystem services?	Vegetation, food web and soil structure.	Amount and coverage of plant litter cover on the ground (forest and grassland) Forest canopy cover Vegetation biomass Herbivore biomass Predator biomass Pollinator abundance Extent of bare soil Soil organic layer depth	Quadrat, field observation, transects	3-5 years	Pilot areas
Biodiversity (Flora and fauna)					
How are species (keystone and flagship) responding to changes?	Plant phenology	Flowering and fruiting pattern	Geospatial analysis and field observation	Seasonal	Ecosystems

Key questions	Parameters	Indicators	Data collection methods	Frequency	Scale
How are species (keystone and flagship) responding to changes? *(continued)*	Species composition and habitat conditions and change (elevation)	Vascular plant community composition at monitoring sites	Quadrats, field observation, transects	Seasonal	Ecosystems
	Status of red-list species	Change in species numbers, population size, age composition, sex ratio and distribution	Camera trap transects, quadrates, sign observation	Five years	Landscape
Socioeconomics					
How is the social fabric of local communities changing?	Demographic changes Outmigration	Family composition Gender role (changed workload)	Household survey Focused group discussions	3-5 years	Pilot areas
What is the state of poverty and how it is changing?	% of population living below poverty line Water access Modern energy access	Change in % of population Change in access to water and energy	Household survey	3-5 years	Pilot areas
How the agricultural practices changing?	Arable area Unutilized agricultural area Percentage of agricultural area under irrigation Use of pesticides, inorganic fertilizers Employment in agriculture (percentage of women in agriculture) Cropping intensity Livestock density (LSU)	Change in arable area Amount of use of pesticides Agriculture diversity Change in employment numbers Change in cropping pattern and LSU	Household survey	3-5 years	Pilot areas
How is economic status of local communities changing?	Socioeconomic status	Changes in source and level of income (standard of living, expenditure pattern, landholding, livestock holding)	Household survey Focused group discussions	3-5 years	Local (pilot sites)
	Local resource based income and employment	Vulnerability (wealth indicator) and availability of ecosystem services	Household survey Focused group discussions	3-5 years	Local (pilot sites)
What are the perceived changes on environment, conservation and development?	People's perceptions	Local perception on climate change (temperature and rainfall pattern, and related adaptation), wildlife conflict , availability of resources, dependence on resource, entrepreneurship and income	Household survey Focused group discussions	3-5 years	Local (pilot sites)
Technology					
How innovations and new technologies advancement impact improved livelihoods and ensure ecological integrity?		Innovation and best practices incorporated Disasters and related risks reduction Increased use of integrated planning and management support system	Reviews Questionnaires Field visits Survey Geospatial analysis	Biannual	Both at pilots and landscape levels
Policy					
How policy interventions impact ecosystem management and sustaining ecosystem services?	State of the policies	Access to ES, equitable benefits sharing, and increased inter-sectoral coordination in management for ES	Household surveys, focus group discussion, National policy review	3-5 years	Pilot areas

Key questions	Parameters	Indicators	Data collection methods	Frequency	Scale
How policy interventions impact ecosystem management and sustaining ecosystem services? *(continued)*	Policy influences	Enhance productivity and increased biodiversity co-benefits in production system (forest, rangeland, wetland, agriculture)	Household surveys, focus group discussion, census data	3-5 years	Pilot areas
Have there been any policy change recently? if yes, what are those?	Changes in policy provisions that can potentially impact ecosystem and access for local communities	Changes in policy provisions	Secondary data, policy documents	5 years	National
Institutions and Governance					
How do or can local (both modern and traditional) institutions ensure efficient, and equitable, and sustainable resource use?	Effectiveness of the institutions	State of resources, sharing of benefits to all category and class of community, rules restricting consumption, monitoring and sanctioning , plans, and practices (regular meeting, monitoring)	Household surveys, focus group discussion, field observation	3-5 years	Pilot areas
How institutions deal with inter and intra community sharing of benefits and conflict resolutions	Institutional set up and communication	Existence and functioning of forum (for intra and inter benefit sharing, number of meetings	Focus group discussion, field observation	3-5 years	Pilot areas

3. Operationalizing the LTESM Framework

What principles and strategies are necessary to meet the objectives of long-term environmental and socio-ecological monitoring?

Long-term environmental and socio-ecological monitoring (LTESM) at the transbounadry landscape level is a challenging task. The proposed implementation framework will be instrumental in addressing the overall goal of the Transboundary Landscapes Regional Programme of ICIMOD, as well as the objectives of LTESM in the region. ICIMOD would like to develop research protocols on selected themes in a consultative manner, leveraging the expertise of the Centre and its partner organizations, so that the data generated through its programmes are compatible for comparison and applicable in all landscapes. Seven basic principles for effective monitoring suggested by Lovett et al. (2007) could help guide this collaborative and interdisciplinary journey.

- **Design the programme around clear and compelling scientific and management questions.** Questions are crucial because they determine the variables measured, the spatial extent of sampling, the intensity and duration of the measurements, and, ultimately, the usefulness of the data.
- **Include review, feedback, and adaptation in the design.** Guiding questions may change over time, and the measurements should be designed to accommodate such changes. The programme leaders should continually ask: "Are our questions still relevant and are the data still providing answers?" The programme should have the capacity to adapt to changing questions and incorporate changing technology without losing the continuity of its core measurements.
- **Choose measurements carefully and with the future in mind.** Not every variable can be monitored, and the core measurements selected should be important as either basic measures of system function, indicators of change, or variables of particular human interest. If the question involves monitoring change in a statistical population, measurements should be carefully chosen to provide a statistically representative sample of that population. Measurements should be as inexpensive as possible because the cost of the programme may determine its long-term sustainability.
- **Maintain the quality and consistency of the data.** The best way to ensure that data will not be used is to compromise quality or to change measurement methods or collection sites repeatedly. The confidence of future users of the data will depend entirely on the quality assurance programme implemented at the outset. Sample collections and measurements should be rigorous, repeatable, well documented, and employ accepted methods. Methods should be changed only with great caution, and any changes should be recorded and accompanied by an extended period in which both the new and the old methods are used in parallel to establish comparability.
- **Plan for long-term data accessibility and sample archiving.** Metadata should provide all the relevant details of collection, analysis, and data reduction. Raw data should be stored in an accessible form to allow new summaries or analyses if necessary. Raw data, metadata, and descriptions of procedures should be stored in multiple locations. Data collected with public funding should be promptly made available to the public. Policies of confidentiality, data ownership, and embargos for sharing data should be established at the outset. Archiving of soils, sediments, plant and animal material, and water and air samples provides an invaluable opportunity for re-analysis of these samples in the future.
- **Continually examine, interpret, and present the monitoring data.** The best way to catch errors or identify trends is for scientists and other concerned individuals to use the data rigorously and often. Adequate resources should be committed to managing data and evaluating, interpreting, and publishing results. These are crucial components of successful monitoring programmes, but planning for them often receives low priority compared to the actual data collection.

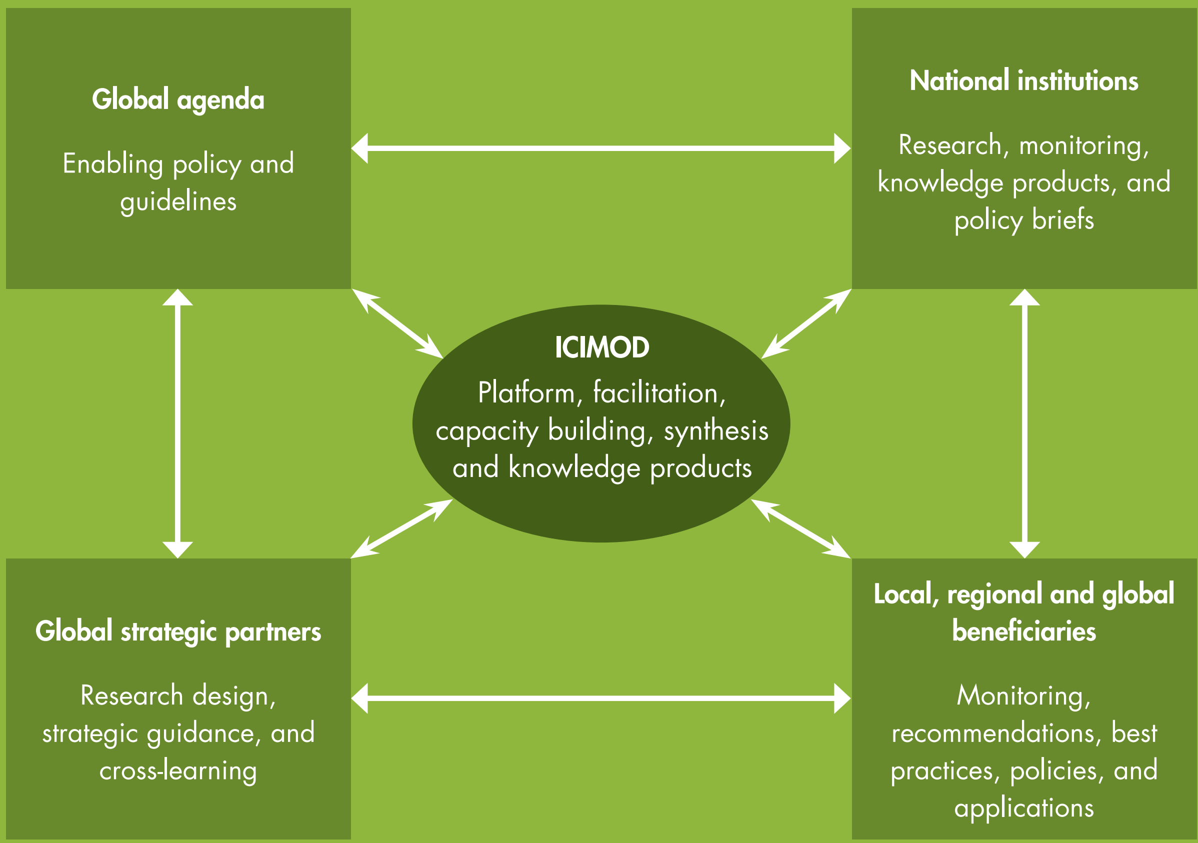
- **Include monitoring within an integrated research programme.** An integrated programme may include modelling, experimentation, and cross-site comparisons. This multi-faceted approach is the best way to ensure that data are useful and are used for integrated research programme to look for changing conditions such as increase in human population, migration of youth, forest species and vegetation changes etc.

What steps can be taken to guide the LTESM process towards its goals and objectives?

Facilitation of a regional platform

As an intergovernmental knowledge and enabling Centre with expertise on the themes identified, ICIMOD could play a pivotal role as a facilitator and common platform for the HKH region's researchers, conservation practitioners, policy makers and other stakeholders (Figure 7). It could help in supporting informed decision-making processes and the development of sound adaptation options for local communities. This will be achieved by facilitating partnerships between local, national, regional and global organizations to support capacity building and a sound research framework with reliable spatial-temporal data. Recognizing the importance of the availability of good quality data, ICIMOD is committed to investing its financial and human resources to managing and sharing data and also encourages its member countries and partners to also do so. ICIMOD will ensure that its organizational structure and management recognize the importance of managing and sharing data and follow an agreed upon mechanism for data management and sharing within the programmes. In addition, to ensure that the data generated are directly available to users, ICIMOD, with support from peers and concern institutions, will invest in the development of a regional platform and knowledge products derived from data, including interactive maps, models, publications, decision applications, and value-added products and services to make data more useful for policy makers, scientists, and the general public.

Figure 7: **The roles and relationships between potential actors**



Institutional development and sustainability

As described in the previous sections, concerted efforts are needed to understand the process of change in socio-ecological systems at both spatial and temporal scales and to develop a response strategy. Thus, ICIMOD encourages its collaborating partners to develop interdisciplinary teams and to develop a mechanism for the continuity of research and monitoring with learning from regional (e.g., China's LTER research by the Chinese Academy of Sciences) and global examples (e.g., GLORIA). As one of the means for continuity, relevant departments from universities and research and development organizations could support Master's and PhD students undertaking multidisciplinary research, including through the provision of opportunities for post-doctoral research and positions as visiting scientists. Efforts should also be made to strengthen the monitoring system through citizen scientists (local communities, tourists, amateur naturalists) through an established reporting system, community organizations, and other appropriate means (e.g. Fu et al. 2010; Jürgens et al 2012; Rivera-Monroy et al. 2004).

Linking to societal and environmental security

The results of research and monitoring should be directly linked to societal development and environmental security. They can be translated into practical solutions through demonstration and exposure visits, into trends and projections using geospatial tools, and documented and shared as best practices and policy recommendations. The learning and knowledge products produced as a result of LTESM should also benefit local, regional, and global conservation and development practitioners.

Contribute to national, regional and global conservation and development agendas

The LTESM should also support the implementation of the relevant conservation and development agendas endorsed by the regional member countries in various national, bilateral, and multilateral environmental regional and global agreements. Some of the linkages are listed below:

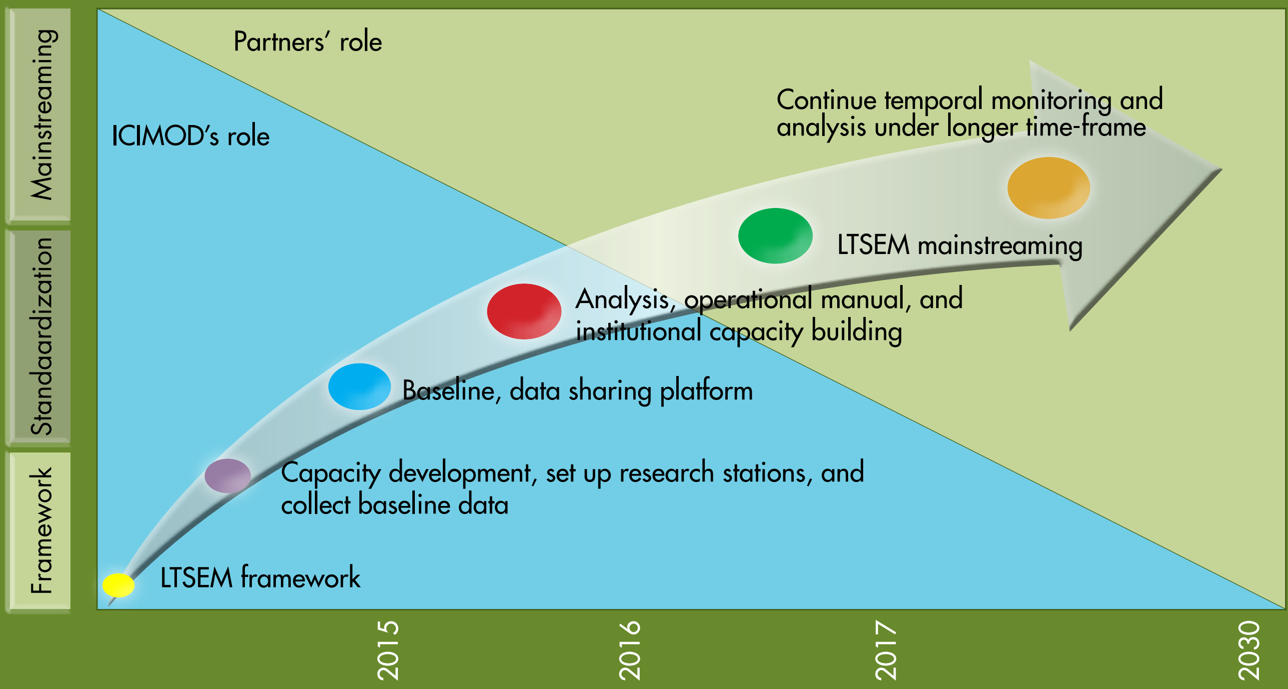
- Conventions from the 1992 Earth Summit in Rio de Janiero, namely the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC), and other multilateral agreements such as the Convention on International Trade In Endangered Species of Wild Fauna and Flora (CITES).
- Specific goals on landscape and transboundary cooperation as indicated in the CBD's Programme of Work on Mountain Biodiversity and Programme of Work on Protected Areas through decisions VII/27 and VII/28, respectively, including the Ecosystem Approach (VII/11) suggested by the parties during the Seventh Conference of the Parties in 2004.
- The Aichi Biodiversity Targets for 2020 adopted at CBD COP-10.
- Global processes on the science-policy interface through the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).
- Agreements endorsed by individual regional member countries (e.g., National Biodiversity Strategy and Action Plan, Sustainable Development Goals, National Adaptation Programme of Action, Local Adaptation Programme of Action, etc.).

Outline roadmap towards LTESM objectives

A clear roadmap with measurable milestones is necessary to lead the process of LTESM towards its outlined objectives. Within its third Medium Term Action Plan (2013-2017), ICIMOD aims to establish and institutionalize the LTESM in at least three landscapes and to facilitate the process of establishing and mainstreaming the use of standard research protocols, developing capacity, developing an open access database platform and an operational manual, and facilitating cross-learning for partners within and among regional landscape and global transboundary initiatives. Within the present programme cycle, ICIMOD aims to develop research protocols, to establish at least two experimental research stations for the broad themes identified, and to come up with a manual for long-term operation (Figure 8). However, the process of up-scaling and continued monitoring will go beyond the present programme cycle. Ownership by partners of long-term monitoring within specific transboundary landscapes will be worked out as the programme develops. ICIMOD is committed to making long-term monitoring an integral element of its strategic planning and activities and will continue to provide a regional platform fo facilitate collaboration on LTESM.

To support the success of LTESM, it is beneficial to draw the boundaries for each of the thematic areas for comparability and complementarity in each landscape and also across the seven landscapes. The indicative entry points are provided in Annex 1 and are subject to discussion.

Figure 8: **Roadmap for LTESM**



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Annex 1: Key questions the LTESM could address, as identified during the ICIMOD expert consultation, May 2014

1. What are the major stressors on ecosystems in the study area?
2. What is the state and trend of land use and how they are impacting on biodiversity, ecosystems and local communities?
3. Which ecosystems are the most vulnerable?
4. What are the key ecosystem services having immediate consequence to daily life of people?
5. How water availability is changing at local and landscape levels?
6. What are the people's perceptions over ecosystem change and their values?
7. To what extent the project interventions have improved biodiversity and ecosystem health?
8. How the ecosystem structure and their functions are responding to the changes?
9. How species and ecosystems are responding to climate change?
10. How the ecosystem functions and structure in terms of composition of species and diversity are responding to the changes?
11. How flagship/keystone and rare and threatened species (RET) population are changing over time?
12. What the major drivers impacting livelihoods of ecosystem dependent communities?
13. How do or can local (both modern and traditional) institutions ensure efficient, equitable and sustainable resource use?
14. How wetland ecosystem are supportive to water recharge or availability of water to downstream communities?
15. How does forest ecosystem contribute to human well being of ecosystem people and biosphere people?
16. How far conservation and development efforts have brought in desired change in perception, mind set and attitudes of local communities?
17. What are the drivers of changes, income and employment, and socioeconomics situation?
18. What are the policy level hindrances on access to resources on access to resource viz a viz protected area/ conservation or common property resources?
19. How far losses due to disasters and related risks have reduced?
20. At what level local people are involved in decision making?
21. What are the remote sensing based parameters to link with ground socio economic monitoring to understand cross scale process and impact?

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