Ecosystem-based Adaptation and Water

Improved Management of Extreme Events through Ecosystem-based Adaptation in Watersheds

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Department of Water Resources

ECOSWat
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Improved Management of Extreme Events through Ecosystem-based Adaptation in Watersheds

As a result of climate change, floods and droughts in Thailand will increase in frequency as well as intensity. Local water management institutions lack technical capacity and innovative concepts to address such extreme events. Therefore the population of Thailand is expected to face large economic losses due to crop failure and loss of production. Water providing and regulating ecosystem services present untapped adaptation potential for cost effective and sustainable prevention measures.

In addition, Thailand faces a competition for land. Agricultural areas increase at the expense of ecosystems. This weakens the capabilities to resist extreme event even more and makes the population and infrastructure more vulnerable.

River Basin Inventory

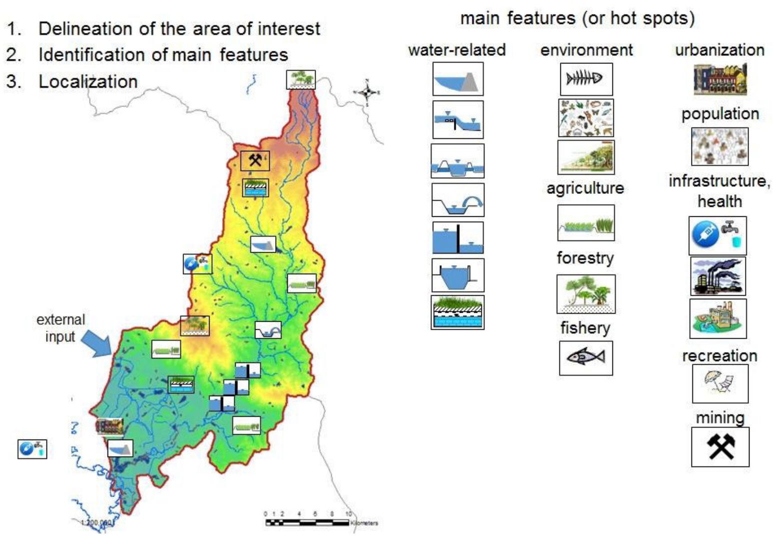
River basin inventory is the first step in a chain of actions which finally reveals existing vulnerabilities and links them to mostly socio-economic root causes.

River basin inventory

River basin inventory is closely linked to IWRM principles. It aims at building capacities to independently conduct an assessment which constitutes the basis for a cause-effect analysis. The steps are:

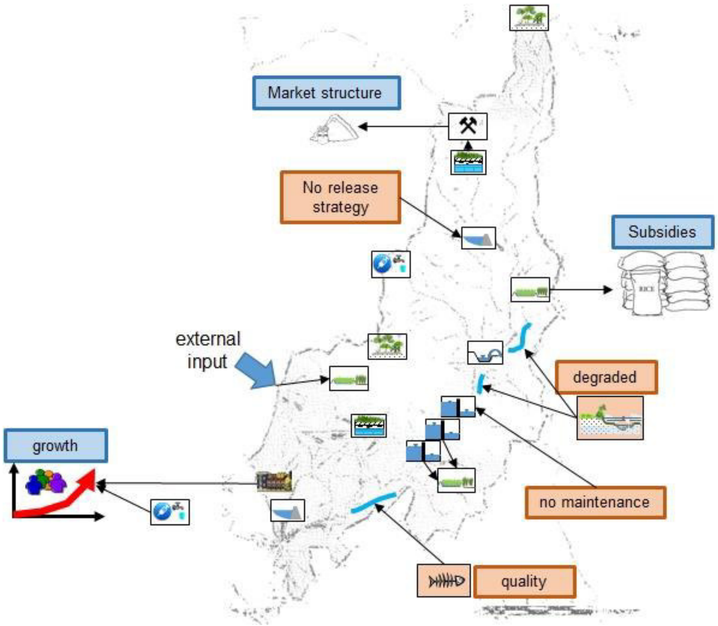
- Geographical Scaling

  Geographical scaling defines the geographic boundaries of the river basin under consideration which is given by the watershed and additional determinations. Subsequently, sub-regions are identified within each project area and major hydrosystem features and economic activities need to be mapped out.



- Scoping

  Within the scoping procedure the critical major concerns and issues by assessing their environmental and socio-economic impacts are addressed. Considering the near future, estimates of the likely environmental and socio-economic impacts are conducted which is followed by establishing priorities among the major concerns and issues.


Market structure
No release strategy
Subsidies
external input
degraded
growth
no maintenance
quality

Causal-Chain Analysis

Causal chain analysis

The basin inventory is the prerequisite for the causal-chain analysis. This analysis traces the proximate to the root causative factors behind the selected concerns and issues and is conducted to serve as the foundation of the selection of policy options. This stage will mainly be done by as group work with stakeholders with different backgrounds guided by one or more experts. The Cause-Effect Relationships found by the group are first re-evaluated by the expert and second after results from detailed assessment are known. It is important that findings are structured according to a certain pattern to easily identify major concerns and their manifold root causes.

The causal-chain analysis is backed by a database which incorporates a rather comprehensive list of possible

- socio-economic Impacts
- environmental Impacts
- physical and biological impacts
- immediate causes which first become perceptible
- sector activities
- root causes

The database was adopted from UNEP and tailored according to the needs of a river basin inventory. It is easily adjustable and extendable if new topics emerge which are not yet included.

- Policy option analysis

A policy option analysis indicates potential policy interventions based on the identification of the root causes conducted in the Causal Chain Analysis. For example, it includes the evaluation of alternative scenarios, developed on the basis of projected actions taken to address the identified root causes of environmental degradation.

- Detailed assessment

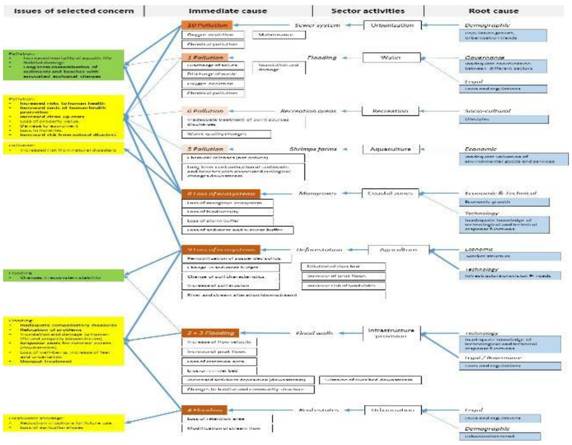
The detailed assessment accompanies the scoping and causal chain analysis process and is therefore not confined to one stage in the assessment process. Since it is an integral activity within the other components, it is carried out at several stages in the assessment process. It aims to substantiate the experts conclusions by identifying and documenting the nature and availability of information related to the identified/selected priority concerns and issues. It also quantifies the severity of the impacts.

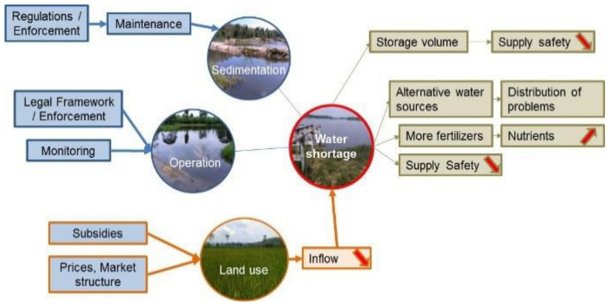
Information may come from various sources including previous assessments, research papers, scientific publications, surveys, government reports, status reports, EIA reports, economic reviews, observations and records, etc. Detailed Assessment usually consists of applying different types of models where results from these models constitute the main source to underline the causal-chain analysis.

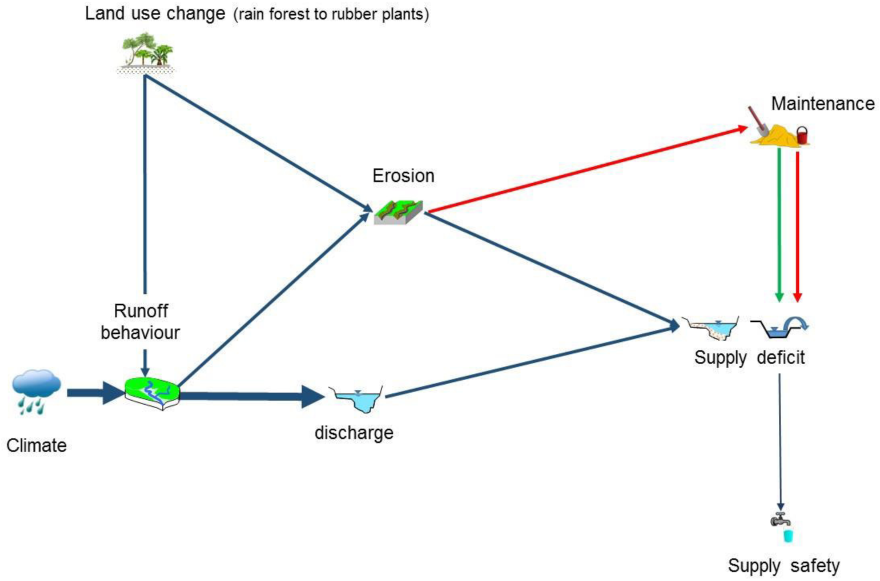
During the Detailed Assessment a more precise indication of geographical locations of major concerns and issues will emerge. Environmental problems may be localized to a certain hot spot, a part of the river or other particular areas.

Vulnerability Assessment

The vulnerability assessment builds on the river basin inventory and causal-chain analysis. By structuring the cause-effect relationships as a graph, the most vulnerable topics are revealed as those which receive the largest numbers of arrows.







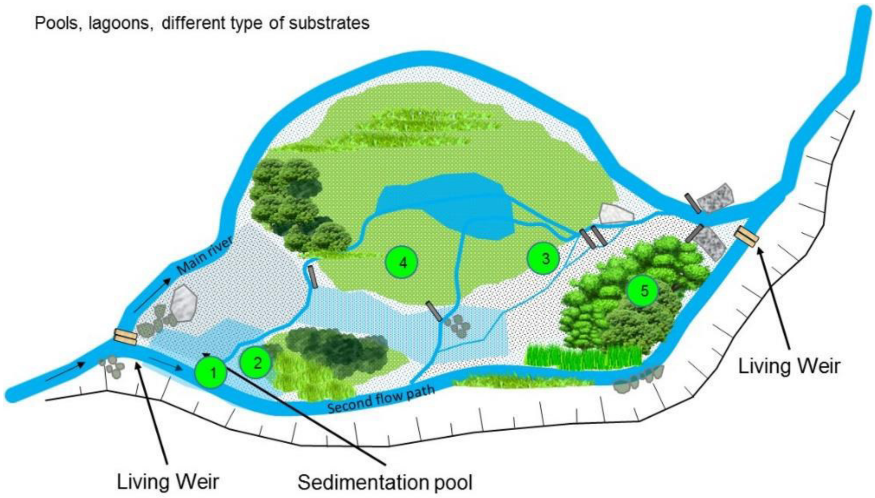
Each arrow obtains a weight according to the evidence of the cause-effect relationship. The evidence is the result of the detailed assessment so that qualitative and quantitative details can be determined. If the graph is backed with icons and illustrations, it provides an easily understandable tool which is suitable not only for technicians but also for non-experts or grass root level.

Ecosystem-based Measures Fact sheets

There are a number of potential options concerning ecosystem-based measures. The introduction of each measure is best accomplished by using a form concisely comprising the most important attributes. This helps especially in order to compare different measures or to identify measures which complement others. The fact-sheet developed shows not only the attributes but provides also information about mutual dependencies between different measures.

ID	{number}	EbA	{name}		
Location	{description of preferred locations}				
Illustration	{demonstration of measure by drawing}				
Measures	{short description}				
Purposes and reasoning	{list of purposes with background and arguments}				
Complementary measures	{complementary measures}				
Replicability	{indicators about the potential to be transferred to various locations}				
Effects	on-site	upstream	downstream		
	{list of effects}	{list of effects}	{list of effects}		
Stakeholders	{list of stakeholders}				
Beneficiaries	{list of beneficiaries}				
Legal concerns	{list of legal concerns}				
Structural work / Requirements	{list of main components}				
Work plan and cost estimate	Preliminary work plan	Costs [THB]			
	{sequence of work to be done}	{list of major cost items}			
Maintenance	{short description about necessary regular services needed}				
Example	{example picture or drawing}				
Pros			Cons		
{list of advantages}			{list of disadvantages}		

An example is provided showing the fact sheet for a potential wetland development area.

<table>
<tr><td>ID</td><td></td><td>5</td><td>EbA</td><td>Floodplain and wetland development</td><td>Example</td><td>-</td></tr>
<tr><td></td><td colspan="2">Location</td><td colspan="4">Flood plains should be developed in areas which had been originally flood plains before being occupied and converted into other forms of land use.</td></tr>
<tr><td></td><td colspan="2">Illustration</td><td colspan="4">
</td></tr>
<tr><td></td><td colspan="2">Measures</td><td colspan="4">A thorough survey is needed to identify suitable features within a flood plain. Landscaping should facilitate old, cut-off and abandoned river reaches to be reconnected to the main river. In addition, landscaping also should allow for various forms of water bodies like pools, lagoons and swamps. Soil reconnaissance might be necessary to find suitable grounds and to obtain necessary parameters for water balance calculation.
Agriculture is not necessarily banned from floodplains but require crops adapted to the specific hydrological conditions.</td></tr>
<tr><td></td><td colspan="2">Purposes and reasoning</td><td colspan="4">Floodplains would develop automatically in plain landscapes if no intervention by human activities took place. Floodplains require the flood pulse with raising and receding water levels occupying considerable amount of land depending on slope and terrain characteristics. In highly populated areas without proper land use planning in place, floodplains are drained, utilized and occupied with settlements and infrastructure. As a consequence, settlements and infrastructure are exposed and vulnerable to inundation which in turn calls for flood protection and control measures. In the wake of such developments, floodplains turn from originally self-regulated ecosystems into a populated cultural landscape, finally and understandably indicated as a flood-prone area. Such a common scenario can be countered by applying clear land use planning regulations with areas dedicated for floodplain development. It is obvious that effects of floodplains like flood retention, sediment trapping, filtering solids and nutrients, plant growth will increase with size of the floodplain. First and most importantly, space is required to re-establish a floodplain. Plain terrain is needed for widening a river bed, creating diverse river channels and facilitating meandering of streams. Floodplains need water so that landscaping and river restoration must ensure connectivity with the main river, overflowing of river banks and regular flooding. To support this, flood paths can be established ensuring sufficient overflows. Moreover, different flow paths enhance diversity of flow regimes and provide opportunities for different water-related plants and wetland areas. Floodplain development can also be combined with reforestation of water-tolerating trees. Moreover, floodplains are areas with high biodiversity.</td></tr>
<tr><td></td><td colspan="2">Replicability</td><td colspan="4">Medium as considerable space for implementation is required</td></tr>
<tr><td></td><td colspan="2">Complementa ry measures</td><td colspan="4">2, 3, 6, 7, 9, 10, 11</td></tr>
<tr><td rowspan="2"></td><td colspan="2" rowspan="2">Effects</td><td colspan="2">on-site</td><td>upstream</td><td>downstream</td></tr>
<tr><td colspan="2">Change of accessibility</td><td>none</td><td>Reduction of flood peaks</td></tr>
</table>

ID		5	EbA	Floodplain and wetland development	Example	-

		Change of cultivation Mostly higher evaporation and transpiration More opportunities due to plants and moisture in selected areas inside the flood plain Possibly other forms of cultivation inside flood plain are feasible		More slowly rise and receding of floods Improvement of water quality
	Stakeholders	Land owners and/or land tenants at the area of concern RID, DWR, municipality		
	Beneficiaries	Stakeholder downstream due to higher water quality Stakeholder at site due to more biodiversity enabling new opportunities of harvesting plants Downstream municipality		
	Legal concerns	Land ownership where the flood plain is situated		
	Structural work / Requirements	Considerable survey of terrain and soil including landscaping. Possibly earth movements are required. Replanting to some extent.		
	Work plan and cost estimate	Preliminary work plan	Costs [THB]	
		Land survey Flow duration curve Removal of old vegetation Creation of varying terrain in case it is not present Inventory of plants and replanting Hydraulic connectivity of all streams at the location required		
	Maintenance	Removal of barriers along the main river if needed		
	Example	 This section offers all opportunities for the development of a floodplain.		
	Pros		Cons	
	Flood retention Enhancement of water quality		Loss of current cultivation forms on site Possibility of more undesired insects due to	

ID		5	EbA	Floodplain and wetland development	Example	-
	Floodplain as large water storage Contributes automatically to non-structural measures like flood zoning Opportunity with adapted forms of agriculture inside flood plain			stagnant water Possibility of higher losses due to evapotranspiration		

Design and Hydraulics

Data requirements

A complete list of data requirements has been developed which enables participants to independently conduct data acquisition campaigns and to clearly understand what is needed to design EbA or to assess water-related regulating and provisioning ecosystem services.

Excel-based training sheets

- Simple precipitation runoff model

  This module calculates a storm event based on a simplified atmosphere-vegetation-soil accounting approach. Results are urban and surface runoff, interflow and base flow. The model supports participants in their understanding of parameter needs, why they are necessary and demonstrates effects of different vegetation, soils and what happens if soil degrades and chances its capability to retain water.

  The tool helps to foster knowledge about cause-effects of vegetation, soils and runoff. Furthermore, it aims to raise awareness of the importance to preserve undisturbed areas.

- Universal Soil Loss Equation (USLE)

  The Excel-based module is a simple application of the USLE. Sub-basins characteristics can be changed and in combination with a work book all necessary parameters can be derived and applied to estimate annual soil loss.

- Sediment calculation

  Flow, sheer stress, transport capacity and trap efficiency is integrated in the module about sediment. Given user-defined flow conditions and cross-sections of a river reach, the user can choose between different grain-size distributions or applies a user-defined one in order to assess whether actual sheer stress is below or above critical sheer stress of a pre-defined material. A list of different materials is provided so that the user can make an appropriate decision on how to design a cross-section adequately to avoid river bed and bank erosion.

  As sediment calculation is rather complex, the tool needs explanations.

- EbA Evaluation tool

  A wide range of EbA measures are incorporated and rated according to European Union fact sheets about EbA. By selecting measures, water retention and biophysical impacts are shown.

Hydrological and 2D Hydraulic Analysis with/without Ecosystems Services

By means of hydrological and hydraulic modelling of a catchment, which can be a complete river basin, a sub-basin or only a rather small plot, effects of ecosystems can be demonstrated and animated. If the area under consideration is too small, hydrological modelling may be omitted and only 2D hydraulic modelling comes into effect. Two scenarios are necessary: with and without ecosystem services

The "without" ecosystem services scenario assumes that ecosystems such as healthy river reaches, wetlands, forests, buffer strips, suitable land use management, etc. are degraded or completely lost. The degree of degradation can be varied and is implemented into the models. This scenario either represents the current state or an expected future degraded situation.

The "with" ecosystem services scenario incorporates aforementioned elements to an extent which represent a healthy current situation or a desired future state.

Both hydrological and hydraulic models cover the ecosystems or their degree of degradation with parameters directly related to aforementioned elements. For example, loss of vegetation and soil degradation are represented by canopy parameters, infiltration capacity and permeability. The latter two, in turn, are affected by a proper vegetation. A forest with a well-rooted soil is more permeable than a field of maize which lacks of shadow crops or shadow plants.

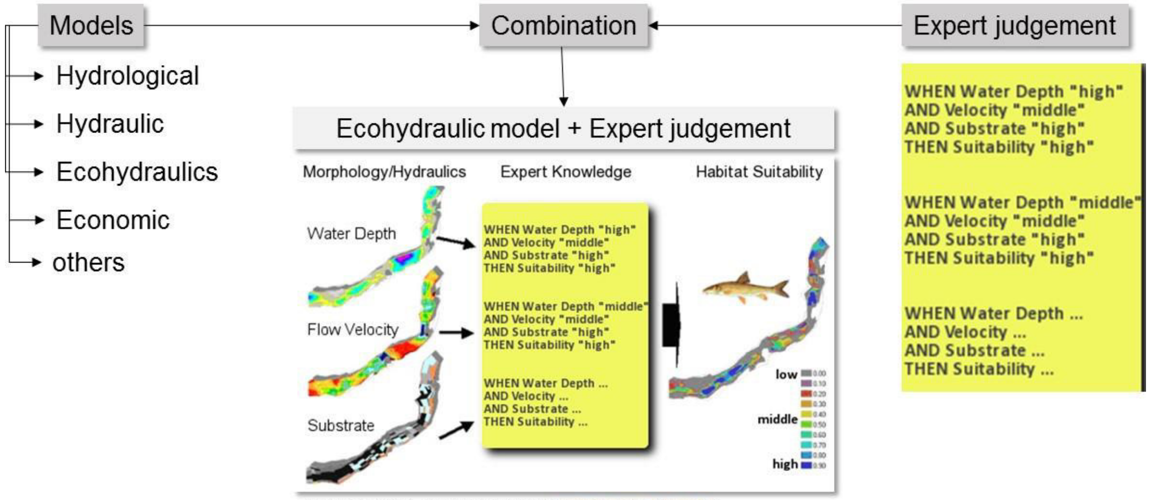
Some of the effects become more visible than others all depending on the difference between healthy and degraded states. If water quality components are included, oxygen respiration and nutrient emissions can be used to demonstrate impacts on fish. The animation of effects works by means of inundation maps. The extent of flooding can be illustrated dynamically as extent of inundated and flow velocity. A simple example is shown here: https://youtu.be/ae7Xah35vxw

A more sophisticated step includes eco-hydraulic models. They incorporate not only water quantity and quality but also habitat conditions.

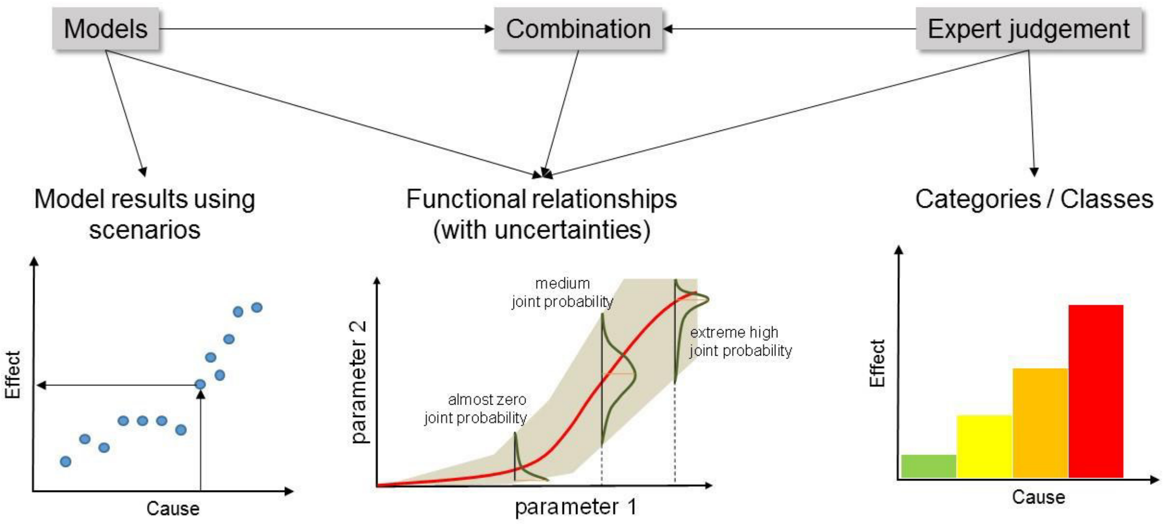
Data requirements:

Data needed can be globally available elevation models (e.g. SRTM30), soil and land cover database supplemented by local information and data. The more local information is available the better are results and can be used as absolute figures while less local information provides only relative information between the two scenarios.

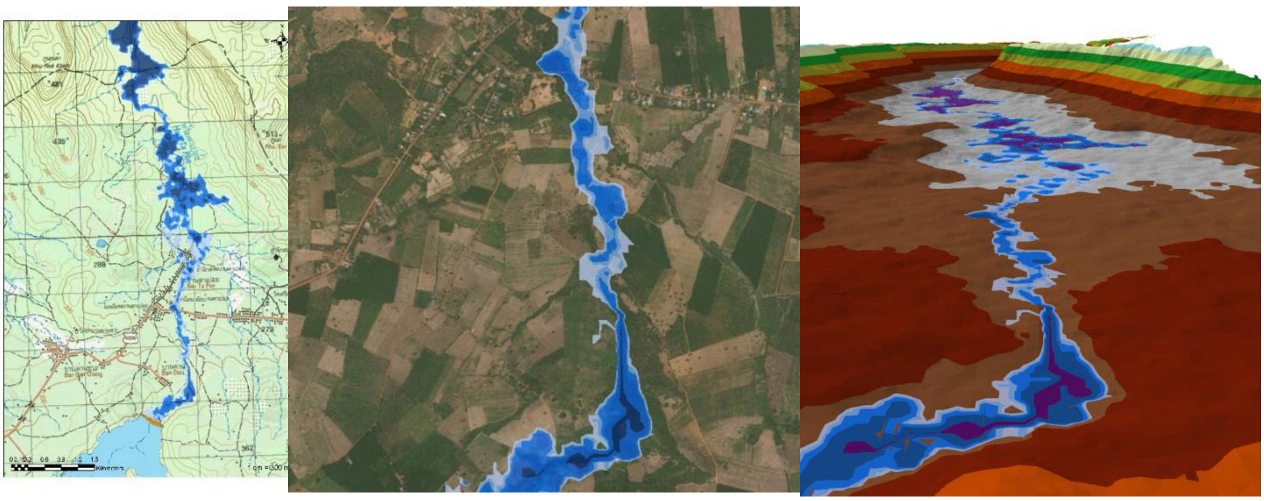
Principle of eco-hydraulic modelling



Source: CASIMIR ecohydraulic model (www.casimir-software.de)



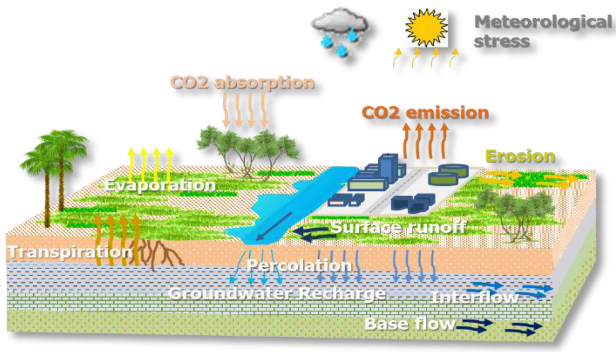
Examples of maps



Ecological Balance and Evaluation of Ecosystem services

An approach was developed which considers the intrinsic values of ecosystems by means of hydrologic response units (HRU) and CO2 accounting. CO2 balance, water footprint of land use and storage potential for each HRU are used. By linking accepted economisation of CO2 emission/absorption with water storage capacities a clear and concise concept was derived in order to

- evaluate land according to their effects on climate change and net water storage
- identify most favourable locations to preserve or promote ecosystem services
- focus and streamline discussions between stake-holders from different sectors in view of disaster risk management
- display the spatially-distributed value of carbon absorption and water storage
- generate coherent and fair values to less favoured regions



The approach can be applied to all scales of river basin and with different level of details concerning data availability.

Interactive Excel-Sheet

An Excel-application was developed in which the economic values of grey infrastructure and green measures can be assessed interactively.

Drones Application in the Water Sector and 3D Models

The integration of drone technology into the water management sector combines technology with the science of socio-economics. Aerial photography and data collected by drones, together with terrestrial pictures, have proved to be reliable sources for the generation of 3D models of floods, which then allow further simulation of the effects from flood and droughts. Not only is the quality of the data high, but the cost of flying drones at a low level is not expensive when compared to other data collection methods. Data collection from different heights with multiple flights during diverse weather conditions can be conducted by drones.

Introducing a new concept and technology is challenging. While it was rather difficult to introduce and get acceptance for the EbA concept, it was much easier to introduce the drone technology into the monitoring system. Interestingly, hands-on approaches such as drones are accepted easily. Even the civil society was involved in this approach. Still, a core challenge is not to forget the traditional evaluation and monitoring approaches and to keep hydrologic and morphological data recording.