trAndeS

Programa de Posgrado en Desarrollo Sostenible y Desigualdades Sociales en la Región Andina

Course Reader

Integrated Watershed Management

Stefan Thiemann, Henry Schubert, Brigitta Schütt

DAAD

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The **trAndeS** Material Docente Series provides course readers that gather different topics relating to the overarching theme of the program: the relation between social inequalities and sustainable development. These materials are intended to serve as resources for teaching and training activities.

Edition and production: Stefan Thiemann / Henry Schubert / Brigitta Schütt / Joana Stalder

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1. Course information

1.1. Course description

COURSE DESCRIPTION		Date: 01.02.2018		
Code	Name	Lecturer(s)		
	Integrated Watershed Management			
Position in course of studies, amount of time, credit points				
Applicability, module type, frequency of offer				
Master programme, core course, theoretical, annual offer				
Admission requirements for the conclusion (exam)				
Form of work and examination, requirements, amount of work, credit points				
Forms of performance	Requirements	Amount of work (h)	CP	Weight of marks
				100%
				100 %
Which technical, methodical and practical matters are imparted?				
Teaching material: lecture notes and reference materials, internet downloads for self-study;				
Which technical/methodical skills and key qualifications shall be gained?				
Understanding of human and environmental processes and interactions between natural resources and water utilisation, understanding of interventions and their impacts.				

1.2. Learning objectives

The course shall enable the students to:

1) Gain a holistic view about environmental and social aspects with regard to Integrated Watershed Management
2) Gain knowledge about all aspects of Integrated Watershed Management in order to manage a watershed through consultancy of experts for necessary actions. As a manager an overall knowledge of all aspects is necessary, but deep-inside knowledge for specific aspects can be hired.
3) To participatory develop sub-catchment management plans, to monitor management activities and evaluate socio-economic and environmental conditions of a watershed area.
4) To train local water resources user groups and managers in developing and implementing watershed management plans.

1.3. Examination

A written examination will take place at the end of the course. The written examination shall focus on testing the mutual understanding of climate, the hydro-meteorological parameters, processes, interactions and response systems. The examination will be weighted 100%.

2. Course content

2.1. Introduction into the module

introduction into the module

A self-introduction at the beginning of the course shall open the course atmosphere among lecturer and students. It also enables the lecturer to get first impressions about the students' situation, background and motivation.

learning objectives

The learning objectives of this course shall be presented to the students. Due to the wide range of subjects the students graduated and the prerequisite to participate in this course, it is important to make the students understanding that not only theoretical knowledge is important to learn, but also to understand overall processes and interactions of response systems. Thus, the course shall also focus on intensive discussion rounds on case studies and recurring explanations from the students. The complexity of climate and hydrology does not allow going too much into details and consequently, the students should know the threshold of deep inside knowledge transfer.

Administrative issues (e.g. mode and details of exam) shall be clarified prior the lecture starts in order to avoid uncertainties and probable juristically consequences.

The students have different scientific background. To getting familiar with knowledge of students towards the topic of climate and water systems assists very much in estimating the level of in depth teaching. It is important to consider the fact that the aim of the Master programme is to graduate students for management purposes.

Presentation of course content at the beginning shall give the chance to the students for pre-preparation for the lecture courses. It is also a nice opportunity to get an overview.

Some courses consist of overlapping topics. Discussion and repetition of lessons learned from previous courses reactivates student's knowledge and allows going more into detailed knowledge transfer.

2.2. Introduction into Integrated Watershed Management

What is "Integrated Watershed Management"?

introduction into IWM

IWM is a **holistic** and **integrated** approach; a watershed area is an ecological system, which can only survive as a unit. Thus, a holistic view is essential in IWM (Förch & Schütt 2004 b):

- the individual components of the watershed (e.g., water resources, water user)
- the relationships between the characteristic form (e.g., slope, bedrock, soil)
- the process factors (e.g., average precipitation intensity

characteristics of IMW

Management of vital resources available in the watershed is to be carried out collectively and simultaneously to improve the living conditions of the local population (Tidemann 1996). Watershed-based planning aims to balance environmental goals with socio-economic and political goals within the watershed considered (Butler 2003, Heathcote 2009).

Its goals should comply with sustainability and environmental appropriateness (Förch et al. 2005; Förch & Schütt 2004 b).

The planning process consists of comprehensive rational, transactive and adaptive planning modes IWM is a process of *rational decision making* in successive steps (Butler 2003). Systematically the available management options are compared, and a Watershed Management plan is developed that is mainly a rural development concept (Heathcote 1998; Tidemann 1996).

A central feature of integrated watershed management is the involvement of local people including their traditional knowledge and practices, which are to be combined with modern knowledge and techniques (Heathcote 2009).

characteristics of IMW

Furthermore, the cooperation between stakeholders, governmental departments (different sectoral departments, across jurisdictions and between the administrative levels), non-governmental organisations, industrial companies is essential. In this sense, the watershed planning process is a consensus-building process rather than a unidimensional scientific exercise (Heathcote 1998).

Integrated Watershed Management is a flexible process that has to be adapted to the unique characteristics of distinctive watersheds and to changing conditions within individual watersheds (Heathcote 1998).

Integrated Watershed Management measures are implemented by technical cooperation schemes at the level of projects or programmes. Nowadays it is accepted as a measure in regional and inter-regional programmes and has become an integral part of development co-operation (Förch & Schütt 2004 b). It can especially be a reasonable approach to trans-boundary watershed management.

What is a watershed area?

General Definition:

definition watershed

A watershed is a natural or disturbed system that functions in a manner to collect, store, and discharge water to a common outlet, such as a larger stream, lake, or ocean. Between collection and runoff, water is stored (Wani & Kaushal 2009).

A watershed embraces all its natural and artificial (manmade) features, including its surface and subsurface features: climate and weather patterns, geologic and topographic history, soils and vegetation characteristics, and land use. A watershed may be as small as a house roof's gutters and downspout, and as large as the Amazon, Mississippi, or Nile basins (Wani & Kaushal 2009).

definition watershed

The science embraces a comprehensive understanding of the basic functions of a watershed as well as awareness that functions and physical characteristics may vary dependent on watershed size as well as proximity to neighbouring watersheds that may drain into and be part of connected, larger, and multiple watershed systems. These may be of particular importance in the effective management of the several natural drainage units (Förch & Schütt 2004 a).

Hydrological Definition:

hydrologic definition of a watershed

"A watershed is defined as any surface area from which runoff resulting from rainfall is collected and drained through a common point. It is synonymous with a drainage basin or catchment area. A watershed may be only a few hectares as in small ponds or hundreds of square kilometres as in rivers. All watersheds can be divided into smaller sub-watersheds" (Wani et al. 2002).

(sub-)watershed separation

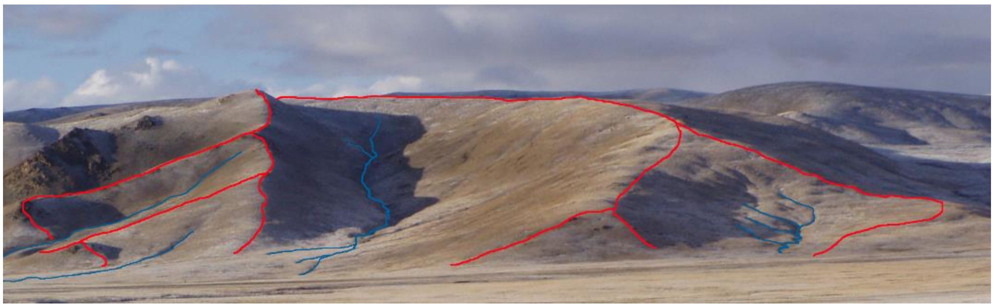


Figure 1: Sub-watersheds in the east of Madoi, Tibetan Plateau, China. The red lines are the drainage divides and the blue lines are the drainage channels (own picture by S. Schütt 2003)

Why using the watershed approach?

watershed approach

The watershed approach allows a clear geographical and hydrological definition of an area to be managed. Due to the nature of stream flow, the management of water must ignore administrative and political boundaries. Typical conflicts in a management area are upstream-downstream user conflicts inclusive impacts on environment and social-economic conditions. In rural areas most conflict are caused direct or indirect by water utilisation. The watershed approach is directly addressing upstream-downstream water user conflicts and is consequently leading to problem solution. Next, management and modelling hydrologic definition of watershed modelling of water resources can only be conducted professional, when a hydrological watershed is defined (European Commission 1998, Heathcote 2009):

- The size of the catchment is known
- Water demand can be derived
- Water availability can be computed
- Management area can be split into pieces due to geomorphologic conditions

What does 'integrated' mean?

integrated approach

Using the terminology 'integrated' always leads to the assumption to 'compose and coordinate to form a whole'. In the context of Integrated Watershed Management the term 'integrated' demonstrates that all aspects of watershed management will always be considered for each individual activity. There are never 'stand-alone' actions possible: Each activity in a watershed is influencing the whole watershed - and the whole watershed is influencing each activity (Förch & Schütt 2004 a).

Table 1: Example for integrated approach

example integrated approach

<table>
<tr><td colspan="2">Precipitation in the mountains occurs and surface runoff is collected by a dam</td></tr>
<tr><td>tentative consequence 1</td><td>tentative consequence 2</td></tr>
<tr><td>evaporation is increasing due to the water collection in the dam:
less water will be available for downstream users</td><td>storage of water allows stream flow in dry season:
downstream user benefit from continuous water availability</td></tr>
<tr><td colspan="2">Which assumption is correct?</td></tr>
<tr><td colspan="2">➔ Integrated approach to discuss the tentative consequences is needed</td></tr>
<tr><td colspan="2">Factors to be considered for both tentative consequences:</td></tr>
<tr><td colspan="2">- evaporation rates
- difference between natural and anthropogenic retention areas
- water source protection
- climate predictions
- economic and ecologic benefit and/or disadvantage of dams
- community involvement
- etc.</td></tr>
</table>

What does “Integrated Watershed Management” mean?

definition of IWM

Definition of Integrated Watershed Management

Integrated Watershed Management organizes and guides the use of natural and human resources on a watershed to provide the goods and services demanded by the society, while ensuring the sustainability of the natural resources. It involves the interrelationships among natural and human resources and links between upland and down-stream areas (Ffolliott et al. 2003).

Objectives of Integrated Watershed Management

objectives of IWM

- conserve soil, rainwater, and vegetation effectively and harvest the surplus water to create water sources in addition to groundwater recharge
- promote sustainable farming and stabilize crop yields by adopting suitable soil, water, nutrient management and crop management practices
- cover non-arable area effectively through afforestation, horticulture, and pasture land development based on land capability class
- enhance the income of individuals by adopting alternative enterprises
- restore ecological balance
- build capacity to appreciate economic value of ecologic functioning watersheds

(Bollom 1998, Förch & Schütt 2004 b, Panda 2003, Wani et al. 2002)

Principals of Integrated Watershed Management

principals of IWM

- utilizing natural resources according to its sustainable capability
- secure adequate vegetation cover during the rainy season
- conserving as much rainwater as possible at the place where it falls
- effective utilisation of surface and groundwater resources
- avoiding gully formation and control soil erosion
- increase groundwater recharge
- ensuring sustainability of the ecosystem benefitting the man-animal-plant-water-land complex in the watershed
- improving infrastructural facilities with regard to storage, transportation, and marketing
- preventing water pollution and increasing WASH (water and sanitation hygiene) facilities
- solving water conflicts within the watershed
- securing access to water

(Förch & Schütt 2004 b, Panda 2003, Wani et al. 2002)

Components of Integrated Watershed Management

components of IMW

Following fields are part of IWM (Förch & Schütt 2004 a):

- Human resource development (qualification of resource managers and users, empowerment, etc.)
- Water management and utilization of water resources
- Rainwater harvesting and water storage techniques
- Soil and land management (reforestation, land rights, land use planning, soil conservation, etc.)
- Crop yield management, agroforestry
- Pasture and livestock management
- Rural energy management
- Farm and off-farm activities to create and enhance value

These components are interdependent and interrelated. Therefore, any technical or institutional change should be evaluated in terms of impacts on the other fields. The figure below sum up the components and processes of IWM.

processes influencing the IWM process

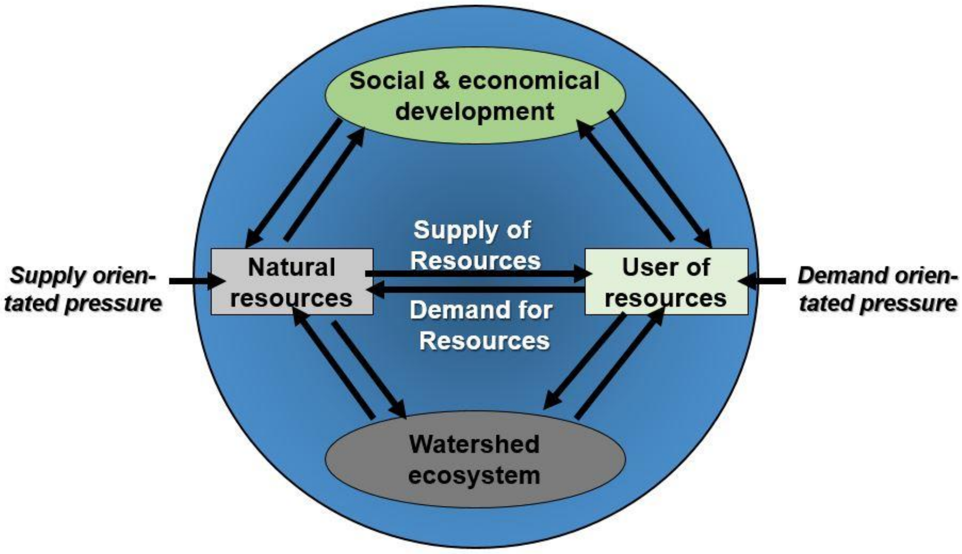


Figure 2: Processes influencing the process of watershed management (own illustration by B.Schütt 2007, after Heathcote 1998, p.376)

Complexity and dynamics of IWM

complexity and dynamics of iwm

The complexity of IWM is all over and cannot describe in one term. The following ***examples*** demonstrate considerations that might come up for assessment and impacts of management options[1]:

land ownership

- Land ownership
  The management of a catchment area is very much depending on the personal input and commitment of the landowners. Land ownership is quite often not regulated by laws and often not secured. Therefore, farmers might not be interested in managing land, which they do not own by law. IWM requires for best management options landowner change in order to create larger pieces of land for better conservation, agriculture or reforestation. Land ownership is crucial for sustainable implementation of IWM and needs special attention.

resilience against new development

- Resilience against new development
  Rural or urban development is often coming along with new ideas and concepts and a change of living conditions. Acceptance of development actions is depending on status of education and on self-confidence towards the better. Both are a challenge especially in rural areas. Thus locals tend to be resilient against new introduced methods and concepts. IWM is strongly considering this aspect by acting in a holistic and strong participative way. All activities in a watershed area are implemented in close cooperation with the local population. Sustainable development is only possible through strong ownership of concepts and ideas by the local population.

[1] Additional information: FU Berlin: http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/introduction_iwm/aspects_integrated/

- Holistic approach
  IWM acts only in a holistic approach. All kinds of disciplines that effective contribute to best management are incorporated in the approach, e.g. geography, engineering, climatology, social science, justice, geology, hydrology, agriculture, agro forestry, education, etc. The IWM manager shall consider the different disciplines and if necessary consult experts for best knowledge gaining and sharing.

holistic approach

- Educational level
  The educational level of IWM stakeholders is widely ranged from illiterate to university level. Thus, awareness and knowledge about IWM is rather high differing in theory and practice. Capacity building measures shall be adapted to the educational level of farmers, local managers, regulatory authorities, ministries, students, researchers and lecturers. There exists no universal teaching book for IWM. Also knowledge and capacity for implementing IWM measures is depending on the all over understanding of the concept and the deep understanding of practical aspects. Working for IWM at different educational levels require next to sound understanding of the topic a sensitive and adjusted workaround with all stakeholders.

educational level

- Natural dynamics
  IWM is addressing all kind of natural and human induced or fostered dynamics. A sound understanding of natural processes with regard to water, weather, soil, biomass and agriculture. It is necessary to evaluate the natural dynamics of a watershed area. This evaluation is one of the first steps for the development of sub-catchment management plan (see the landscape sensitivity chapter). Natural dynamics are usually overlapping with human induced activities and differentiation is in particular cases rather difficult.

natural dynamics

Industrial, agricultural and household competition
Each watershed area underlies competition of different kind of water users: industrial, agricultural and domestic. Next, size of water users is leading to different empowerment (e.g. through financial resources) and unequal water consumption. All stakeholder groups need to be involved into the action for conflict resolution.

water user competition

- Natural versus administrative boundaries
  Administrative boundaries are usually not following hydrological units. Watershed areas may fall in several districts with different local administrative actors and willingness for cooperation. Investigation of administrative boundaries and relevant political structures are essential for implementation of sub-catchment management plans.

administrative boundaries

- Upstream – downstream interest
  Typical upstream-downstream user conflicts need to be considered for assessment, development and implementation of sub-catchment management plans. Upstream – downstream user conflicts are not only addressing human conflicts, but also those of ecological functions of water bodies.

upstream-downstream conflicts

- Short term – long term visions
  Sub-catchment management plans are dynamic tools for best management options. Timelines need to be agreed upon, since plans shall be drafted according the needs of the local population. Idealistic long-term plans do not necessarily serve the population when short term action is needed. Vice versa, short term plans shall not ignore long-term needs of the environment.

timing

- Heritage systems
  Sustainable implementation of sub-catchment management plans requires commitment of all local actors. Land management, as one part of IWM, is often conflicting with land ownership and/or the heritage systems of the country. Traditional but inappropriate heritage systems hinder proper land management and IWM.

heritage systems

- Conflictive laws
  Conflictive laws leas to misunderstanding and to passiveness of local actors towards environmental protection in order to protect them before acting against one law. One the other side enforcement of laws is blocked when several laws address the same issues.

conflictive laws

Benefits from IWM[2]

benefits from IWM

a) for farmers
   - increased productivity and higher profits
   - improved water availability
   - improved soil quality and better drainage
   - improved livelihoods

b) for local community:
   - lower land-development costs
   - reduced flooding and water logging
   - reduced soil erosion and land degradation
   - increased agricultural productivity
   - improved livelihoods options
   - improved land management
   - less socio-economic conflicts

c) for larger society:
   - reduced risks from floods to downstream cities and farmlands
   - reduced sedimentation in agricultural productive areas and dams
   - better conservation of natural resources
   - higher resilience of communities

[2] Additional information: FU Berlin: http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/introduction_iwm/benificiaries/

History of IWM

history of IWM

Two statements about the novelty of the IWM approach are given in the following:

- IWM is a well-established approach as it already existed in 1950. The management of water resources was practised even in prehistoric time (Heathcote 1998).
- IWM is a new approach: as it is understood today, it has not been practised at any earlier time.

Which statement is correct?

Watershed Management is a new concept with a long history during which it has been understood in different ways.

For thousands of years people have attempted to control the flow and quality of water. Different activities undertaken to manage water have been documented since these early times. This included also irrigation of agricultural land. In addition, conflicts about water use are known from Mesopotamia 4,500 years ago, but the management of water was not done within watersheds. Heathcote (1998, p.2) stated:

"Despite this long experience in water use and water management, humans have failed to manage water well".

Especially the economic developments since the 19th century have proceeded at the expense of sound water management (Heathcote 1998).

Rethinking took place in the 1960s. It was recognised that a centralistic way of water management on a national level failed. Instead, it was realised that decentralised water management at level of watersheds is required (Heathcote 1998). An early concept of watershed management emerged in 1950. However, this was not a concept of rural development which is orientated to a sustainable and integrated natural resource management (Förch & Schütt 2004 b). As the ecosystem concept emerged in the 1980s the integrated approach for a sustainable management of natural resources and rural development was developed (Neary et al. 2000).

2.3. Resource Water

What is a resource?

definition resource

Definition:

A **resource** is a source or supply from which benefit is produced. Typically, resources are materials, money, services, staff, or other assets that are transformed to produce benefit and in the process may be consumed or made unavailable. Benefits of resource utilization may include increased wealth, meeting needs or wants, proper functioning of a system, or enhanced well-being. From a human perspective, a natural resource is anything obtained from the environment to satisfy human needs and wants (Miller & Spoolman 2011).

repetition hydrologic cycle

Repetition – Hydrologic Cycle:

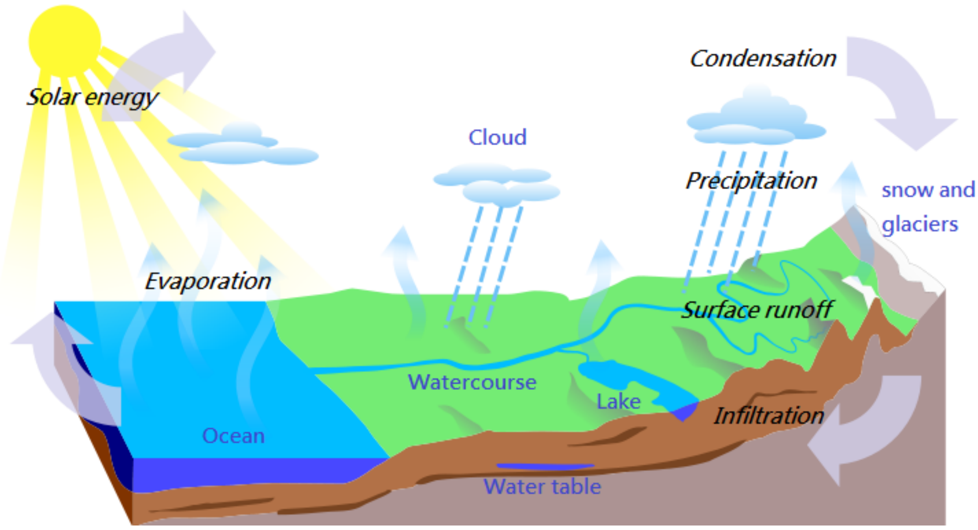


Figure 3: The hydrologic cycle (by Cmdrjameson / CC-BY-SA-3.0, source: https://commons.wikimedia.org/wiki/File:Water_Cycle-en.png)

It is strongly recommended to repeat the hydrologic cycle, since it is the base for IWM from physical point of view.

Where is the water coming from?

freshwater availability

The freshwater availability is a factor of climate and environment only, not putting into account technical possibilities and infrastructure for water harvesting, storage or processing (UNEP 2002).

Freshwater is accounting glaciers and ice caps, groundwater and surface water, inclusive other freshwater. The global freshwater available (where we have direct access to) is ice & snow, from lakes, soil moisture, swamps, rivers, biological water and atmospheric water. The total amount of available freshwater is only 1.3 % of the global freshwater which is only 2.5 % of the total global water (UNEP 2002).

distribution of earth's water

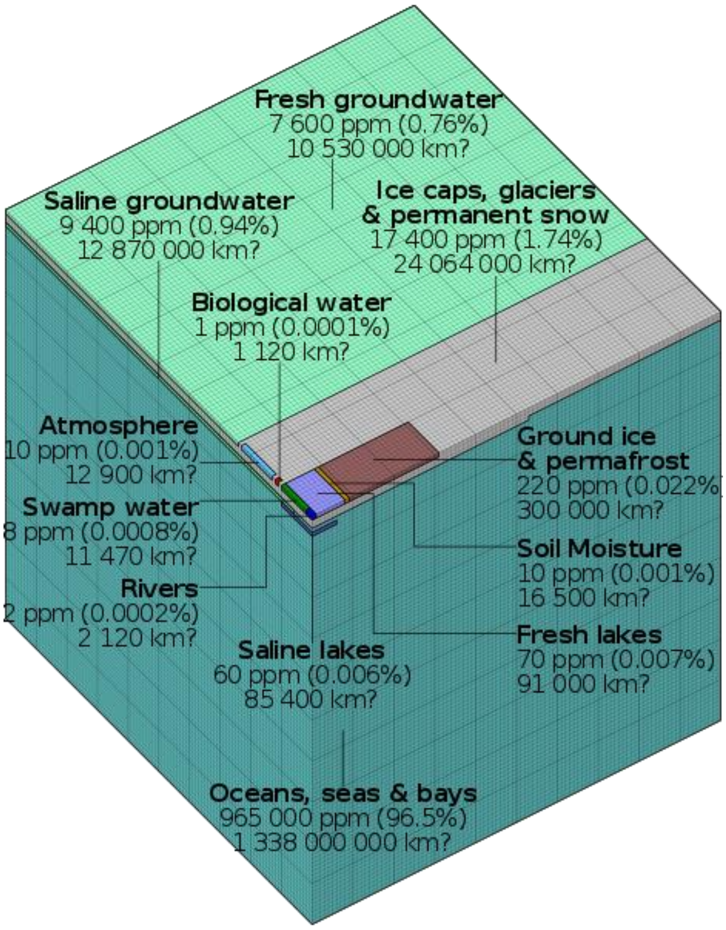


Figure 4: Distribution of earth's water (by Cmglee / CC-BY-SA-3.0, source: https://commons.wikimedia.org/wiki/File:Earth_water_distribution.svg)

Freshwater available is seems to be infinite, but since it is a very small percentage of the global water. It needs special attention!

Surface water versus ground water

surface water versus groundwater

Table 2: Surface water versus ground water

Raindrop A infiltrates the soil, reaches the water-table and becomes groundwater. - After years in underground it is pumped from a water-well and used for potable supply. - It is then discharge as sewage effluent to a river, becoming surface water perched above the local water-table, which seeps through its bed to recharge the underlying aquifer. - The raindrop then joins the groundwater flow in aquifers and discharges directly to the sea.	**Raindrop B** falls directly into an upland lake, becoming surface water. - After some days it evaporates back to the local atmosphere and falls again as rain, but this time e.g. on permeable ground where it infiltrates to become groundwater. - If flows underground in an aquifer for more for several years and discharge eventually as a lowland spring. - It thus becomes surface water again, part of a stream and river system, which some days or month later reaches the sea. - If not infiltrating it becomes directly surface water. It is a part of a lake, stream or river system and reaches some days or month later the ocean.

The table above demonstrate possibilities of a water drop changing from surface water to ground water and vice versa, or evaporating into the atmosphere.

An entirely distinction between surface water and ground water is not possible considering the processes of the hydrologic cycle, but depending on the time considered, clear separation is possible.

The challenge for IWM is the fact that ground water is not having the same hydrologic boundaries that surface water (watershed) and thus, subsurface trans-boundary ground water occurs – with regard to the surface boundaries of a defined watershed area (Heathcote 2009).

groundwater versus catchment area

Due to the fact, that in most areas only little is known about groundwater occurrence, flow, quantity, and recharge activities of IWM towards groundwater are commonly kept out – scientifically wrong, but practically done, since it easy the hydrologic assessment processes.

Knowledge and sensitivity about groundwater utilisation needs attention at, since only few percentages of groundwater available is used for consumption. Groundwater recharge needs more attention at, since it reduces surface water runoff, erosion risk but increases water availability during dry seasons (Ahnert 2003, Mendel 2000).

Ground water generally must see as a whole system across large areal extend. Activities in one can affect the groundwater table in several ten kilometres distance (Mendel 2000).

The figure below show the global groundwater. In many parts of the world, huge groundwater resources are available, only the large arid zones (Sahara, Central Asia, parts of Australia and southern Africa) have limited groundwater resources. However, groundwater is used to a wide range of different intensity due to high investment and running costs for exploration and withdraws (UNEP 2002).

groundwater resources

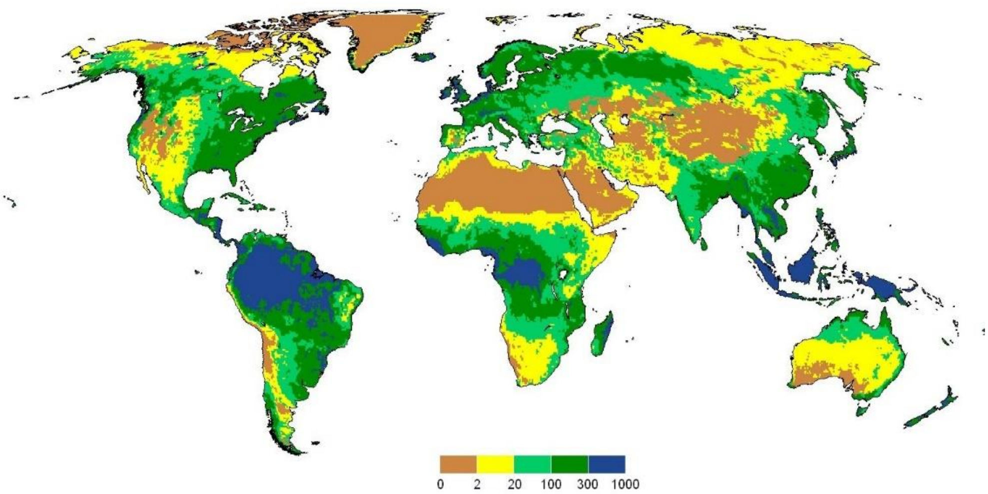


Figure 5: Renewable groundwater resources of the world, in mm/yr (average 1961-1990). 1 mm is equivalent to 1 l of water per m² (by Döll & Fiedler 2008 / CC-BY-SA-3.0, source: https://commons.wikimedia.org/wiki/File:Renewable_Groundwater_Resources_in_mm_per_year_By_WaterGAP_Average_1961-1990.jpg)

global freshwater

The global freshwater use differentiated by sectors. So freshwater consumption do not strongly correlate to groundwater availability, but is much more depending on surface water (UNEP 2002).

Political boundaries

political boundaries

IWM is consequently designed for management of hydrological based catchment areas. The management of the resources human, biomass, soil, water and energy requires close cooperation with local, regional and national authorities. Due to the fact, that these authorities are usually scattered by political boundaries (national or international), the IWM approach is facing the challenge that two or more local or regional authorities governs are parts of one catchment area. Transboundary water management is a widespread topic, but usually discussed for international water management options. However, also on sub-catchment level political structures need to be considered. Transboundary water management needs effectively be addresses for surface and for groundwater management[3].

Transboundary water management

transboundary water management

The world's transboundary river basins span 145 countries, include more than 2.8 billion people (around 42 % of the world's population), cover 62 million km2 (42 % of the total land area of the Earth), and produce around 22 000 km3 of river discharge each year (roughly 54 % of the global river discharge) [4].

The Transboundary Waters Assessment Programme (TWAP) is based on a number of indicators and methodology and analyse the risks to societies and ecosystems for the basins. During this design phase, five 'clusters' of issues were identified as being of relevance to both populations and ecosystems: water quantity, water quality, ecosystems, governance, and socioeconomics[5].

[3] Source: UN 2014:http://www.un.org/waterforlifedecade/transboundary_waters.shtml; SIWI 2017: http://www.siwi.org/priority-area/transboundary-water-management/

[4] Source: UN 2014:http://www.un.org/waterforlifedecade/transboundary_waters.shtml

[5] Source: UNEP & GEF 2016: http://twap-rivers.org/

Integrated Watershed Management is addressing both water quantity and quality.

Too little water

too little water

The most common aspect for IWM is the management of too little water, since it is generally affecting livelihood in manifold aspects. IWM is targeting water conservation measures, water savings at domestic, agriculture and industrial level, and water retention in order to mitigate drought and flood effects. Water management in terms of drought effects mitigation is long term oriented through awareness creation measures, water source rehabilitation and establishment and protection of natural water retention areas (e.g. forests, river banks, etc.). These IWM measures have double effect: natural retention areas also protect for floods, since water is stored in the areas of reaching the soil (Heathcote 1998, Tidemann 1996).

Too much water

too much water

Too much water occurs due to extra ordinary rainfalls and storms, but also due to uncoordinated depletion of the natural vegetation and water retention areas (water sources). All measures to mitigate the effects of droughts also mitigate the risks of floods (Heathcote 1998).

Too dirty water

too dirty water

Figure 6: Water pollution of river channel in Puerto Colombia, Colombia (own picture by H. Schubert 2016)

too dirty water

Too dirty water occurs almost everywhere in non-developed countries and in countries with weak governmental structures and little awareness about the environment. Water pollution comes from irregular solid waste disposal, from human and animal faeces, from water source pollution, e.g. discharge of wastewater from industry and towns, from spraying herbicides and pesticides, etc (Heathcote 2009).

Polluted water is the main trigger for water born (diarrhoea, etc.) and vector born (Malaria, etc.) diseases dominantly affecting rural and urban poor (Heathcote 1998).

IWM is addressing also water / environmental pollution by awareness creation measures, but also by installation of waste collection systems. However, the aspect of waste disposal, wastewater treatment and environmental pollution has manifold and complex aspects and thus need specialists for individual and complex problem solutions. IWM is addressing the issue, but cannot solve these problems directly (Förch et al. 2005, Heathcote 2009).

water source problems

Protections of water sources against any kind of pollution are underlying manifold challenges. There are four important water source problems, which lead direct or indirect to water pollution (next to pollution through waste disposal, sewage disposal and chemical pollution) [6]:

- polluted river water from upstream water consumers are directly affecting downstream water users
- overexploiting groundwater consumption leads to water shortage and contamination of water due to concentrations of pollutants of little water left
- pollution of shallow wells triggers water born deceases
- water allocation problems can lead to armed conflicts and consequently water source protections will be neglected

[6] Additional information: FU Berlin: http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/watershed-resources/ressource_water/quantity_quality/

How do we get access to water?

no access to safe drinking water

Reasonable access to safe drinking water is defined as the availability of at least 20 litres per person per day from an improved source within 1 kilometre of the user's dwelling[7].

Access to potable and safe drinking water is not related to environmental and climatologic conditions. Other aspects, like water management structures or peoples way of living are more important, e.g., pastoralist cannot have access to potable water, because of their migrations. Wars play an extraordinary role to water management, since infrastructure and governmental structures (regulatory authorities) are often destroyed and dismissed (Heathcote 2009).

water stress and mitigation of natural resource scarcity

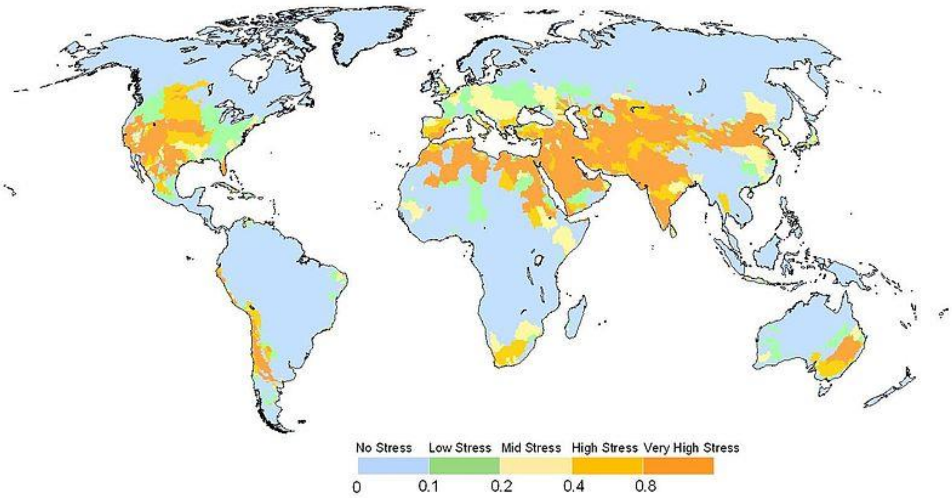


Figure 7: Water stress in river basins around the year 2000, as described by the ratio of annual water withdrawals to renewable water resources. (by Döll & Fiedler 2008 / CC-BY-SA-3.0, https://commons.wikimedia.org/wiki/File:Water_Stress_Around_2000_A.D._By_WaterGAP.jpg)

With regard to water stress it is highlighted that it is occurring in any places of the world independent the water availability. This physical water stress is often related to the relation between water consumption and physically availability, e.g. the United States. On the other side countries, where the local population have experiences with water shortages, are not necessarily under water stress. The challenge here is the access to water. However, water stress is globally increasing in all major basins (UNEP 2002, Heathcote 2009).

[7] Source: Fair Observer 2016: http://www.fairobserver.com/more/global_change/access-safe-drinking-water-challenges-opportunities-improving-global-health-32394/

access to surface water

Southern countries show a wide variety of water supply systems for its population (Tidemann 1996, UNEP 2002). There are several possibilities of water supply systems[8]:

a) direct water collecting from rivers and lakes
b) access to water from shallow springs and boreholes
c) access to water through water kiosks
d) tapped water, with is in developing countries only in towns the normal access
e) access to water through bottled potable water

A widespread and common way of fetching water in developing countries is the direct access to surface water (from lakes and rivers). These access places to water as used for several purposes (Tidemann 1996):

- fetching water domestic use
- cleaning of cloth
- personal hygiene
- washing cars, bikes, etc.
- watering livestock

Water pollution takes place exact where people fetch drinking water!

[8] Additional information: FU Berlin: http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/watershed-resources/ressource_water/access/

How can we protect the resources?

infinite water resources?

The current global water crisis is not addressed appropriate. Limited access to water and upcoming water scarcity is widely not addressed through proper implementation of water management measures (e.g. IWM), but through installing larger and energy intensive water distribution systems. Regional and global efforts on sustainable water management put little considerations in watershed management. Due to its holistic manner, this is the only way to solve on local level water scarcity, limited access to water and leading to increasing food production and livelihood (Förch & Schütt 2004 a).

Next to water source protections by riparian river buffers or forest protection the implementation of proper water treatment plans play a major role (Förch & Schütt 2004 a).

Worldwide only a small percentage of households are connected to sewer and treatment plants[9]. Whereas Europe and USA reaches more than 90 % the other continents are far below 40 % or even 20 % (UNEP 2002).

The situation is even worse in rural areas. Here, sewers and water treatment plants as well as wastewater connection systems are very rare (Tidemann 1996).

wastewater treatment

Wastewater treatment plants are cost effective and require skilled personnel for operation. A wide variety of treatment plants exist worldwide, but the processes for treatment rather similar. However, wastewater treatment plants are – due to operational costs – usually established in or nearby cities and towns but rare in rural areas (Heathcote 2009).

The focus of IWM is more on rural areas than on urban. Therefore, other management options for water treatment must be considered (Heathcote 2009):

- small scale biological treatment
- holistic sanitation management, such as ecological sanitation

[9] Source: UNESCO 2016: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/2015-water-for-a-sustainable-world/

ecological sanitation

"Ecological sanitation is a new paradigm in sanitation that recognises human excreta and water from households not as a waste but as resources that can be recovered, treated, where necessary, and safely used again. Ecological sanitation systems offer a range of low cost to high tech sanitation options which are hygienically safe, comfortable to use, environmentally friendly and often more economic than conventional systems. In addition, they ideally enable a complete recovery of nutrients in household wastewater and their reuse in agriculture. In this way, they help preserve soil fertility and safeguard long-term food security, whilst minimising the consumption and pollution of water resources." (Werner et al. 2004).

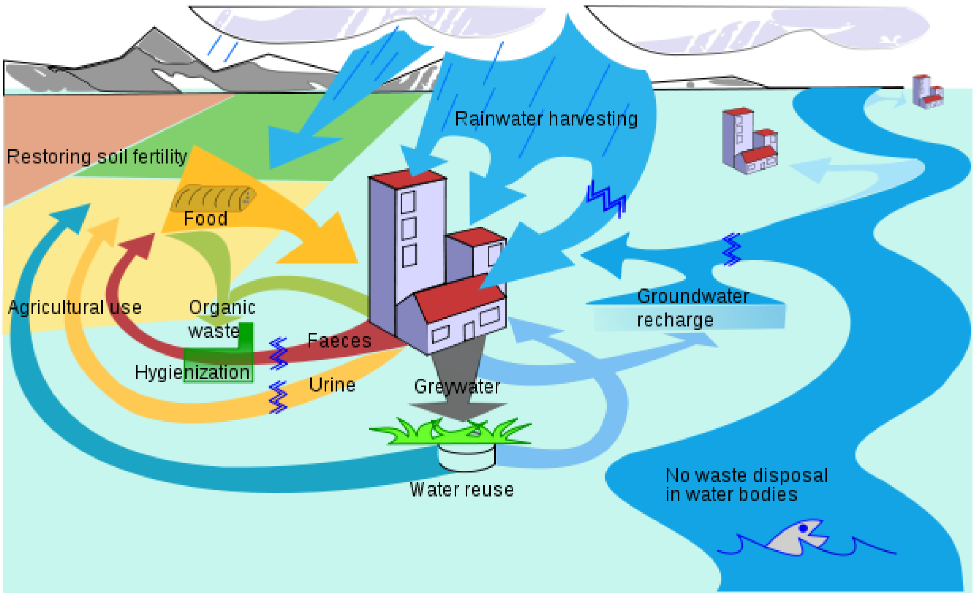
principle of ecological sanitation

The principal of ecological sanitation relies in the fact that nutrients (e.g. from faeces) serves at biological fertiliser for better food production. Faeces are not considered as waste but as high potential resource. [10]

Ecological sanitation triggers positive effect on the environment and livelihood (Werner et al. 2004):

- it reduces water pollution
- it promotes higher hygiene
- it preserves soil fertility
- it is a decentralised waste treatment without additional energy
- it promotes a holistic and interdisciplinary approach

[10] Additional information: SSWM 2018: https://www.sswm.info/category/planning-process-tools/programming-and-planning-frameworks/frameworks-and-approaches/sani-4



cycle of ecological sanitation

Figure 8: Cycle of ecological sanitation (by Barbetorte / CC-BY-SA-3.0, source: https://commons.wikimedia.org/wiki/File:Ecological_sanitation_cycle-en.svg)

water source protection zones

In many countries existing few laws for the protection of water sources. Regulations are differing to the extent of protection areas but always follow similar concepts[11]:

- **water point sources** are protected by zones of different protection grade in relation to the distance and the landscape to the point source.
- **linear water sources** and **water bodies** are protected by buffer zones of different functionality with regard to the distance to the water

The establishment of water source protection zones is often involving awareness creation measures such as installing posts or claiming illegal activities of nearby water polluters (Heathcote 2009).

[11] Source: SSWM 2014: http://www.sswm.info/category/implementation-tools/water-sources/hardware/groundwater-sources/water-source-protection

Forested riparian buffers

forest riparian buffers

Forested riparian buffers are linear multiple-row plantings of trees, shrubs and grass designed primarily for water quality and wildlife habitat purposes. They are planted along rivers, streams, lakes and some wetlands to prevent potential pollutants in agricultural runoff, such as sediment, nutrients, pesticides, pathogens, from reaching surface waters (MDA 2017).

Forested buffers are suitable for landscapes that were originally forested or wooded, as opposed to prairie or dry landscapes. The width, layout and composition of the trees or shrubs of forested riparian buffers vary depending on the floodplain characteristics, landowner goals and conservation program requirements (MDA 2017).

environmental benefits

Environmental benefits (MDA 2017)**:**

- protects water quality by reducing the amount of sediment and the excess of nutrients, pesticides and other pollutants entering streams, dikes, lakes, wetlands and other surface waters
- reduces excess nutrients and other chemicals in shallow groundwater flow
- minimize flood waters velocity and reduces stream water volume
- helps stabilize stream banks and shorelines through root absorption
- provides shade, shelter and food for fish and other aquatic species (shade is especially important for cold water species)
- provides habitat and travel corridors for diverse plants and animals; especially birds, reptiles and others that require water with adjacent woods

practical benefits

Practical benefits (MDA 2017):

- provides woodland recreational opportunities such as fishing, hunting, birding, hiking and camping
- provides opportunities for additional income from timber, firewood and specialty woodland products such as nuts, berries, mushrooms, decorative floral and material and medicinal plants
- provides an alternative for frequently flooded cropland, and may reduce flood damage on adjacent cropland
- provides a barrier against nearby dust, noise or light pollution

Headwater areas

headwater areas

Mountainous areas are typical water sources for lowlands. These areas are also described as headwater areas or water tower. In general, they do not underlay any specific protection laws despite the scientifically proven fact of providing most of the fresh water (Ahnert 2003, Mendel 2000).

rainfall in headwater area

The headwater areas like the Andes are important for the water supply of many countries in South America. The photo above demonstrates the effect of headwater areas:

- rainfall increase due to raising altitude
- mountainous areas are rarely used for agricultural activities; rainwater easily infiltrates and percolates – contribution to groundwater recharge
- surface runoff is collected by stream and rivers; due to little population density, the collected water is of good quality
- mountains release the water permanently throughout the year and thus contribute to water security downstream

These effects are only persistent as long as the natural environment of headwater areas are not changes and do not underlay anthropogenic and unsustainable activities (Ahnert 2003, Mendel 2000).

Water demand management

Definitions for Water Demand Management:

water demand management

(1) WDM aims to increase water efficiency through both wise use and reduction, which in turn will reduce or postpone the need to build more dams and drill more boreholes (Arntzen 2003).
(2) WDM is a management approach that aims to conserve water by influencing demand. It involves the application of selective incentives to promote efficient and equitable use of water. WDM has the potential to increase water availability through more efficient allocation and use. This is guided by economic efficiency; equity and access; environmental protection and sustainable ecosystems functioning; governance based on maximum participation; responsibility and accountability and political acceptability (IUCN 2000).

Incentives for implementing WDM[12]:

incentives for implementing WDM

The incentives for implementing WDM in the region and in individual countries are numerous:

- resource protection: Managing demand eases pressure on scarce resources
- increased production: It is more productive to encourage or adopt measures for efficient use of water than to invest in additional sources of supply
- a sound basis for planning: Estimates of present and future sectoral water use can be made
- water loss reduction: This promotes the sustainability of the resource

[12] Additional information: FU Berlin: http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/watershed-resources/ressource_water/water_demand/; Pacific Community 2018: http://www.pacificwater.org/pages.cfm/water-services/water-demand-management/what-water-demand-management/

initial situation for WDM

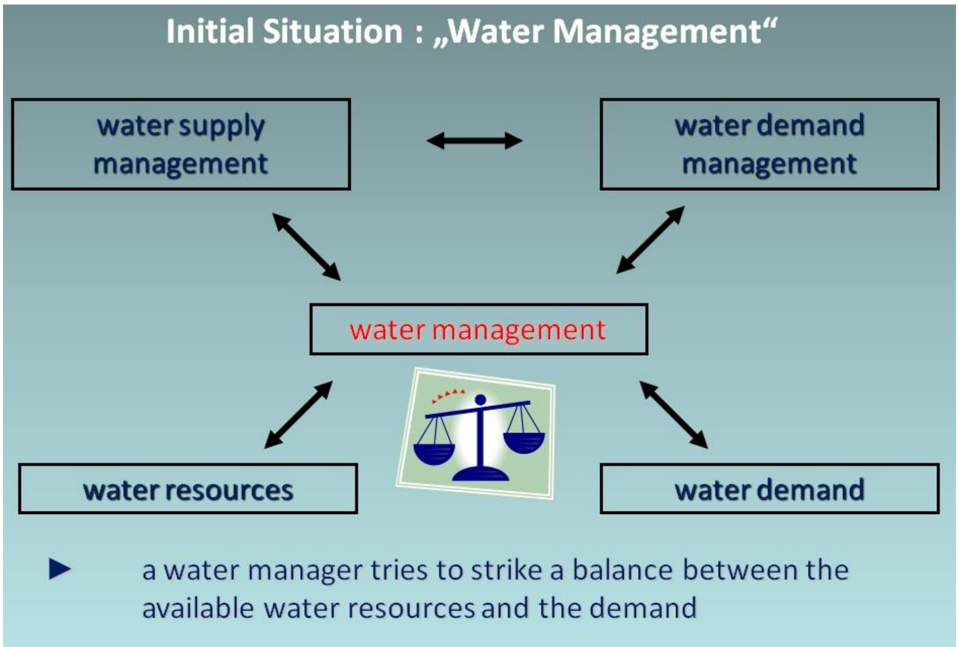


Figure 9: Initial situation for WDM (own illustration by S. Thiemann 2014; http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/watershed-resources/ressource_water/water_demand/)

examples for WDM implementation

Examples of WDM implementation:

- attitude change
- small scale irrigation
- irrigation in agriculture
- rainwater harvesting
- measurement of losses
- the environmental perspective on water subsides
- health risks and benefits
- development of WDM-plan

How can we collect and use water efficient and sustainable?

water categories

Proper water collection and use require the differentiation between the different water categories[13]:

- blue water: freshwater withdrawn from lakes, rivers and groundwater and used for irrigation, industry and domestic supply
- green water: the natural water in soil used by plants to grow
- grey water: the volume of polluted water created from the growing and production of goods

[13] Source: Water Footprint Network 2018: http://waterfootprint.org/en/water-footprint/what-is-water-footprint/

Rainwater harvesting

rainwater harvesting

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams. There are also ancient techniques like tanks, cisterns, qanat, etc. In different parts of the world which still serve as a major source of water supply in rural areas (UNEP & SEI 2009)[14]

rooftop rainwater harvesting system

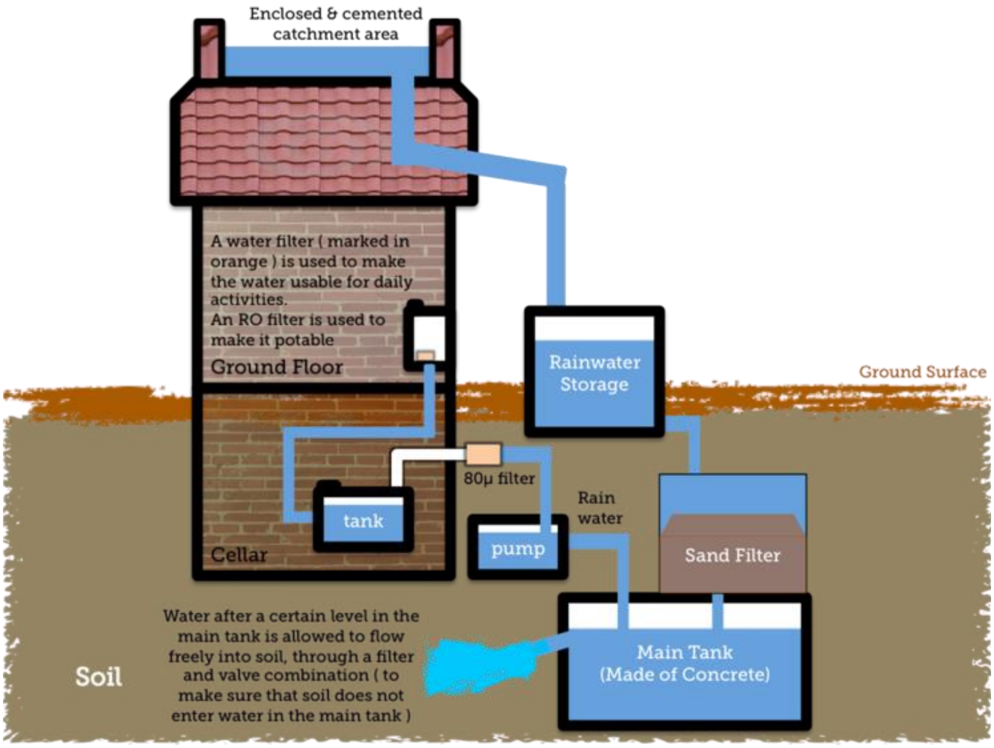


Figure 10: A simple diagram to show the various parts and functions of a Rooftop rainwater harvesting system. The process makes the collected rainwater suitable for drinking or common household use (by Adityamail / CC-BY-3.0, source: https://commons.wikimedia.org/wiki/File:Simple_Diagram_to_show_Rainwater_Harvesting.png)

[14] Additional information: UNEP & SEI 2009: https://www.unenvironment.org/resources/report/rainwater-harvesting-lifeline-human-well-being;
Important India 2017: https://www.importantindia.com/23766/rain-water-harvesting-meaning-methods-advantages-and-disadvantages/

Water recycling / reuse

water recycling and reuse

Water recycling and reuse is part of common settings for water saving in developed countries. Typical options for water recycling and/or reuse[15]:

1) direct industrial reuse
2) in-stream flow augmentation
3) direct agricultural use
4) groundwater recharge
5) urban use
6) indirect potable reuse from river
7) indirect potable reuse from well
8) indirect agricultural reuse

Biological wastewater treatment

biological wastewater treatment

All kind of water recycling must underlay the generally the same treatment process as displayed above. Same treatment processes can be of different execution from pure biological to pure chemical. However, type of used treatment processes is very much depending on the size of the treatment plant and of type of incoming wastewater[16].

Benefits:

- mimics an ecological process
- clean water entering watershed
- restore groundwater aquifers
- infrastructure cost savings
- energy inputs are minimal
- easy maintenance
- decentralized or centralized

How can we safe water?

how can we safe water

Water savings are possible in manifold directions independent the level of livelihood and income. Water saving measures can be enforced by laws, monetary pressure or by attitude change (Heathcote 1998).

[15] Source: Californian Department of water resources 2013: http://www.water.ca.gov/recycling/

[16] Additional information: Water technology magazine 2017: https://www.watertechonline.com/biological-wastewater-treatment /

how can we safe water

The first two options are the most effective, but not sustainable options. The most sustainable way to water savings is generating attitude change and increase awareness of the population. One example for saving water in agriculture is the use of more efficient irrigation systems like drip irrigation (Heathcote 1998).

water prices

Saving water through monetary pressure is quite common and widely accepted in developed countries. However, this option does not necessarily lead to overall water savings: the high the monetary wellbeing the less is the incentive to safe water.

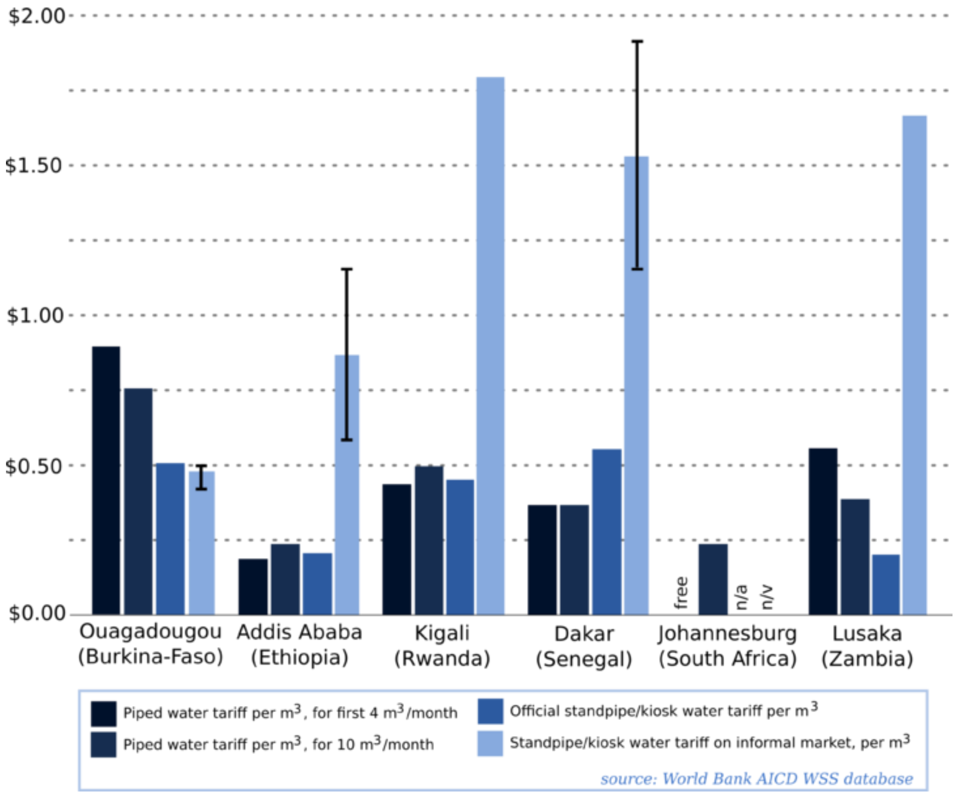


Figure 11: Graph showing the formal and informal water tariffs in 6 Sub-Saharan African Countries. Data taken from http://data.worldbank.org (by Jcherlet / CC-BY-SA-3.0, source: https://commons.wikimedia.org/wiki/File:Water_tariffs_in_7_Sub-Saharan_Cities.png)

possibilities to safe water

An extract of the global water process shows that water process are not related to national water availabilities, but to installed infrastructure for water supply and sewage systems. The higher the water price, the higher the incentive to safe water (Heathcote 1998).

own examples

Important is an attitude change! There are many ways and possibilities to safe water. The students should have many own examples.

2.4. Resource Soil

resource soil

Soil is a natural body consisting of layers that are primarily composed of minerals, mixed with at least some organic matter, which differ from their parent materials in their texture, structure, consistency, color, chemical, biological and other characteristics. It is the unconsolidated or loose covering of fine rock particles that covers the surface of the earth (Birkeland 1999).

Soil is the end product of the influence of the climate, relief (slope), organisms, parent materials (original minerals), and time. In engineering terms, soil is referred to as regolith, or loose rock material that lies above the 'solid geology'. In horticulture, the term 'soil' is defined as the layer that contains organic material that influences and has been influenced by plant roots, and may range in depth from centimetres to many metres (Gilluly et al. 1975).

generalised soil layers

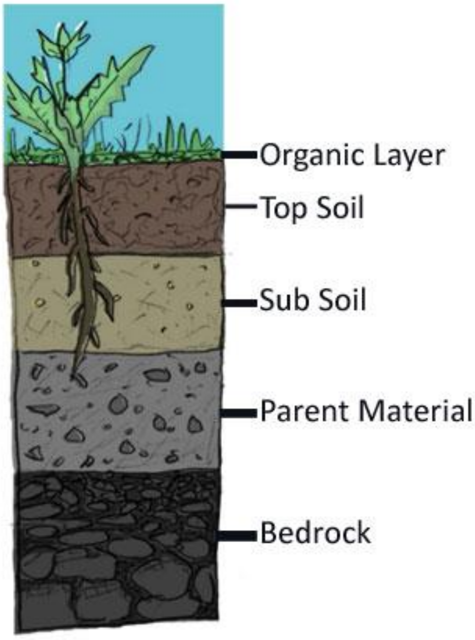


Figure 12: Layers of soil (by Radhika Mehrotra / **CC-BY-SA-4.0, source: https://commons.wikimedia.org/ wiki/File:Soil_Layers.jpg)**

characteristics of soil

Soil is composed of particles of broken rock (parent materials) which have been altered by physical, chemical and biological processes that include weathering with associated erosion. Soil is created from the alteration of parent material by the interactions between the lithosphere, hydrosphere, atmosphere, and biosphere. It can also be considered a mixture of mineral and organic materials in the form of solids, gases and liquids (Birkeland 1999, Gilluly et al. 1975).

characteristics of soil

Soil is commonly referred to as "earth" or "dirt"; technically, the term "dirt" should be restricted to displaced soil (Raloff 2008).

Properties of Soil

properties of soil

The physical properties of soil reflect several processes of formation that occur simultaneously along with primal material. The proportions of decomposed organic components; inorganic particles, water and air determine the physical and chemical properties that influence its vegetation and capacity for use.

external soil forming factors

Soil is permanently underlying processes of degradation, erosion and formation. In a natural equilibrium, the processes are balanced and lead to a permanent “refreshment” of the soil quality and quantity. The processes are highly depending on external factors:

- rock type (bedrock)
- climate
- vegetation
- relief
- time

Each factor underlies also changes at different time levels and these changes consequently disturb the equilibrium. As result soils either erode and degrade or form new. Erosion, soil erosion and degradation is a relative quick process, whereas soil formation takes rather long. At a certain stage of degradation, soil formation is not possible anymore (Ahnert 2003, Birkeland 1999, Gilluly et al. 1975).

Soil forming processes a rather complex. They are depending on weathering processes, climate and land formation.

➔ *Repetition: Soil formation and weathering*

Soil erosion processes

soil erosion processes

There is a difference between erosion and soil erosion. Human activities fostering soil erosion and degradation (Förch & Schütt 2004 a).

- ➔ Erosion: Under natural conditions erosion causes a levelling of relief.
- ➔ Soil erosion: Due to man‘s activities the natural erosion gets enforced, now called soil erosion.

differentiation between erosion and soil erosion

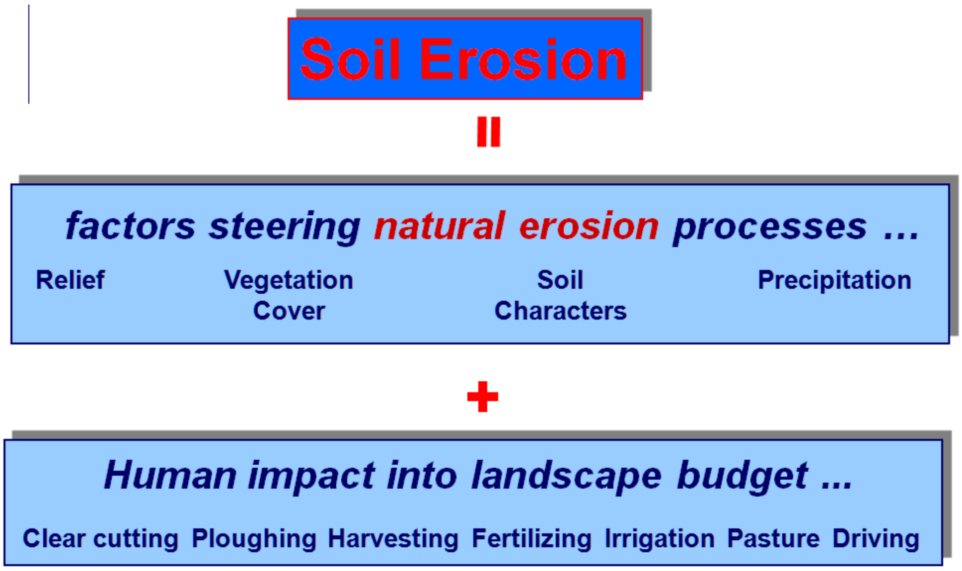


Figure 13: Definition of soil erosion (own illustration by B. Schütt 2004, Förch & Schütt 2004 a)

- ➔ <u>*Repetition: Typical soil erosion damages / features*</u>

typical soil erosion features

sheet erosion

- **Sheet erosion**: Soil removed in an uniform layer, lowest movement of water

rill erosion

- **Rill erosion** is the removal of soil by concentrated water running through little streamlets, or head-cuts. Detachment in a rill occurs if the sediment in the flow is below the amount the load can transport and if the flow exceeds the soil's resistance to detachment. As detachment continues or flow increases, rills will become wider and deeper. [17]

[17] Additional information: Queensland Government 2015: https://www.qld.gov.au/environment/land/soil/erosion/types/

rill erosion

Figure 14: Rill erosion in El Palomar, Piojo, Colombia (own picture by H. Schubert 2016)

gully erosion

Gully erosion occurs when running water erodes soil to form channels deeper than 30 cm. Gullies start when fast flowing runoff hits a 'nick' point such as a rabbit burrow, root hole, stock/vehicle track, or bare soil. The energy of the water scours away the soil, undermining the vegetation. Once the vegetation and topsoil are removed, gullies spread rapidly up and down drainage lines until there is insufficient runoff to continue the erosion.[18]

Figure 15: Gully erosion in Luriza, Usiacuri, Colombia (own picture by H. Schubert 2016)

[18] Additional information: Queensland Government 2015: https://www.qld.gov.au/environment/land/soil/erosion/types/

- **Tunnel erosion** is the removal of subsoil. When water penetrates through a soil crack or a hole where a root has decayed, the soil disperses and is carried away with the flow to leave a small tunnel. Initially, the surface soil remains relatively intact but, with every flow, the tunnel becomes larger and the soil may eventually collapse and form a gully.

tunnel erosion

- The major cause of **stream bank erosion** is the destruction of vegetation on river banks (generally by clearing, overgrazing, cultivation, vehicle traffic up and down banks or fire) and the removal of sand and gravel from the stream bed.

stream bank erosion

- **Mass movement** occurs on cleared slopes. Gravity moves earth, rock and soil material downslope both slowly (millimeters per year) and suddenly (e.g. rock falls). Different forms of mass movement include: soil creep, earthflow, slumping, landslips, landslides and rock avalanches.

mass movement

landslide

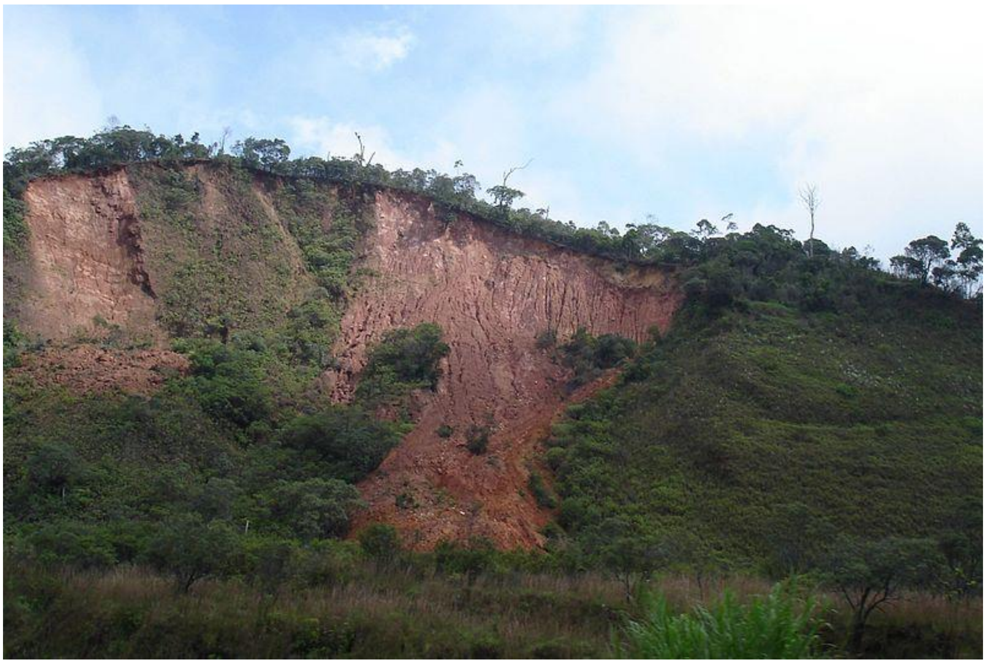
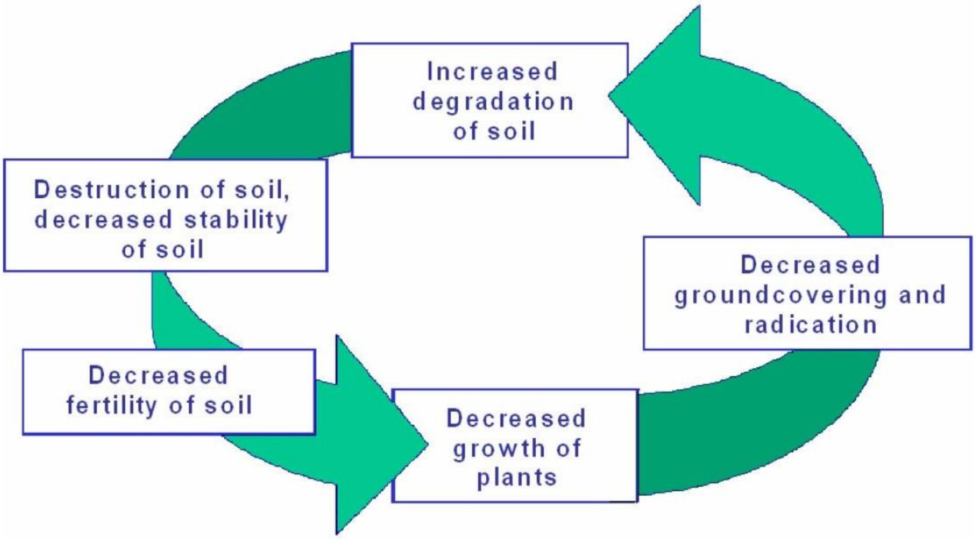


Figure 16: Landslide at Rio de Janeiro-Petrópolis road, Brazil (by Eurico Zimbres / CC--BY-SA-2.5, source: https://commons.wikimedia.org/wiki/File:Landslide.jpg)

- **Wind erosion** occur when strong winds blow over light-textured soils that have been heavily grazed during drought periods. Sandy soils are vulnerable to wind erosion because they cannot store very much moisture and have low fertility. [19]

wind erosion

[19] Additional information: Queensland Government 2015: https://www.qld.gov.au/environment/land/soil/erosion/types/



cycle of soil degradation

Figure 17: Vicious cycle of soil degradation (own illustration by B. Schütt 2004, Förch & Schütt 2004 a)

How can we protect soil?

soil protection

Soil protection goes very much with these aspects (Förch & Schütt 2004 a, Morgan 2005):

- decrease of erodibility (resilience of the soil against erosion forces)
- decrease of erosivity (force of water to detach the soil)
- decrease of degree of slope
- increase of vegetation cover
- increase of soil stability (aggregate stability)
- increase of organic carbon content

increase of organic carbon content

The increase of organic carbon content in the soil is an easy but very effective task. Organic carbon content can be increased through the above mentioned actions (Morgan 2005):

- applying compost
- leaving crop residues on the field
- mulching
- reducing soil tillage
- using green manures or cover crops

Soil Erosion Assessment

soil erosion mapping

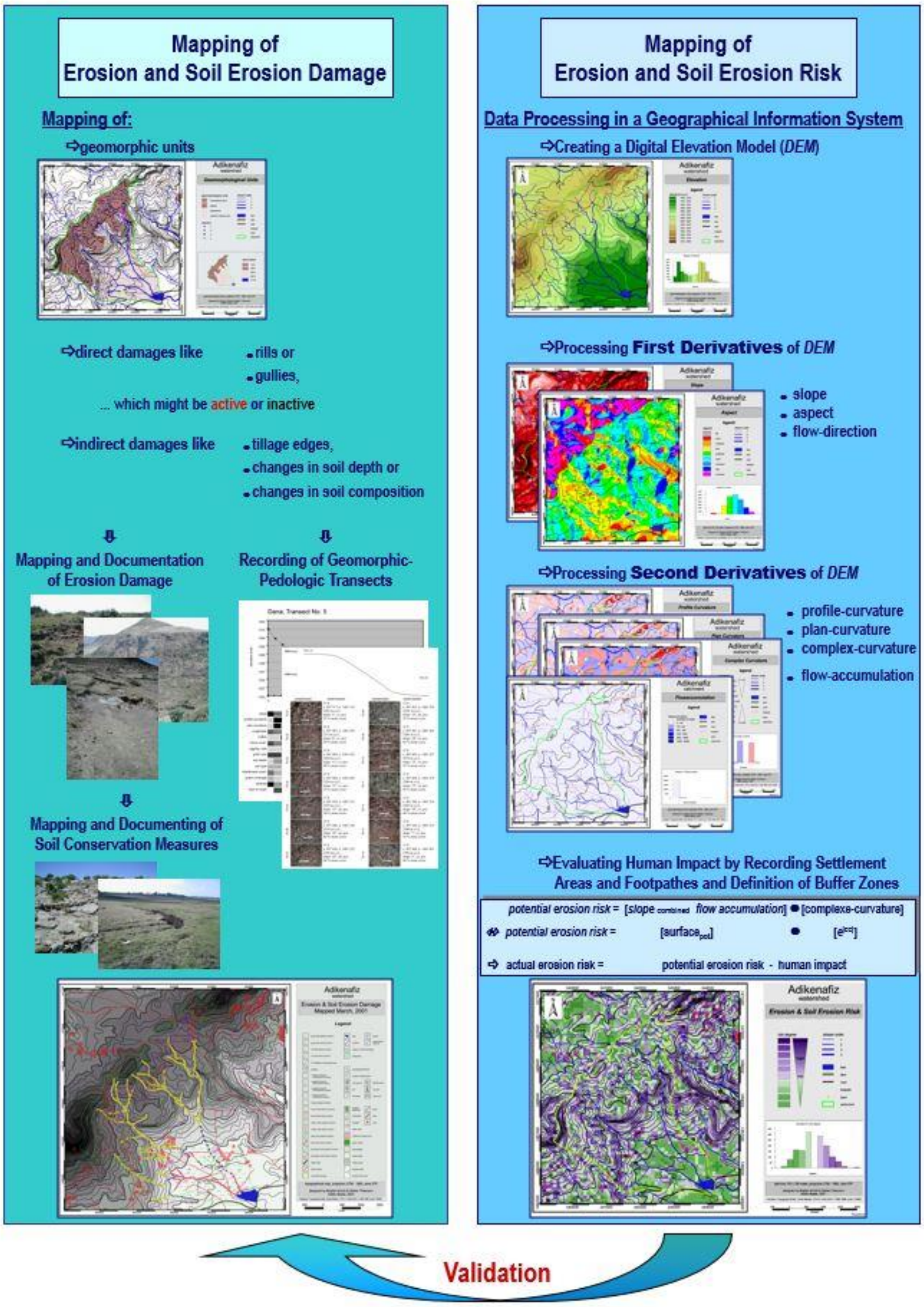


Figure 18: Mapping of Soil Erosion Damage and Soil Erosion Risk (own illustration by B. Schütt & S. Thiemann 2014)

Traditional knowledge

traditional knowledge

Traditional knowledge is knowledge that local societies have acquired and preserved through generations; it is based on their experience in managing nature to secure their livelihood (Lal 1995).

This definition points out some central features and characteristics. For examples traditional knowledge (Warren 1991):

- is strongly bound to its respective context and is deeply rooted in the society;
- provides the base for agriculture, food processing, activities to conserve the environment, health, etc.;
- is passed down orally over generations;
- is subject to an inherent dynamic resulting from the adaption of knowledge to the steadily changing social, ecological and economic conditions of the society

Because of these characteristics, traditional knowledge is contrasted with scientific knowledge, while parallels and overlapping may occur (Warren 1991). The differences between traditional knowledge and scientific knowledge consist mainly in the fact that the latter asserts a claim to globalisation. Furthermore, the methods of gaining new knowledge and the way and sources for application of the respective knowledge differ (Antweiler 1995).

incan terraces

Figure 19: The gorgeous Incan circular terraced bowl of Moray (by McKay Savage / CC-BY-2.0, source: https://commons.wikimedia.org/wiki/File:Peru_-_Sacred_Valley_%26_Incan_Ruins_277_-_Moray_(8118164055).jpg)

soil conservation measures

Water harvesting methodologies also contribute to soil protection measures, since water harvesting methodologies usually reduce surface water runoff in combination with increase of infiltration processes.

soil bunds

An example are **soil bunds,** which have two effects: Reduction of surface runoff and increase of soil moisture (Lancaster 2008).

check dams

Another are **Check dams** are small rock dams that are installed across swales or ditches. They reduce the velocity of lowing water, allowing sediment to settle and reduce erosion (Lancaster 2008).

Advantages:

- Can function as a permanent flow control
- Can be used as a cost-efficient temporary solution
- Reduce steep grades to a series of more gentle grades
- Rocks can be used as a chanel lining when check dam is no longer needed
- Synthetic permeable barriers are generally reusable

Limitations:

- Only suitable for small drainage areas and low-flow velocity
- Susceptible to failure if water undermines structure
- Only remove a small amount of sediment due to limited detention time[20]

How can we increase soil fertility?

soil fertility

Soil quality is an assessment of how well soil performs all of its functions now and how those functions are being preserved for future use. Soil quality or health cannot be determined by measuring only crop yield, water quality, or any other single outcome (Morgan 2005).

[20] Source: City of Calgary 2017: http://www.calgary.ca/UEP/Water/Pages/Watersheds-and-rivers/Erosion-and-sediment-control/Sediment-control-measures/Check-Dams.aspx

increase of soil fertility

Soil quality cannot be measured directly, so we evaluate indicators. Indicators are measurable properties of soil or plants that provide clues about how well the soil can function. Indicators can be physical, chemical, and biological properties, processes, or characteristics of soils. They can also be morphological or visual features of plants (Morgan 2005). Useful indicators:

- are easy to measure,
- measure changes in soil functions,
- encompass chemical, biological, and physical properties,
- are accessible to many users and applicable to field conditions,
- are sensitive to variations in climate and management.

Indicators can be assessed by qualitative or quantitative techniques. After measurements are collected, they can be evaluated by looking for patterns and comparing results to measurements taken at a different time or field.

soil quality indicators

Table 3: Examples of soil quality indicators (NRCS 2017) [21]

Indicator	Relationship to soil health
Soil organic matter (SOM)	Soil fertility, structure, stability, nutrient retention; soil erosion
Physical: soil structure, depth of soil, infiltration and bulk density; water holding capacity	Retention and transport of water and nutrients; habitat for microbes; estimate of crop productivity potential; compaction, plow pan, water movement; porosity; workability
Chemical: pH; electrical conductivity; extractable N-P-K	Biological and chemical activity thresholds; plant and microbial activity thresholds; plant available nutrients and potential for N and P loss
Biological: microbial biomass C and N; potentially mineralizable N; soil respiration.	Microbial catalytic potential and repository for C and N; soil productivity and N supplying potential; microbial activity measure

[21] Source: National Resource Conservation Service 2017: https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/assessment/

influence of soil organic matter on soil, water and air

The management of soil organic matter is not only increasing soil fertility and health. It is also contributing to air quality, water quality and productivity in general. [22]

Organic matter in the soil leads to:

- increasing water holding capacity
- increase soil structure and aggregate stability
- increase infiltration capacity (less surface runoff)
- increase of soil organisms and nutrients

The degree of organic matter is increasing through:

- reduced tillage
- high biomass rotation
- proper manure management
- prescribed grazing

Both actions are leading to:

- fewer pollutants
- less dust from soil
- less sediment transport
- higher resistance to droughts, floods and diseases

Table 4: Factors influencing soil fertility (own compilation by S.Thiemann 2014)

factors influencing soil fertility

Factor influencing soil fertility	Anthropogenic actions supporting or hindering soil fertility
infiltration of water	tillage can cause a plow pan that is blocking water to infiltrate
soil structure	plowing is destroying the soil structure and soil is more opposed to soil erosion and degradation
content of organic matter	grazing of residuals (after harvest) is reducing organic matter
ground water and water retention	pumping ground water can decrease the water table and reduce water availability especially during dry season
release of nutrients and minerals	use of chemical fertiliser can increase the con tent of nutrients, use of biological fertiliser are best, see next page
soil depth	can decrease due to intensive agriculture and consequently soil erosion

[22] Source: National Resource Conservation Service 2017: https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/mgnt/

resource biomass

2.5. Resource Biomass

Definition

definition biomass

Biomass can be defined as the total weight of the living components (producers, consumers, and decomposers) in an ecosystem at any moment, usually expressed as dry weight per unit area. Biomass is a quantity per unit area; productivity is a rate of biomass gain per unit area (Allaby 2006)

The ultimate source of energy of this renewable biomass is inexhaustible solar energy, which is captured by plants through photosynthesis. It includes both terrestrial as well as aquatic matter, such as wood, herbaceous plants, algae, aquatic plants; residues such as straw, husks, corncobs, cow dung, sawdust, wood shavings, wood based panels, pulp for paper, paper board, and other wastes like disposable garbage, sewage solids, industrial refuse and so on. Biomass can provide approximately 25% of our current energy demand, if properly utilized (Pant & Mohanty 2014)

Plant material[23]

plant material

The carbon used to construct biomass is absorbed from the atmosphere as carbon dioxide (CO_2) by plant life, using energy from the sun. Plants may subsequently be eaten by animals and thus converted into animal biomass. Generally, plants perform the primary absorption. If plants are not eaten directly, they are broken down by micro-organisms or burned.

If plant material broken down it emits mainly carbon dioxide (CO_2) and methane (CH_4), depending upon the conditions and processes involved. If it burned the carbon is returned to the atmosphere as CO_2.

These processes are a part of what is known as the carbon cycle.

[23] Source: Forest Research 2017: http://www.forestry.gov.uk/fr/beeh-9uhlqv

carbon cycle

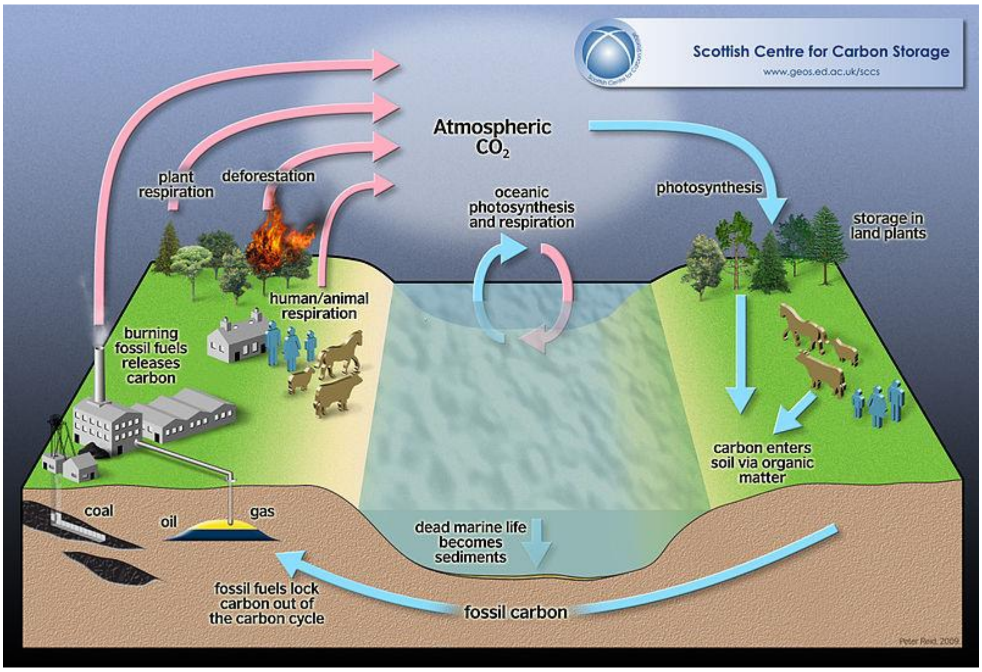


Figure 20: The carbon cycle (by Harry C / CC-BY-SA-3.0, source: https://commons.wikimedia.org/wiki/File:Carbon-cycle-full.jpg)

types of biomass

There are five basic categories of material[24]:

- **virgin wood**, from forestry or agroforestry activities
- **energy crops**: high yield crops grown specifically for energy applications like oil palms, maize or rapeseed
- **agricultural residues**: residues from agriculture harvesting or processing
- **food waste**: from food and drink manufacture, preparation and processing, and post-consumer waste
- **industrial waste and co-products** from manufacturing and industrial processes.

[24] Source: Forest Research 2017: http://www.forestry.gov.uk/fr/beeh-9uhlqv

How can biomass serve our needs?

options for biomass use

The most common use of biomass in the context of IWM is the direct combustion and the generation of:

1) heat for cocking and heating a house
2) light
3) electricity

Next to these direct outcomes, the biomass processing can lead to side products, such as:

1) fertiliser (solid and liquid)
2) compost
3) clean water
4) less environmental pollution

Biomass production and consumption has a wide range of positive effects to livelihood and income generation, but tend to be over utilised and such leading in the long term to the opposite!

How can we produce biomass?

sustainable versus unsustainable biomass use

The production of biomass is just the process of plants growing and collection of human and animal excrement. However, the growth of biomass is depending on the environmental conditions as well as on the attitude of human towards sustainable use of biomass.

A typical non-sustainable use is clearing forests for biomass use, but it is not considering the negative effects on the environment, such as e.g.:

- natural reforestation might take decades
- the ground water table will deplete
- surface run-off and soil erosion will increase
- the micro-climate will change towards warmer and dryer

On the other side the sustainable use of biomass is also leading to a beautiful environment that is keeping its natural functions and serves our needs. [25]

[25] Additional information: European Commission 2018: https://ec.europa.eu/energy/en/topics/renewable-energy/biomass;
FU Berlin: http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/watershed-resources/ressource_biomass/serve-our-needs/

The sustainable use of biomass includes the following considerations:

sustainable biomass use

- use biomass only as much as it is not effecting the natural functionality of a system (e.g. a forest)
- return energy back to the system (e.g. through bio-fertiliser)
- process biomass for best utilisation (e.g. through fermentation)

One of the most effective biomass processers are with regard to IWM and in particular IWM in rural areas biogas plants. Their advantages are:

advantages of biogas production

- collection of human and animal excrement, kitchen bio-waste, which is also leading to less environmental pollution
- the biogas production is leading to:
  1) energy for cooking (gas) and lighting (gas)
  2) solid and liquid fertiliser
  3) treated water
- biogas production is leading to higher yields through the utilisation of the produced fertiliser
- biogas production can lead to income generation

sketch of a biogas plant

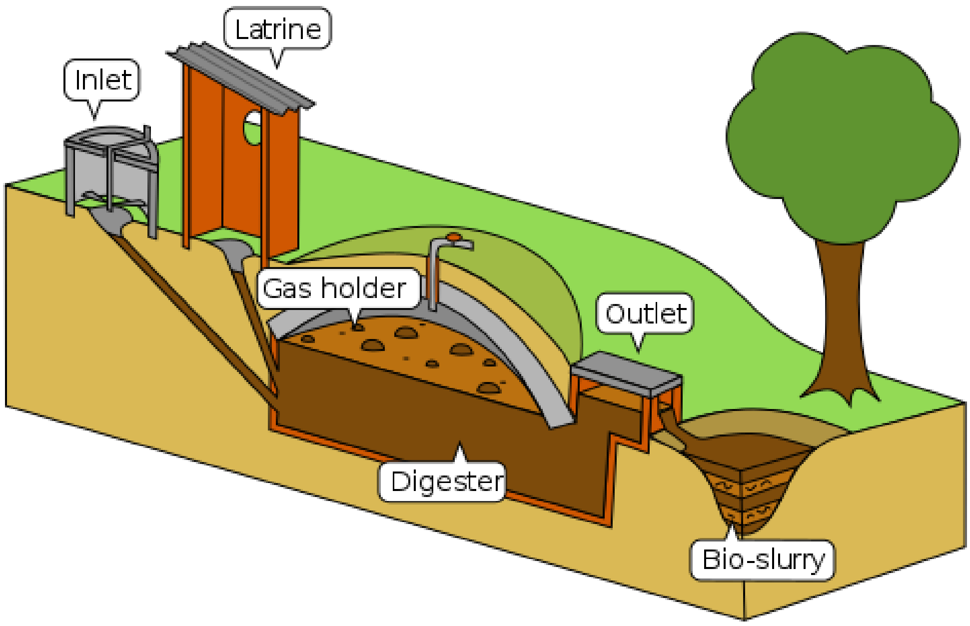


Figure 21: Sketch of a household biogas plant (by Tkarcher / CC-BY-SA-4.0, source: https://commons.wikimedia.org/wiki/File:Biogas_plant.svg)

The schematic sketch of a simple biogas plant shows the simplicity of the entire system. The construction of biogas plants require special knowledge, but can be done with local materials. [26]

[26] Additional information: Energypedia 2017: https://energypedia.info/wiki/Planning_Guide_for_Biogas_Plants

There exist a wide range of descriptions on establishment and operating biogas plants all over the world. However, the acceptance of working with human and animal excrement is the crucial factor for the success. [27]

acceptance of biogas plants

How can we save biomass?

Biomass is not infinite. Therefore saving biomass should go parallel to the production and consumption. Saving biomass is possible by utilisation of energy efficient techniques such as energy saving stoves.

saving biomass

A typical process for increasing the energy density of biomass is the production of charcoal. The traditional charcoal production is a simple process, which consume a lot of wood. Today, energy saving technologies are introduced, such as the charcoal production in drums. Another sustainable and more effective utilisation of biomass is the use of wood pellets, which are usually used for house and water heating through central heating system. [28]

charcoal production and wood pellet heating

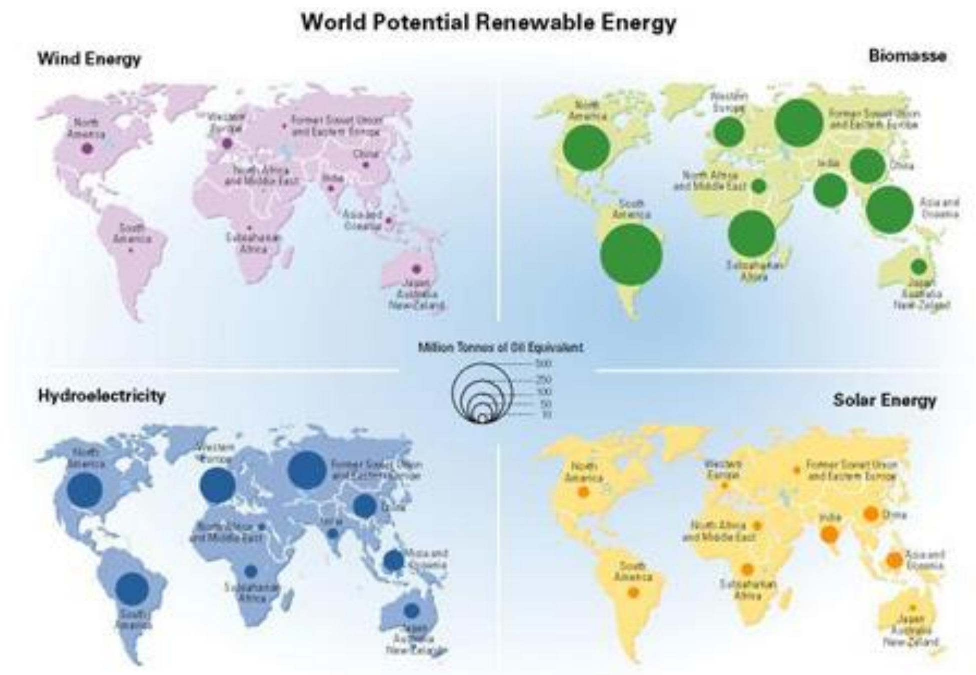


Figure 22: Potential of renewable energies (by GFDL / CC-BY-SA-3.0, source: https://commons.wikimedia.org/wiki/File:Renewable_energy_potential.jpg)

potential of renewable energies

[27] Additional information: Energypedia 2017: https://energypedia.info/wiki/Planning_Guide_for_Biogas_Plants
[28] Additional information: European Commission 2018: https://ec.europa.eu/energy/en/topics/renewable-energy/biomass

2.6. Resource Energy

resource energy

The resource energy must be distinguished between renewable energies and non-renewable. In the context of IWM the focus of attention is towards the renewable energies:

- solar
- biomass
- wind
- water
- geothermal

The focus is on decentralised and simple operating devices and systems.

The global energy consumption, as shown in the following figure, shows that the percentage of renewable energies was in 2015 at 10.1% only, 85.5% were different types of fossil fuels.

global energy consumption in 2015

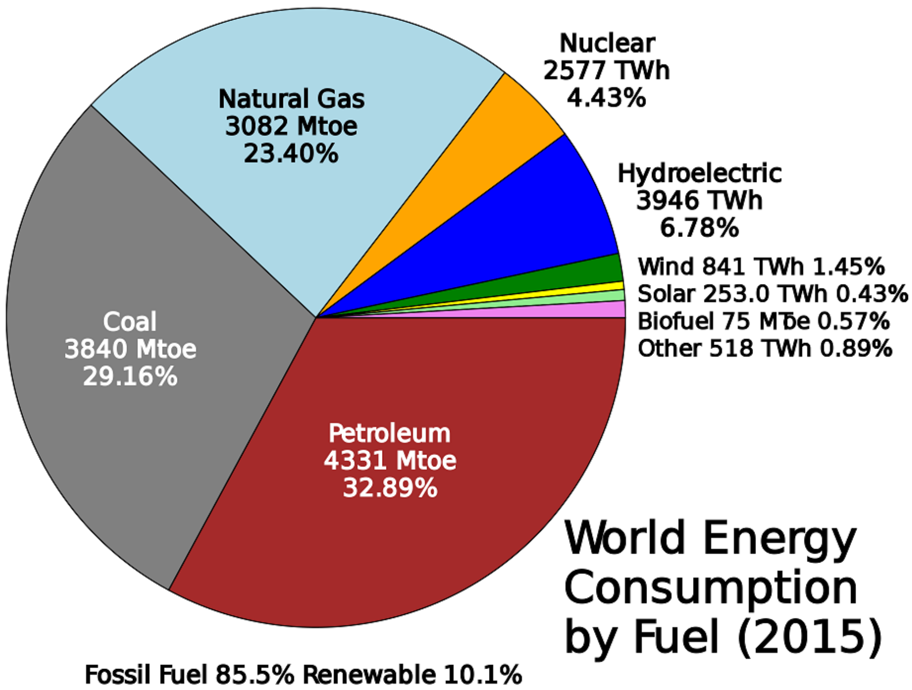


Figure 23: World primary energy consumption by fuel, based on data from BP Statistical Review of World Energy 2016. Combustibles are reported in Mtoe, nuclear and renewables that are used to produce electricity are reported in TWh. The percentages, though, are based on Mtoe conversions. (by Delphi234 / CC-Zero, source: https://commons.wikimedia.org/wiki/File:World_energy_consumption_by_fuel.svg)

primary energy and consumption in Peru

The structure for the production of primary energy and the consumption of energy in Peru in the year 2015 correlate with the global trends. [29]

global energy demand

The global energy demand will continue increasing, but the energy sources will change: The decrease of non-renewable energies will be substituted new energy technologies and renewable energies. [30]

Energy from sun

solar energy

Solar energy offers a clean, climate-friendly, very abundant and inexhaustible energy resource, relatively well-spread over the globe. Its availability is greater in warm and sunny countries. In these dynamic countries lives the majority of the world's population. The costs of solar energy have been falling rapidly and are entering new areas of competitiveness. Solar thermal electricity (STE) and solar photovoltaic electricity (PV) are competitive against oil-fuelled electricity generation in sunny countries, usually to cover demand peaks, and in many islands.

Roof-top PV in sunny countries can compete with high retail electricity prices. In most markets, however, solar electricity is not yet able to compete without specific incentives. [31]

Energy from water

water energy

IWM is focussing on the availability and the access to water for different purposes: industrial, domestic and agricultural. However, use water on a sustainable way as an energy source can be also a focus. The utilisation of water for energy production is not or only little consuming water and therefore sustainable, as long as IWM is implemented.

[29] Source: Ministerio de Energía y Minas (MEM) 2016: http://www.minem.gob.pe/minem/archivos/BNE_2015_COLOR.pdf
[30] Source: European Commission 2018: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union
[31] Source and additional information: International Energy Agency (IEA) 2011: https://www.iea.org/publications/freepublications/publication/Solar_Energy_Perspectives2011.pdf

scale of hydropower plants

Hydropower plants exist on small and on large scale. Large-scale constructions such as huge dams are not addressed in the context of IWM, but small-scale constructions and schemes, which can be handled by the local population.

water wheel for electricity

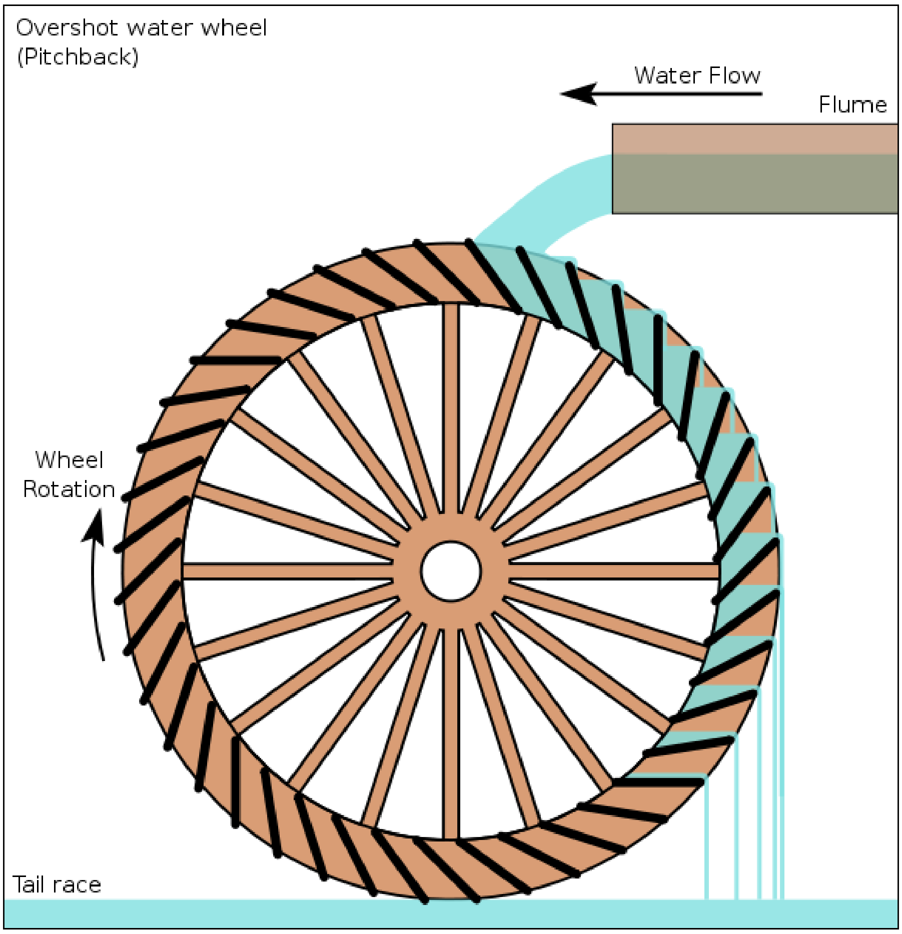


Figure 24: Schematic of a pitchback or backshot waterwheel (by D.M. Short / CC-BY-SA-3.0., source: https://commons.wikimedia.org/wiki/File:Pitchback_water_wheel_schematic.svg)

micro hydropower plants

The water wheel is the most known and traditional way of producing energy from water. It is easy to operate and maintain and can be – as a decentralized system – installed everywhere, where water and a certain slope gradient is available.

Small scales and decentralized schemes have high potential of energy production. However, these small scale or micro hydropower stations do not produce energy for large communities, but on village or at a household scale. [32]

[32] Additional information: Practical Action 2018: https://practicalaction.org/micro-hydro-power

Decentral energy systems

decentral energy systems

Conventional power stations, such as coal-fired, gas and nuclear powered plants, as well as hydroelectric dams and large-scale solar power stations, are centralized and often require electricity to be transmitted over long distances. By contrast, decentral energy systems are modular and more flexible, that are located close to the load they serve.

These systems typically use renewable energy sources, including small hydro, biomass, biogas, solar power, wind power, and geothermal power. The importance of the distribution system is increasing in the last years. They can be managed and coordinated within a smart grid. So, this systems haver lower environmental impacts and improve security of supply. [33]

renewable energy system at a national level

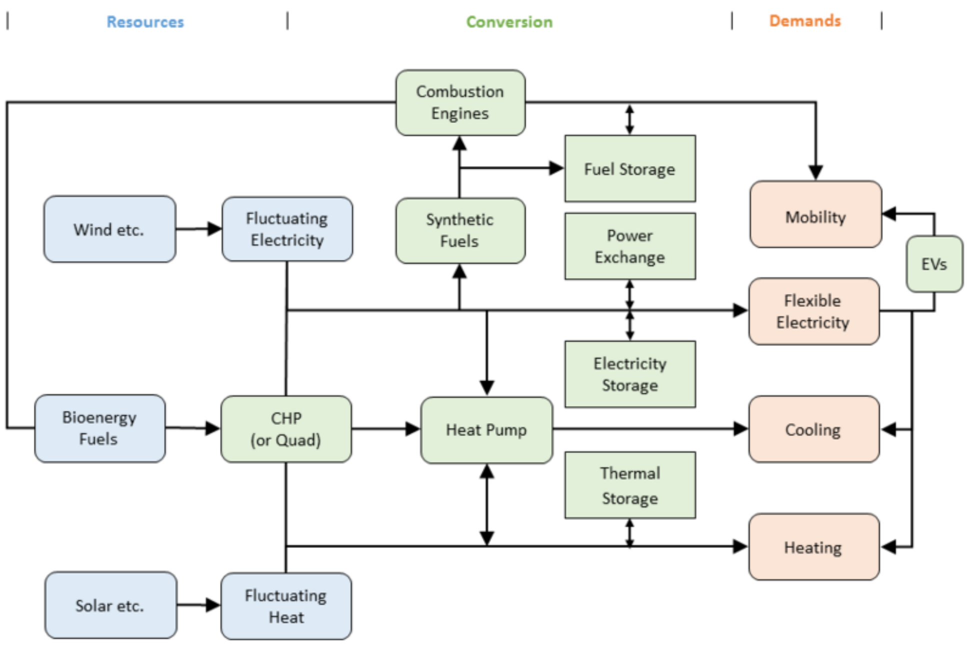


Figure 25: Represents the key components of decentral energy system at the national level, so that it can be based on 100% renewable energy (by David Conolly / CC-BY-SA-4.0., source: https://commons.wikimedia.org/wiki/File:Smart_Energy_System.png)

[33] Source and additional information: University of Cambridge Programme for Industry 2008: https://www.cisl.cam.ac.uk/publications/publication-pdfs/decentralised-energy.pdf;
European Parlament 2010: http://www.europarl.europa.eu/document/activities/cont/201106/20110629ATT22897/20110629ATT22897EN.pdf;

mixed energy system

A typical situation in southern countries is a mixed energy systems that combine:

- non-renewable and renewable energy production systems
- storage systems
- centralised and decentralised control systems
- all kind of energy consumers

Mixed energy systems are typical systems developed step by step involving latest technologies, but also keeping old technologies running. It is a permanent growing system.

Decentralised energy systems is a chance also for remote areas with no access to centralised systems. The current focus on decentralised energy systems is a result of technologically better and more reliable renewable energy production systems.[34]

Local energy systems benefit from these advantages:

- small investment costs
- individual installation possible
- no energy transportation
- technical efficient but little maintenance necessary
- to be combined in small local grids
- sustainable when using renewable energies
- independent from national and regional politics and companies

decentralised energy system

An example for a decentralised energy system is biogas and ecological sanitation (e.g. the Ecosan System. [35]). Other examples are:

- production of electricity from wind and solar
- heating water from solar
- geothermal heat

[34] Source and additional information: University of Cambridge Programme for Industry 2008: https://www.cisl.cam.ac.uk/publications/publication-pdfs/decentralised-energy.pdf;
European Parlament 2010:
http://www.europarl.europa.eu/document/activities/cont/201106/20110629ATT22897/20110629ATT22897EN.pdf;

[35] Additional information: SSWM 2018: https://www.sswm.info/category/planning-process-tools/programming-and-planning-frameworks/frameworks-and-approaches/sani-4

2.7. Resource Human

human resource management

The approach of IWM is also focussing on the human resource. Sustainable management option and devices are only a real sustainable option as long as human are trained and awareness and sensitivity for sustainability are imparted in each generation. Human resources are the most crucial resource to be addressed. It all goes or falls with education at all levels.

IWM at different educational levels

IWM is in most parts of the world a newly developed and introduced tool. The single measures of IWM are known for decades and centuries, but the collation of all measures and options to one overall seen umbrella function requires sound understanding of the single measures, its interactions, implications and side effects. Thus, the working relationships among the three stakeholder groups assist in a cooperating team very strong in learning and understanding of IWM[36]:

- universities as researchers, lecturers and solution finders
- regulatory authorities
- community based organisations / locals

important stakeholder groups for IWM

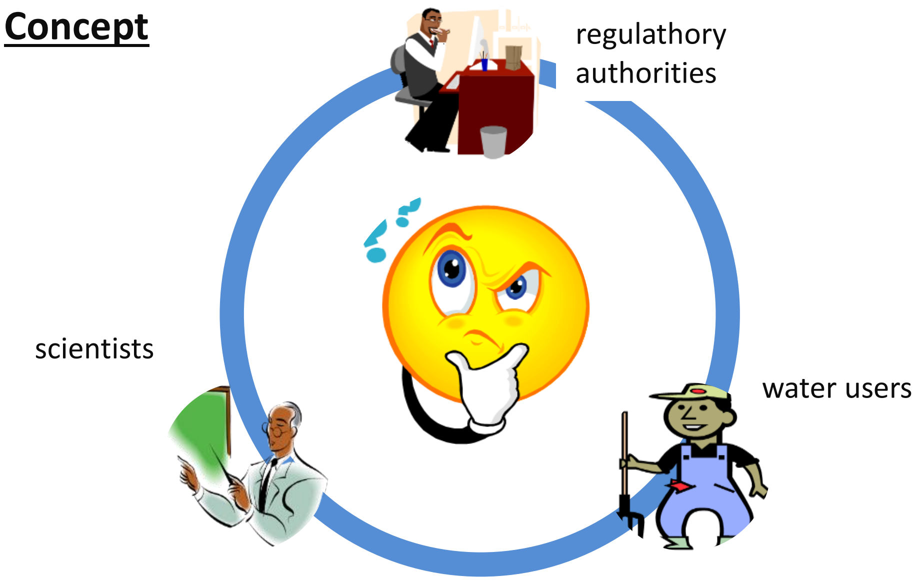


Figure 26: Three major stakeholder groups for IWM implementation (own illustration by S.Thiemann 2014; http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/watershed-resources/ressource_human/educational/)

[36] Additional information: FU Berlin: http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/watershed-resources/ressource_human/

participatory IWM

The overall concept to make IWM understandable at different educational levels requires high participatory approaches and acceptance of the already existing knowledge for IWM at each stakeholder group.

Participatory IWM trainings also showed that the acceptance of well educated IWM stakeholders against the knowledge from e.g. local population is limited although it is there.

knowledge exchange and translation

The concept of bringing the three stakeholder groups together for best knowledge exchange and knowledge translation (e.g. from high level to lower level) is very successful as long as undertaken in participatory and joint actions. The joint action is automatically leading to common understanding of IWM, since:

a) lecturers from higher education can explain processes in details
b) staff from regulating authorities know in details about local and regional governmental structures and settings; they also have high knowledge about existence of any kind of data relevant for IWM
c) locals can in details explain their needs and challenges, but also opportunities

However, teaching and learning approaches must be adapted to the level of understanding of the different stakeholder groups.

Benefit of IWM for human wellbeing

benefit of IWM for human wellbeing

Capacity building and training towards best and common understanding of the concept of IWM contribute vice versa to human wellbeing and increase of livelihood.

The participants should understand the holistic concept of IWM, which serve and protect both nature and human needs. The moment people understand that IWM generates win-win effects for the environment and biodiversity as well as for human and income generation in a long term and sustainable way; it is much easier to motivate them in implementation of IWM measures. [37]

[37] Additional information: FU Berlin: http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/watershed-resources/ressource_human/

Resilience and vulnerability

resilience and vulnerability

Local communities often perceive themselves as victims of a bigger and non-influence able system. Instead of focussing on their resilience, power, and opportunities the focus is often on their own vulnerability.

This perception towards the negative is psychological hindering development and capacity strengthening. A long series of research towards resilience of local communities highlight the fact that a strong resilience is available, but not seen (Förch 2012).

IWM and the empowerment of local communities and water users are leading towards the perception of higher resilience instead of vulnerability. Thus, the following sustainability strategy should be used for fostering resilience perceptions and actions. [38]

connecting sustainability to competitive strategy

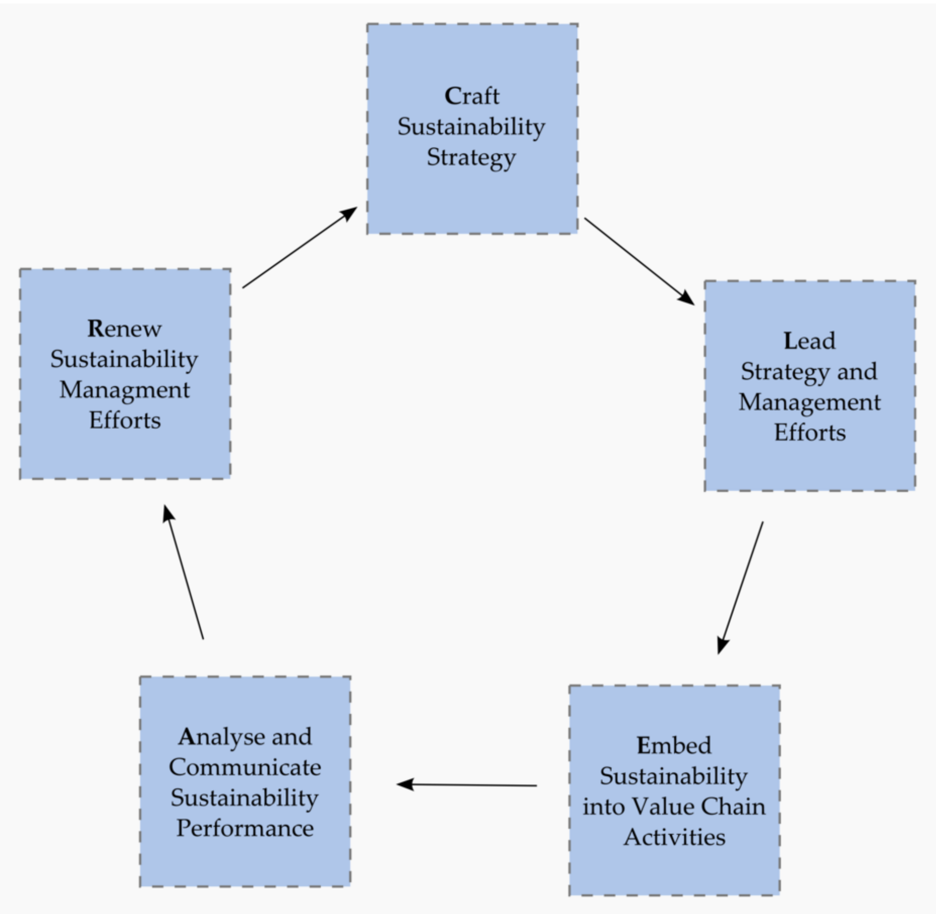


Figure 27: Sustainability strategy and management (own illustration by F. Becker 2014, after E. Lowitt, 2014; http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/watershed-resources/ressource_human/resilience/)

[38] Additional information: E. Lowitt 2018: http://www.ericlowitt.com/sustainability/a-clear-approach-to-connect-sustainability-to-competitive-strategy/

Economic value of natural resources

economic value of natural resources

Natural resource economics deals with the supply, demand, and allocation of the Earth's natural resources. One main objective of natural resource economics is to better understand the role of natural resources in the economy in order to develop more sustainable methods of managing those resources to ensure their availability to future generations. Resource economists study interactions between economic and natural systems, with the goal of developing a sustainable and efficient economy (Jantzen 2006).

pillars of sustainability

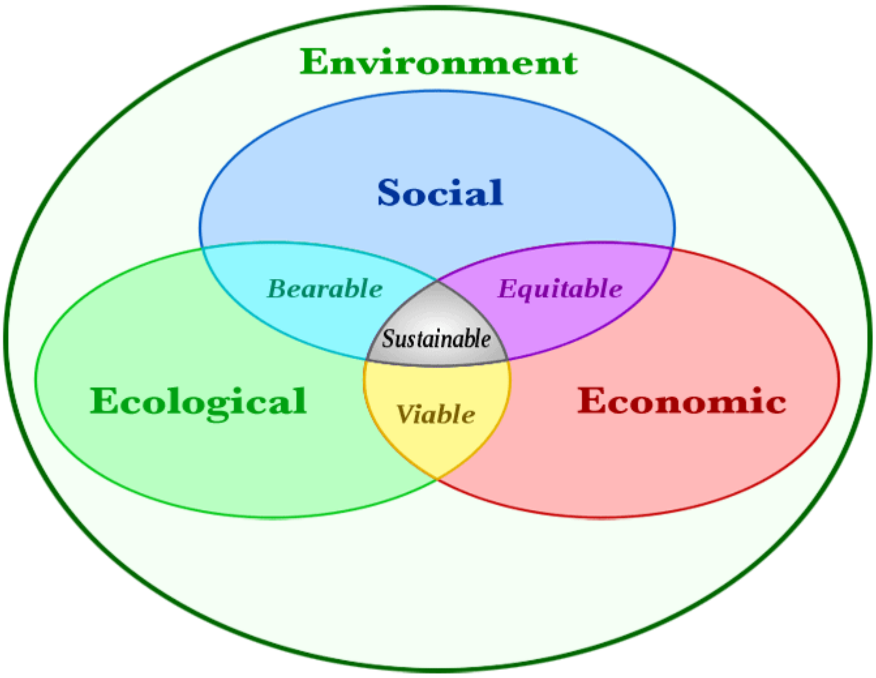


Figure 28: Three pillars of sustainability bounded by the environment (by Andrew Sunray based on Johann Dréo/ CC-BY-SA-4.0, source: https://commons.wikimedia.org/wiki/File:Sustainability-diagram-v4.gif)

Natural resource economics is a transdisciplinary field of academic research within economics that aims to address the connections and interdependence between human economies and natural ecosystems. Its focus is how to operate an economy within the ecological constraints of earth's natural resources (Jantzen 2006).

Resource economics brings together and connects different disciplines within the natural and social sciences connected to broad areas of earth science, human economics, and natural ecosystems.[39]

[39] Source and additional information: SOAS University of London 2018: https://www.soas.ac.uk/courseunits/P122(P505).html

Payment for Environmental Service

payment for environmental service

Payments for ecosystem services (PES), also known as payments for environmental services (or benefits), are incentives offered to farmers or landowners in exchange for managing their land to provide some sort of ecological service. They have been defined as "a transparent system for the additional provision of environmental services through conditional payments to voluntary providers. These programmes promote the conservation of natural resources.” (Tacconi 2012).

PES have same decade’s history in Europe and in particular in the mountainous areas, where farmers are paid from government to keep the environment as a cultural heritage. Farmers are often substituted to continue farming in non-rentable areas in order to maintain the area for tourists and as recreation areas. The side effect is the stable and non-degrading environment for sustainability.

introduction of PES

Because of different factors, payment for environmental service very little introduced and implemented (Pearce & Turner 1990; Tacconi 2012):

Limiting factors for introduction:

- unsecure money flows
- lack of knowledge of potential payers
- lack of commitment of receivers towards proper utilisation of the money
- lack of knowledge on proper environmental management
- failure in developing and installing instruments for operation and monitoring PES

Fostering factors:

- additional income for land users
- less efforts needed to rehabilitate degraded land
- conserving land is cheaper than rehabilitating already destroyed land
- higher “functionality” of the environment to serve people’s need
- knowledge from operating PES can easily be transferred

2.8. Management and measures

definition planning

Definition of planning

"Planning is usually interpreted as a process to develop a strategy to achieve desired (...) objectives, to solve problems, and to facilitate action" (Mitchell 2002).

The role of the planner is thus to identify a desirable future and to prepare a course of action to achieve this goal (Mitchell 2002). He records this in a plan. In the course of this module you will learn how planning can be carried out.

Natural resource planning thus is - with regard to resources - "the identification of possible desirable future end states, and development of courses of action to reach such end states" (Mitchell 2002).

definition management

Definition of management

Management refers to the controlling and planning of details (Bauer 1998). By judicious use of available means the actual decisions are made and actions are carried out to achieve the objectives (Storey 1960). Management thus requires both plans and objectives (Storey 1960).

The manager has therefore to control, handle and direct the decision-making and the course of action. He has the responsibility and the authority to allocate the capital, technology and human resources to achieve the desired end (Ratter 2002).

Natural resource management thus comprises actual decisions and actions concerning policy and practice regarding how resources are appraised, protected, allocated, developed, utilised, processed, rehabilitated, remediated and restored, monitored and evaluated (Ewert et al. 2004).

measures

Measures are the concrete actions aiming at sustainable resource management.

2.9. Landscape Sensitivity

Definition

definition landscape sensitivity

Landscape sensitivity is regarded as the potential for and the probable magnitude of change within a physical system in response to external effects and the ability of this system to resist the change (Thomas & Allison 1993).

The external effects can be varied. They include natural as well as human induced phenomena (Thomas & Allison 1993). An example for the former may be a change in a climatologic parameter, e.g., an increasing temperature and a changed discharge level. Any hydrological system will adapt to this new level. Human induced phenomena can be summarised by the term human impact; i.e. the probable effects of human activity (whereas they use natural resources) on the landscape and the degree to which the system may be altered. Disturbances of the soil or water balance by agricultural activities are an example of the latter.

Climate and human activities are - to different extents - important driving forces for changes and development of landscapes and landforms worldwide. Thus, the sensitivity issue concerning both these changes is one of the most relevant ones (Thomas & Allison 1993).

Assessment of landscape sensitivity

assessment of landscape sensitivity

The sensitivity of a landscape is evaluated by an environmental analysis: investigations of the environmental conditions on the basis of indicators. These include the recording and analysing of natural as well as man-made characteristics of the landscape. In the specific context, it is crucial to select indicators which reflect the environmental conditions and problems. The selected indicators are to be recorded. These assessments establish the basis for answering the landscape sensitivity and the development of resource management concepts (Beck et al. 2004).

Indicators to evaluate the landscape sensitivity (Beck et al. 2004):

indicators to evaluate landscape sensitivity

- precipitation
- soils
- land use
- soil conservation measures
- soil erosion damages
- rainfall-runoff processes

Related terms to Landscape Sensitivity

related terms to landscape sensitivity

Landscape Sensitivity can vary through space and time (Thomas & Allison 1993). The physical systems considered in this module are watersheds, exemplified by the Gina River catchment. It is located in Eastern Africa, a semi-arid to sub-humid region, which shows generally a high fragility. Hence, growing pressure on land and water resources shows more rapid effects than in temperate zones. Traditional resource management measures are no longer feasible today and traditional knowledge might get lost (Förch & Schütt 2004 a).

How can landscape sensitivity analyses assist in IWM?

The analyses of the landscape sensitivity assist for IWM planning, since the output of the assessment serve as basis for characterisation of the catchment area. These data are needed as input data for scenario modelling or drafting management options.

principles of landscape sensitivity assessment

The Countryside Agency and Scottish Natural Heritage publish a demonstrative example for a guidance of Landscape Sensitivity Assessment in 2002.[40]

They identify four central key principles for the understanding and appropriate use of Landscape Sensitivity Assessment. They are:

a) the emphasis placed on landscape character;
b) the division between the process of characterisation and the making of judgements to inform decisions;
c) the roles for both objectivity and subjectivity in the process;
d) the potential for application at different scales.

[40] Source and additional information: The Countryside Agency & Scottish Natural Heritage 2002: http://www.snh.org.uk/pdfs/publications/LCA/LCA.pdf

2.10. Environmental Impact Assessment

environmental impact assessment

Environmental Impact Assessment (EIA) is emerged internationally after the 1972 Stockholm Conference and is now recognised internationally in the Rio Principles and the 1991 Espoo Convention (UN 1992).

It is a national instrument and shall be undertaken for proposed activities. That are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority (UN 1992).

advantages of EIA

The main advantages and benefits of EIA are:

- improved project design/siting
- more informed decision-making (with improved opportunities for public involvement in decision-making
- more environmentally sensitive decisions
- increased accountability and transparency during the development process
- improved integration of projects into their environmental and social setting
- reduced environmental damage
- more effective projects in terms of meeting their financial and/or socio-economic objectives
- a positive contribution towards achieving sustainability

Despite widespread agreement on these achievements, it is recognized that they do not occur uniformly or consistently in all countries or organizations (Abaza et al. 2004).

How can EIA assist in IWM?

Links between socio-economic and environmental impacts

link between EIA and IWM

A water resource development initiative caused changes in the hydrological regime of the river downstream of the project. The changes in the quality of water and the flow reduced, significantly, an area of reeds that were used by local villagers to make baskets and other articles. Selling these products provided an important source of income. Without the resource of the reeds, the villagers had to find an alternative source of income. They did so by exploiting trees that they processed into charcoal for which a market existed. By exploiting this resource they contributed to an already serious problem of deforestation and added to the attendant problems of soil depletion and erosion that accompany deforestation. This chain of events could have been foreseen if the socio-economic importance of downstream natural resources had been investigated and likely impacts predicted (Abaza et al. 2004).

water pollution and illegal abstraction

It would have been possible either to protect the reeds, through controlled discharges, or to provide an alternative economic resource that could have been exploited without adding to existing environmental degradation (Abaza et al. 2004).

Often small rivers in the rural headwater areas are under heavily utilisation, for example by (Abaza et al. 2004):

- illegal water abstraction (here through pipes) takes place wherever the local population need water
- the water level is already depleted, but people continue using the water as long as possible
- people use the water for drinking, washing cloth, watering animals, personal hygiene ignoring all kind of water pollution
- pit latrines are located quite often in proximity to the rivers
- people are not aware of the implication of their activities or simple ignore them

EIA can be a tool for defining management options for individual IWM implementation measures.

2.11. Mitigation of Natural Resource Scarcity

mitigation of natural resource scarcity

"World population growth and increased consumption stemming from economic levelling are leading to scarcity of a number of natural resources on a global scale. Scarcity of critical natural resources such as oil, water, food, and precious metals has the potential to greatly impact commercial activity as the twenty-first century progresses. The challenge of continuing to provide needed goods and services in the face of these constraints falls to supply chain managers, who are ultimately responsible for delivering utility to customers. Unfortunately, there has been almost no research focused on supply chain strategies aimed at mitigating natural resource scarcity's (NRS) potential effects." (Bell et al. 2012)

dimensions of resource scarcity

The dimensions of resource scarcity are (Bell et al. 2012):

- physical
- economic
- geopolitical

In the context of IWM the focus is on physical and economical resource scarcity.

economic and physical water scarcity

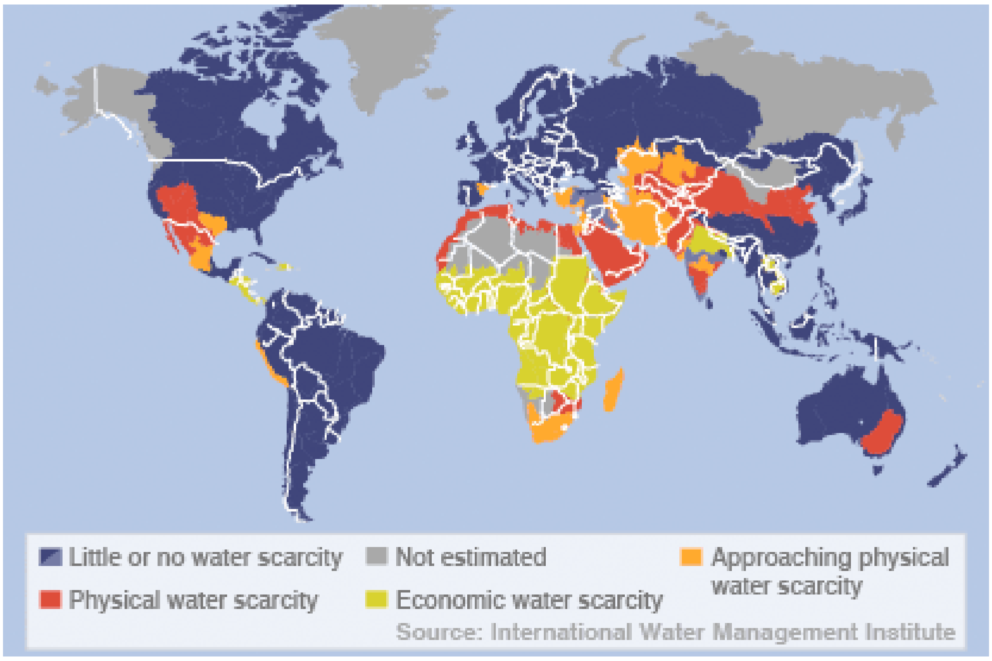


Figure 29: Map of the global distribution of economic and physical water scarcity as of 2006 (by BBC NEWS / CC-BY-SA-1.0, source: https://commons.wikimedia.org/wiki/File:Map_showing_Global_Physical_and_Economic_Water_Scarcity_2006.gif)

What is natural resource scarcity?

natural resource scarcity

The figure above shown the natural resource scarcity of global water resources (Bell et al. 2012):

a) physical water scarcity: relation between water availability and water demand
b) economic water scarcity: water is available, but there is no or limited access

How can we assess NRS?

assessment of natural resources scarcity

Ecological evaluation is essential for remediation, restoration, and Natural Resource Damage Assessment (NRDA), and forms the basis for many management practices. These include determining status and trends of biological, physical, or chemical/radiological conditions, conducting environmental impact assessments, performing remedial actions should remediation fail, managing ecosystems and wildlife, and assessing the efficacy of remediation, restoration, and long-term stewardship (Burger 2008).

2.12. Participatory Planning and Management Approaches

participatory planning and management

“Present age of human history is known as the information society, or the age of knowledge. The Socio-Economic impact acquired in this manner is huge since sustainable development is unthinkable without knowledge based society. Sustainable development can be defined as constant improvement in the quality of life for the current generation, or better quality of life for the subsequent generation; all form the same sources of Earth.” (Bhattacharyya 2006)

Participation in community development is significant factor, which can help to achieve the development goal. How do the village community having identified their community needs and plan their development themselves? That should reflect through their development plan.

benefits of participatory approaches

What are the benefits of participation in community development?

- community interest in the development process
- community interest in the localities in which such a project is planned
- empower the Communities in the decision making process
- communities able to fully contribute their own local knowledge to the repository of expert environmental and social data
- facilitation, investigation, analysis, presentation and learning by local people and sharing of information and ideas
- expectation of Village development by plans formulated outside the villages at urban centres with less knowledge on the village realities and imposed upon village communities from the top

Participatory approaches

principles of participatory approaches

Participatory approaches follow these principles (Bhattacharyya 2006):

- primacy of people
- peoples knowledge and skills
- empowerment of woman
- autonomy versus control
- local action versus local responses
- allow spontaneity in project direction

2.13. Planning cycle

Overview of the planning cycle

overview planning cycle

The planning process in Watershed Management consists of a combination of different planning modes (planning models) (Butler 2003):

- The planning process encompasses seven steps (see following figure) (rational planning).
- The involvement of the public and all stakeholders is essential in every planning stage (transactive planning). Together they plan and work for an environmentally and socio-economically healthy watershed that benefits all.
- The sequence of steps is not to be strictly adhered to; in fact, it is important to be flexible (adaptive planning). Some steps can be taken simultaneously, while others have to be repeated due to changed conditions or information. Monitoring is carried out during the whole process (although monitoring is together with evaluation explained here as the last step).

The outcome of the planning process is an elaborated Watershed Management Plan which is essentially a rural development concept which is to be implemented. This will serve to guide activities which are carried out to achieve the determined objectives (Tidemann 1996). The first preparatory step is to elect a planning committee.

steps of planning cycle

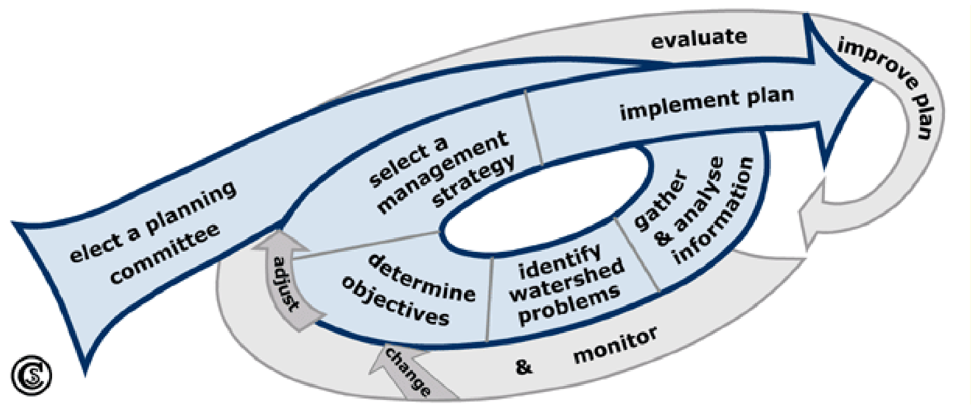


Figure 30: Steps of planning cycle (own illustration by A.Stumptner 2007, after Heathcote 1998; http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/management-and-measures/planning_cycle/)

Elect a planning committee

elect a planning committee

Before the real planning process starts some preparatory work has to been done. The most important step is to elect a planning committee that bears the planning responsibility. Members have to be selected with care. The committee has to represent the community and all important interest groups, organisations, institutions, etc., that have a stake in the condition of the watershed (Förch & Schütt 2004 b).

The planning committee may be composed of members of the following interest groups:

- farmers
- market-women, shopkeepers
- clan leaders
- environmental organisation/local non-governmental organisation
- local scientists from the university
- external experts

Together with the experts they have to work closely together during the planning process and cooperate with organisations and departments. This collaboration among stakeholders, participation of the public and integration of scientific knowledge in a holistic planning process is the characteristic of watershed planning (Förch et al. 2015).

Additionally, the financial budget - or rather fund-raising - has to be set up at the beginning.

Gather and analyse data and information

gather and analyse data and information

After a planning committee is elected, it can start to produce a Watershed Management Plan. The first step is to gather and analyse information about the watershed. The effectiveness of Watershed Management depends on a comprehensive understanding of all individual components of and processes within the ecosystem as well as their interdependence and interconnections (Förch & Schütt 2004 b).

gather and analyse data and information

A comprehensive analysis of the underlying natural and socio-economic attributes of the watershed is the basis for the development of a watershed management strategy (planning goal) (Heathcote 1998). This includes (Tidemann 1996):

- **gathering** and **compiling existing information and data**; in most cases reports, statistics and maps of soil surveys, geologic surveys, forest inventories and hydro-meteorologic as well as socio-economic studies that are mostly already available in government agencies;
- **confirmation** and **completion** of **data** during **field survey** if necessary.

A central file of relevant reports, records and maps should be created and routinely updated. An important tool is a Geographical Information System (GIS) into which the data can be integrated.

The gathered and analysed data can reveal different problems within the watershed that have to be identified in the next stage of the planning process.

Identify watershed problems

identify watershed problems

The next stage of the planning process is to identify concerns and problems that occur in the watershed and may interfere with its functioning. The problem types that have to be considered in terms of problem identification and analysis are (Tidemann 1996):

- resource use problems
- socio-economic problems
- final effects of watershed degradation
- physical problems

Some of them may be evident, others have to be disclosed by more detailed investigation or consultations with the local population, or may emerge by comparison with desired watershed conditions (Heathcote 1998).

problem types

Figure 31: Problem types (own illustration by A. Stumptner 2007, after Tidemann 1998; http://www.geo.fu-berlin.de/en/v/iwm-network/learning_content/management-and-measures/planning_cycle/identify_problems/index.html)

Determine objectives

determine objectives

After the problems of the watershed have been identified and analysed the objectives of the Watershed Management project should be determined by the planning committee.

The objectives must be recorded clearly for each problem. Additionally, the objectives should be ranked according to their importance in discussion with all members of the planning committee.

For example: two of the main objectives discussed for the Ükök river catchment in Kyrgyzstan are:

- to stop overgrazing by 70 % in the mountain top areas in the next six years.
- to raise funds about 40% to repair water infrastructure.

The task of the planning committee is now to select a watershed management strategy.

Select a management strategy

management strategy

The next planning step is to select a reasoned watershed management strategy in order to achieve the determined objectives. This is a crucial step which includes several tasks for the planning committee:

1. **determination of constraints** (e.g., budget), decision criteria (e.g., probable life of structures) and criteria weights;
2. **determination of a method to compare management alternatives** (screening method); these can be very simple ones such as graphical matrixes or more complex ones such as simulation models which show the impacts of each alternative)
3. **developing a long list of possible management options** on the basis of the watershed inventory (e.g. contour ploughing or terraces discussed in soil and water conservation; but this is only a selection!); compilation of a list of possible management strategies which are composed of the individual options and their combinations.
4. **elimination of options by criteria** (e.g., if too expensive).
5. **testing of the remaining feasible options** by application of the determined screening methods and decision criteria (Heathcote 1998);
6. **choosing the best management strategy**;
7. **putting together an action plan**, a list of measures for implementing the selected alternatives; usually these will fall into four types: information/education, technical assistance, funding and regulatory (EPA 2002).

Monitor and evaluate

monitoring and evaluation

Monitoring and evaluation are not 'the last' steps as shown in the figure and explained in the following. Monitoring and evaluation are often used together or synonymously. However, it is important to recognise how monitoring differs from evaluation. Although no single definition of monitoring and evaluation exists – and also no standard procedure for carrying it out – some common features can be identified:

definition monitoring

Monitoring is the systematic assessment of the progress of a piece of work over time. It is an integral of project management and is a continuous, on-going process for collecting, storing, analysing and using information. Several types exists. Monitoring ends on the completion of a project or programme (Gosling & Edwards 1995; Oakley & Clayton 2000).

definition evaluation

An **evaluation** is the periodic assessment at one point in time of the impact of a piece of work and the extent to which stated objectives have been achieved. It is undertaken by project staff and beneficiaries and, at times, by external teams. Evaluation may be carried out also a longer time after the end of a project (Gosling & Edwards 1995; Oakley & Clayton 2000).

monitoring and evaluation

It is necessary that the project team agree on how to monitor and evaluate. Generally, there are two main approaches:

- **the orthodox approach**: a detailed monitoring system is set up at the beginning and serves as a basis for the monitoring for the duration of the project. This includes the selection of indicators. An indicator is an proxy measurement; i.e. an phenomenon which is easy to measure and which is closely related to the target phenomenon which is difficult to measure
- **the new developed alternative approach**: It is a more flexible and adaptable approach. The monitoring system is developed during the project period based on the on-going experiences.

An elaborated system provides both the necessary information for decision making within the project team and also an on-going assessment of how the project is developing (Oakley & Clayton 2000). If it becomes clear, that the plan does not result in the intended objectives, then adjustments should be made.

2.14. Watershed (Sub-catchment) Management Plan

What is a watershed management plan?

watershed management plan

"A watershed plan is a strategy and a work plan for achieving water resource goals that provides assessment and management information for a geographically defined watershed. It includes the analyses, actions, participants, and resources related to development and implementation of the plan. The watershed planning process uses a series of cooperative, iterative steps to characterize existing conditions, identify and prioritize problems, define management objectives, and develop and implement protection or remediation strategies as necessary."[41]

The primary purpose of a watershed management plan is to guide watershed coordinators, resource managers, policy makers, and community organizations to restore and protect the resources water, biomass, soil, energy and human in a given watershed. A watershed management plan is a toolbox for dynamical planning, implementing and monitoring watershed management actions; they are also "living documents", meaning that as conditions change over time in a watershed, the plan must be re-examined and revised to reflect goals that have been achieved or not met.

Watershed management plans are not standardised, but reflect needs and demands of the different environmental, cultural, and socio-economic conditions. The following example of a watershed management plan has been drafted in a catchment area of the Nyambene Hills in Kenya.

Content:

- physio-geographical introduction
- socio-economical settings
- hydro-meteorological settings
- situation analysis
- proposed management options
- financial plan
- management monitoring and evaluation

[41] Source: Indiana Department of Environmental Management 2018: http://www.in.gov/idem/nps/3180.htm

How do we develop a watershed management plan?

development of scmp

The development of a watershed management plan is a strong participatory activity requiring sound moderation capacity and knowledge on integrated watershed management. Participants should be representatives of water resources users associations, representatives from regulatory authorities, experts e.g. from universities, and during all field campaigns the local population.

The participatory development of a watershed management plan is conducted in three major steps and last in general two weeks starting from the first meeting until finalizing the first draft:

1) introduction into the topics of IWM
2) field activities for data gathering
3) seminar work for data collation and plan drafting

It is highly recommendable to conduct a watershed management planning meeting in or next to the particular watershed for best spirit of the workshop, but also to minimize transportation time and cost.

methodology for development of a watershed management plan

The methodology for development of a watershed management plan, is timely described: one step must follow the other. The result from development of a sub-catchment management plan can be as followed:

a) drafted map showing the watershed management area, major tributaries and water bodies and the challenges occurring in the catchment
b) a situation analysis showing the causes, problems, impacts, location and current intervention for each kind of management relevant problem
c) a management option matrix showing the problem, intervention and activities, indicators, time frame, means of verification, and responsibilities
d) a financial plan for implementation of single actions

Watershed management plans should be dynamic plans that need regular monitoring of implementation, revisions and amendments!

Table 5: Methodology for watershed management plan development (own illustration by S.Thiemann 2014)

methodology for development of a watershed management plan

- Theoretical introduction into IWM
- Presentation of major geographical settings
- Getting general overview of the catchment - excursion
- Preparing field work
- Data collection in groups - random transect walks
- Synthesis of collected information by each group
- Participatory identification of problem areas on a map
- Compiling information in the structure of the situation analysis
- Drafting management options in each group
- Compiling proposed management options in the plenary
- Drafting monitoring and evaluation options
- Drafting financial plan and financing options
- Drafting management plan

2.15. IWM & GIS

Participatory GIS (PGIS)

participatory gis

Participatory GIS is an emergent practice in its own right; developing out of participatory approaches to planning and spatial information and communication management. The practice is the result of a spontaneous merger of Participatory Learning and Action (PLA) methods with Geographic Information Technologies and Systems (GIT&S).

PGIS combines a range of geo-spatial information management tools and methods such as sketch maps, Participatory 3D Models (P3DM), aerial photographs, satellite imagery, Global Positioning Systems (GPS) and Geographic Information Systems (GIS). With the objectives to represent peoples' spatial knowledge in the forms of virtual or physical, 2 or 3 dimensional maps used as interactive vehicles for spatial learning, discussion, information exchange, analysis, decision making and advocacy. Participatory GIS implies making GIT&S available to disadvantaged groups in society in order to enhance their capacity in generating, managing, analysing and communicating spatial information. [42]

PGIS practice is geared towards community empowerment through measured, demand-driven, user-friendly and integrated applications of geo-spatial technologies. GIS-based maps and spatial analysis become major conduits in the process. A good PGIS practice is embedded into long-lasting spatial decision-making processes, is flexible, adapts to different socio-cultural and bio-physical environments, depends on multidisciplinary facilitation and skills and builds essentially on visual language (Rambaldi & Weiner 2004; Rambaldi et al. 2006).

[42] Source and additional information: Participatory Avenues 2018: http://www.iapad.org/about/about-participatory-gis-pgis/

participatory gis

The practice integrates several tools and methods whilst often relying on the combination of 'expert' skills with socially differentiated local knowledge. It promotes interactive participation of stakeholders in generating and managing spatial information and it uses information about specific landscapes to facilitate broadly-based decision making processes that support effective communication and community advocacy (Rambaldi & Weiner 2004; Rambaldi et al. 2006).

If appropriately utilized, the practice could exert profound impacts on community empowerment, innovation and social change. More importantly, by placing control of access and use of culturally sensitive spatial information in the hands of those who generated them, PGIS practice could protect traditional knowledge and wisdom from external exploitation (Rambaldi & Weiner 2004; Rambaldi et al. 2006).

Ranking and weighting of IWM challenges

ranking and weighting of IWM challenges

The ranking and weighting of assessed IWM challenges should also been done on active participatory level. Experiences show that representatives from different stakeholder groups (local, regulatory authorities, and universities) rank prioritise occurring problems different due to their field of expertise and experiences. Thus, a ranking methodology should be used in order to level the different influences. Here, each participant got three markers to distribute among the challenges listed. The challenge with highest amount of markers was then accepted as highest prioritised problem. According the ranking the situation analyses and management matrix were drafted. [43]

[43] Source and additional information: Participatory Avenues 2018: http://www.iapad.org/about/about-participatory-gis-pgis/

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A Training Manual on Integrated Management of Watersheds
http://oar.icrisat.org/1968/1/Training-manual.pdf

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Watershed Management Plans
http://www.in.gov/idem/nps/3180.htm

Environmental Impact Assessment and Strategic Environmental Assessment
http://unep.ch/etb/publications/EIAMan2_ovhds.htm

European Framework Directive
http://ec.europa.eu/environment/water/water-framework/

4. Possible examination questions

- What is Environmental Impact Assessment?

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- Who are the major stakeholders for development of sub-catchment management plans?

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- What are the major five aspects of IWM?

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- Notice the hydrologic definition of a catchment area.

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- What are the different levels of participation?

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- Describe the methodology for development of sub-catchment management plans.

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- Describe three soil erosion forms.

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- How can infiltration capacity of soils be increased?

- What is biomass and how can it contribute to reducing evaporation small scale agricultural areas?

- What are two major side effects in biomass production beside energy?

- Human resources play a crucial role in IWM. At which levels shall trainings be conducted and why?

- The sustainable management of a watershed shall also deliver energy for the population. Describe one possibility for sustainable rural energy production.

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- How many litres of freshwater are assumed to be the minimum per person and day?

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- What is base flow?

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- Which measure is mitigating flood risks and water scarcity in one?

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- What is the difference between physical and economical resource scarcity?

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- Describe the benefits of the green belts parallel the water course. What is the exact naming?

- Describe methods to reduce soil erosion.

- What are the five renewable resources for energy?

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- What is payment for environmental service?

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About **trAndeS**

trAndeS is a structured postgraduate program based at the Pontificia Universidad Católica del Perú (PUCP) that contributes to sustainable development in the Andean region through its research and training activities. The project partners are Freie Universität Berlin and Pontificia Universidad Católica del Perú (PUCP).

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The objective of **trAndeS** is to create and promote knowledge that can contribute to the achievement of the United Nations Agenda 2030 with its 17 Sustainable Development Goals (SDG) in the Andean Region. It focuses its efforts on identifying how the persistent social inequalities in the region present challenges to achieving SDG targets and how progress toward these targets can contribute to the reduction of these inequalities.

Further information at www.programa-trandes.net

Executive Institutions of trAndeS

Berlin
Freie Universität Berlin
Instituto de Estudios Latinoamericanos
Boltzmannstr. 1
14195 Berlin
T: +49 30 838 53069
contacto@programa-trandes.net

Lima
Pontificia Universidad Católica del Perú
Departamento de Ciencias Sociales
Universitaria 1801
Lima 32, Peru
T: +51 1 626 2000 Ext. 5138
trandes@pucp.edu.pe

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