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Environmental Research Team

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[MDG7 ENVIRONMENTAL RESEARCH GUIDELINES]

Which environmental issues LDCs are facing? What are the relevant data in that field? How can they be identified and quantified?

INTRODUCTION

The Institute for Conscious Global Change is determined to provide a complete and comprehensive tool to help stakeholders of the LDCs making enlightened decision. From this perspective, the environmental dimension appears to be a crucial topic to deal with, as it is from Nature that foster the resources and habitat communities and societies rely on to develop and prosper. And today more than ever, the environment is closely linked and even dependent on climate and the changes it has been undertaking since the last century.

The UN-DESA has designated several fields that must be taken into consideration when dealing with the Least Developed Countries and the Small-Island Developing States in regard to climate change. Four of them are directly linked to the environment, naming:

- Biodiversity and Ecosystems
- Agriculture and Fisheries
- Water Resources
- Coastal Zones and Deltas

All these elements are defining the environmental context and resources of a country. Therefore, in order to manage them in a sustainable manner – and as targeted by the U.N. MDG7- adaptation measures will have to be taken. However, the planning and implementation of these adaptive measures must rely on trustworthy and relevant information. The guidelines of this handbook aim at helping to identify what are 1) the important issues an LDC may have to face and 2) the data that must be taken into account from an environmental point of view. The handbook will cover universal elements which will stand for reflection and action clues applicable to any country in the will to fit into a sustainable development framework.

Two other categories of data relevant to assess the state of the environment and its management will be discussed at the end: Environmental Education and GHG Emissions.

Eventually, a short synthesis exploring how the previous information can be used will close the guidelines.

Contents

1. Biodiversity and Ecosystems

Biodiversity, ecosystems and development issues are more linked to one another that one may think. This relationship has been internationally recognized by the U.N. Secretariat of the Convention on Biological Diversity with the setting of the Biodiversity for Development program. This initiative promotes the "integration of biodiversity considerations into sectoral and crosssectoral policies at the regional and national levels" aiming at alleviating poverty through the conservation of biodiversity.

1.1. Understanding the link between biodiversity, ecosystems and development

1.1.1. What is "biodiversity"?

It stands for "biological diversity" and may refer to different categories depending on the ecosystem they're evolving in. It includes faunal and floral species, which are both equally important to Nature's balance and beneficial to human populations.

1.1.2. Why is biodiversity important?

It is an indicator of the health of an ecosystem, which is characterized by the relationships between a biotic community (i.e. living organisms) and its biotope (i.e. habitat).

Ecosystems are terrestrial like savannahs, deserts, rainforests and alpine regions; or aquatic like coral reefs. Wetlands also refer to as ecosystems and combine both terrestrial and aquatic species living in a biotope with still waters like ponds, swamps, mangroves, peat bogs… There are also ecosystems with flowing waters like rivers and streams. Finally, there are the ecosystems in between like coastal zones, riparian zones, littoral zones…

Human beings can also be part of these ecosystems and be beneficial, detrimental or neutral to them in the way they positively or negatively impact on and interact with them.

Ecosystems are crucial to any community, population or country because of the variety of services they offer, such as:

- Food, fiber and raw material production
- Air quality
- Water filtration and provision
- Climate regulation (e.g. CO2 sequestration)
- Pollination
- Prevention of erosion
- Soil regeneration
- Medicine

1.1.3. The "Biodiversity Hotspots"

They are geographical areas particularly rich in species, often being endemic species. They therefore are also often closely linked to the culture of the people living within these hotspots or

in their surroundings. As a matter of fact, the cultural traditions and livelihood habits are directly related the ecosystem and biodiversity offered by the surrounding environment. Therefore, losing a part of this diversity also means losing a part of culture. This is precisely what has to be preserved too. Traditional Aboriginal Knowledge (TAK) might sometimes have been put aside for the sake of "modernity" but this kind of knowledge are now proving to be more and more topical in a context of climate change, particularly to develop adaptation strategies in countries where technologies are rare. The capacity of using the available resources and the natural processes is a sign of resilience, which is now indispensable for the LDCs.

This is why they must imply themselves in conservation. There are 25 "Biodiversity hotspots" as such, defined by *Conservation International* and eight of them are completely or partially located in LDCs[1]. The protection of these hotspots is important to species, human well-being and development. They represent their economic, cultural and spiritual wealth. Without healthy ecosystems, the provision of the natural resources needed to reach a development can't be insured. Thus, their protection, conservation and restoration must be part of the development strategy they will follow as much at the national scale than at the regional or community scale.

1.1.4. Link between the environment and poverty

The LDCs are geographically situated in areas with high biodiversity, especially Africa, Asia and the Caribbean. However, they are also often the places where ecosystems undergo the highest pressure, which leads in turn to an increase of poverty. However the simple view of this vicious circle between the degradation of the environment and the poverty rate should be expanded. In order to address effectively both these issues in an integrated manner, the definitions of "poverty" and "environment" should be further identified for each country or region. The following questions should be answered to bring custom-made solutions:

- What type of poverty is occurring? Is poverty linked to working or living conditions?

The poverty index is usually established according to welfare conditions so in order to better evaluate the kind of poverty, Reardon T. and Vosti S.A. (1995, p. 1498) propose the use of the "investment-poverty" notion. It is the "ability to make minimum investments in resource improvements to maintain or enhance the quantity and quality of resource base – to forestall or reverse resource degradation". Besides, it is "site-specific, a function of local labour and non-labour input costs and of the types of investments that are needed for the particular environmental problems or risks faced".

- What type of environmental component is affected? Biodiversity, water, soil, air?
- And eventually, how are the two linked?

Then only, can a strategy of action and/or research be launched to match the specific needs of a region or a community within a given country.

[1] For more details about a specific area, you can consult the website of Conservation International: http://www.biodiversityhotspots.org/xp/hotspots/Pages/default.aspx

1.1.5. Link between biodiversity and gender

Larger involvement of women in natural resources management is crucial for different reasons:

- Women and men have knowledge about different things.
- Men and women have different knowledge about the same things.
- Women and men may organize their knowledge in different ways.
- Men and women may receive and transmit their knowledge by different means.

Their greater participation in the decision-making process could therefore be greatly beneficial to biodiversity conservation[2] and to their empowerment process.

1.2. Examples of Pro-Poor Conservation

1.2.1. Biodiversity Conservation and Economic Development

Vietnam has recently launched a project aiming at both protecting its natural ecosystems and their resources and creating jobs for poor rural communities through the implementation of a biodiversity corridor. The concerned area is not under severe threat but the objective was to prevent this situation to occur. Biodiversity is seen as "an essential foundation of economic development as well as a way to adapt to climate change". The director responsible for this program highlighted the important role that played political will in the effective launch of this project (VietNam News). This kind of initiative clearly is a good illustration of a joint strategy towards development and environmental sustainability.

1.2.2. Agro-forestry

It represents a major strategy that enables population to both protect their environment and provide them with revenues. There are mainly two options, with timber products or with non-timber products, each having particular social and environmental benefits.

- Mukungu Reserve, Burundi : Timber and Non-Timber Forest Products

The Enviro-Protect organization led the planting of *Maesopsis eminii*, a **fast growing tree** that can be harvested every 8 years on average (ICRAF). During their growing period, their leaves provide excellent food for cattle and shade to other cultures. Another important aspect is the land-use of the plantation. A **rotating strategy** with "swaths of tree of different generations are mixed together in a mosaic pattern" enables to provide different and constant rich habitats for biodiversity (Ministry of the Environment, Jap. 7). This plantation was combined with the production of *Azadiratha indica (Neem*) which provides a **multi-use plant** to local populations. Indeed, it can be used for its medicinal purposes, as an organic pesticide, as soap and as

[2] For examples of women involvement, you can consult the IUCN factsheet available at: http://generoyambiente.com/arcangel2/documentos/494.pdf

combustible (Ndabirorere). It also helps fighting against deforestation as it constitutes alternative revenue and products to traditional timber production.

Besides diverse activities and change of habits were also promoted to serve the conservation of forests: the use of **improved stoves** (consuming less wood) and **wood-alternative technologies**, **beekeeping activities, training and environmental education** of the main stakeholders (population, administrative agents and technical assistants)(*ibid*.).

- Nam Pheng, Lao PDR: Non-Timber Forest Production (NTFP)

The IUCN supported this project aiming at stopping deforestation and sustainably harvest bitter bamboo and cardamom while providing development means. This was made possible thanks to 1) a **Participative Marketing strategy** involving all the villagers to decide together of the management, rules and implementation of the project and 2) the creation of a **NTFP fund** which is supplied by the participating villagers with 10% to 15% of the revenue they earn from the selling of bamboo and cardamom. The money collected enabled to improve the village's water system, support the construction of a school and provide loans to 15 households. Retrospectively, this project improved the livelihood in the village by eradicating food insecurity and child mortality, granting access to medicines and medical services and more than doubling the number of children going to school between within an 8 year-period (Morris et Ketphanh).

Alternatively to the selling of forest product, the **consumption of wild food plants** also seems to be particularly interesting to both conservation and poverty alleviation goals. Indeed, according to a study made in Western Thailand, the gathering of these plants is an efficient means of subsistence. It has been calculated that by "spending 14.63 days gathering wild food plants for consumption, the Karen can save the money that it would have taken them 143 days to earn" (Delang 283). However, there is a social reluctance for this practice by local populations who prefer to grow or buy food. Therefore by acknowledging and promoting the consumption of wild food plants in national or regional policies, people could save funds that in return could be used for productive investments.

1.3. Examples of data categories relevant to the "biodiversity and ecosystems" theme

BIODIVERSITY INDICATORS	Providing information to assess…
Number of endemic species	The uniqueness of a region
"Biodiversity hotspot" surface area	"
Number of vulnerable species	The level of disturbance of a region
Number of threatened species	"
Number of extinct species	"
Number of invasive species and distribution area	The external threat of a region and its vulnerability to it.

ECOSYSTEMS INDICATORS	Providing information to assess…

Forest surface area	The level of non-disturbance of the ecosystem
Desert surface area (in regions where deserts are "new": less than 50 years)	The progress of the desert
Protected surface area	The level of national commitment to conservation efforts
Inhabited surface area	The level of non-disturbance of the ecosystem
Intact surface area	"
Ecosystems surface area and boundaries	The ecosystem variety and extent
Heavily impacted ecosystems surface area	The most vulnerable areas to biodiversity loss
Desertification rate	The progress of the desert
Deforestation rate	The regression of forest cover
Number of natural disasters since 1950 and distribution area	The most vulnerable areas to natural disasters
Average number of wild fires per year and distribution area	The most vulnerable areas to man-made disasters

SOCIO-ENVIRONMENTAL INDICATORS	Providing information to assess…
Population density in forests	The inhabitation rate of forests
Population density in savanna	The inhabitation rate of savannas
Population density in… [other ecosystem]	The inhabitation rate of [other ecosystem]
Number of forest-dependant poor	The economic dependence over forest products
Total Revenue from forests (GDP share)	"
Revenue from non-timber products	"
Revenue from timber	"
Illegal forest exploitations surface area	The level of threat by illegal forestry
Illegal settlements spots	The number of people who would have to be relocated
Illegal mining spots	The dependency on illegal mining activities
• **Revenue benefiting corporations**	The share of revenues benefiting the local development
• **Revenue benefiting local populations**	"
Illegal hunting spots	The most vulnerable areas to poaching
Legal mining spots	The dependency on legal mining activities
• **Revenue benefiting corporations**	The share of revenues benefiting the local development
• **Revenue benefiting local populations**	"

A more official list of biodiversity indicators also exists and has been used by the Convention on Biological Diversity (CBD):

CBD 2010 Biodiversity Target Headline Indicators		Key partner
Living Planet Index	Indicate the state of global biological diversity, based on trends in vertebrate populations	WWF
Red List Index	Evaluate the extinction risk of species and subspecies	IUCN
Cover of Protected Areas	Measures policy response to biodiversity loss	UNEP-WCMC
Extent & Type of Forest	Examine forest health and look at the usage and management of these forests	FRA, FAO
Marine Trophic Index	Assess the impact of fisheries on marine ecosystems	UBC Fisheries Center

Although, the respective data might not always be available for every country and do not make the link with social components. The previous indicators might then also be interesting to look at considering the multidimensional working area of the Institute.

2. Agriculture and Fisheries

These activities basically stand for the subsistence means of most individuals in LDCs. What makes them vulnerable is that they largely depend on natural factors which will progressively be emphasized in the face of climate change. However, the farmers, shepherds and fishermen also affect their yields and catches through their practices. Therefore, it is at this level that changes can be brought to make both these activities more sustainable and more resilient to climate change.

2.1. The biggest environmental challenges of Agriculture and the Fisheries in LDCs

2.1.1. Agriculture

- Agricultural biodiversity and GMOs

Agricultural biodiversity is essential to a healthy diet. However, it is threatened by monocultural practices and the use of GMOs. Some countries, like Kenya and Zimbabwe, took considerations of the issues related to the use of this modified food for both the environment and the population and are on their way to ban such practices on their territory. Monocultures also represent a threat to food security by making the crops more vulnerable in case of a disease outbreak. Besides, from a nutritional point of view, a diverse food intake is more beneficial to human health, as it enables individuals to be more resistant to diseases. The vulnerability to AIDS for example, which is devastating in Africa and more and more in Asia, could be addressed by combating malnutrition, which requires a richer agricultural biodiversity.

As defined by Thrupp L.A. (2000), agro-biodiversity contributes to:

- productivity,
- resilience in farming systems,
- income generation,
- nutritional values,
- food production
- livelihood security
- pollination,
- fertility,
- nutrient enhancement,
- insect and disease management,
- water retention

Finally, it is important to note that biodiversity is an important aspect of climate change adaptation in the sense that a wider range of crops enables farmers to better adjust according to the weather specificities and variations across time (FAO).

- Pollinators decline

This phenomenon due to a variety of reasons including chemicals, pests, extreme weather, habitat destruction or fragmentation represents a threat to the reproducibility output of plants and crops. By extension, the decline of pollinators also has impacts on food security and rural livelihood, especially in LDCs. Indeed, "pollinators have direct impact on agricultural production system. Around two third of crop plants: field crops, orchard crops, forage crops and medicinal plants need pollinators to ensure healthy productivity". Bees are the most widely known pollinators but other insects, plants and even mammals can act as pollinators. This is why the loss of biodiversity is a transversal issue that needs to be addressed at different levels by different stakeholders.

- Land degradation

Land degradation including soil erosion from water or wind, desertification, excessive soil salinity… It can be considered through different perspectives. Socially, it can foster conflicts between individuals, communities and even countries. Environmentally, it affects the biodiversity. And economically, it impacts the production value (quantitative) and/or the resource value (qualitative) of the crops (Stockings). Better practices will therefore need to be implemented to avoid these issues like vegetative buffer zones *(see also 3.2.3)*.

- Water quantity and quality

This issue will be more largely treated in the "Water Resources" section, but it can be noted that the management of water resources is particularly crucial in agriculture in terms of irrigation and runoffs bringing the issues of water pollution and water stress to the surface.

- Climate change[3]

[3] For more details see Chapters "Africa, Asia and Small Islands States" on http://www.grida.no/publications/other/ipcc_tar/

Experts expect an intensification of meteorological events like droughts and floods in the years to come, that will most certainly affect the LDCs (IPCC). Other effects include extreme events like hurricanes that should be more powerful due to an increase of ocean waters temperature and migration of new parasites. All these events can have dramatic effect for a region and communities should increase their resiliency to it by preparing themselves thanks to new or traditional practices. Cultures will have to be more resistant to drought or floods depending on the studied area - that may include the farming of new species. Crops will require better management to either retain water or humidity, or enable the rain flow without damaging the soil through erosion. In order to achieve that, TAK can play a crucial role in the adaptation process.

- Desertification

LDCs are particularly vulnerable to this phenomenon which is the result of several factors including inappropriate land-use, overexploitation, deforestation, over-grazing but also climatic variations, exacerbated by climate change. It is defined by the FAO as "the degradation of land in arid, semi-arid, and dry-sub-humid areas". Besides, "over 250 million people are directly affected by desertification" mainly living in the world's poorest countries (UNCCD).

- Cattle and other animal resources

Cattle and husbandry practices are particularly vulnerable to climate change regarding the risk of new pandemic, the progress of desertification on pasture lands which can affect the livestock through a lack of water and/or food and extreme meteorological events which can increase the mortality rate and decrease the reproductive rate among animal populations (COPA-COGECA).

2.1.2. Fisheries

- Pollution of watercourses

The pollution of watercourses resulting from the non-treatment of agricultural, industrial and domestic effluents and the lack of a sanitation network as well as the health issues the consumption of contaminated food implies stands for a major issue in LDCs. However, it is important to note that all species of fish don't react the same way to contaminants. In other words, two species evolving in the same polluted-ecosystems don't contain the same amount of pollutant. The clue here is therefore to identify which are the most and least dangerous species and to help communities to switch their diet habits to safer ones thanks to educational programs, giving greater importance to women is also crucial as they can be very influential in that field. This topic of pollution will be further treated in the Water Resources section.

- Overfishing and other unsustainable fishing practices

Overfishing in LDCs is often the result of seafood demand for exporting purposes (Adams). The problem is that instead of consuming the seafood they catch and ensure a certain food security,

seafood is sold to foreign markets at low prices. Therefore, this practice is neither benefiting the present generation nor the future ones, as stocks and ecosystems are being depleted.

Adequate monitoring is necessary to quantify the catches and thus the damages in order to establish quotas in the most stricken areas. The international community also has an important role to play, regarding also the trawling practice of big commercial companies and the allowed fishing zones which threatens the global fish populations, including the ones of certain LDCs. Fisheries Partnerships Agreements should therefore be updated to meet more sustainable and fair objectives at the global scale regarding the state of fisheries.

Eventually, some countries, more particularly SIDS, but also Tanzania use damaging fishing methods like cyanide or dynamite fishing. These practices have devastating consequences as coral, which are hundreds and hundreds of year-old, are either contaminated and eventually die or literally blown up. With cyanide, fish are easier to catch and are sold as living food. Whereas with dynamite, most of the time only fish coming up to the surface are picked up, whereas other fish, the majority in fact, sink to the bottom, leaving certain zones dead and empty (WWF). Although a part of the catch is sold on the local market, the majority is sold for aquarium purposes. Stricter international regulations would therefore be required to control these practices.

- Invasive species and loss of biodiversity

Another threat to fisheries are invasive species. Once they have colonized an ecosystem it is unbalanced and leads to the extinction of endemic species either because they are replaced by these competitors, or because the food chain is disrupted. In order to avoid this kind of situation, two principal measures should be taken: 1) at the international level with the support of the international community to enforce stricter rules regarding the ballast waters of cargo ships; 2) at the local level by encouraging the systematic removal of the invasive species to stop their progress and prevent them from being sustainably implemented.

- Effects of climate-change

According to recent assessments, climate change is fundamentally affecting marine ecosystems and oceanic processes around the world, and more particularly in the tropics, which is one of the most vulnerable areas because of the coral formations (Chen). The two main effects of climate change are the warming temperature and the ocean acidification, which both affect the marine wildlife through the depletion of habitat and disturbance of the food chain. Indeed, corals are very sensitive to temperature and even a slight increase in temperature can have disastrous effects on the ecosystem and the thousands of species which rely on it. Regarding ocean acidification, it directly or indirectly affects all marine species (Doney, Fabry and Feely): a lower PH prevent a full development of both phytoplanktons, which stands for the very base of the food chain, and corals, habitat of most tropical species. Eventually, fishery productions in Small-Island Sates and in littoral countries or communities will undergo additional pressures which have to be taken into considerations by decision-makers.

2.2. Examples of projects and best practices

In this subsection, we will explore some examples of existing projects and best practices aiming at bringing some solutions to the previously-discussed issues.

2.2.1. GIS and Livestock Management

The Holistic Resource Management is used in Zimbabwe to combat desertification. Indeed, this practice enables to regenerate lands through the grazing of cattle which compact the ground and increase the soil cover. In doing so, cattle participate to capture and store both water and carbon, effectively addressing climate change issues. Besides, it eliminates the need to use the brushfire technique, as grass does not dry thanks to the water catchment enabled by the compacted ground. Recently, this practice has been coupled with GIS technology to identify the most desertification-stricken areas and guide the land-use planning national policies. In Zimbabwe, HRM has led to the restoration of land and river, without the need of expensive technologies (Bafana).

In Uganda, another initiative permitted to establish the link between agricultural elements and poverty thanks to GIS maps. The results aimed at providing datasets for decision-makers in order to identity the priority actions to achieve[4]. An emphasis was particularly made on dairy production and the identification of milk surpluses and deficits in order to "highlight geographic differences in market opportunities for poor dairy farmers and help target knowledge dissemination, market infrastructure investments, and service delivery to dairy farmers" (Ministry of Agriculture, Animal Industry and Fisheries, Uganda; Uganda Bureau of Statistics; Food and Agriculture Organization of the United Nations; International Livestock Research Institute; and World Resources Institute 9).

2.2.2. Food security through gender and agricultural biodiversity

As mentioned earlier, agro-biodiversity plays a crucial role in rural societies but it must not be forgotten that women are equally important in this system. Indeed, as noted by Deda P. & Rubian R., "women, through their uses of natural resources for building, cultivating, breeding, nourishing and healing, have preserved biological diversity and developed knowledge of possible uses of biodiversity, which have been transmitted from generation to generation, helping to enhance livelihood security". However, despite this renowned recognition of contribution, women are still not entitled the decision-making power they deserve. A step in that direction would also mean a step towards conservation and sustainability.

2.2.3. Aquaponics

[4] For more details see http://www.wri.org/publication/mapping-a-better-future-livestock

This practice, combining aquaculture and hydroponics, could play an important role in LDCs in terms of food production. Indeed by providing both protein through fish or seafood "culture" and vegetables, aquaponics provide an affordable answer to both food security and environmental sustainability. The system relies on a natural process which only requires fish food input: fish provide fertilizer for the plants, which then purify water for fish. Therefore, the need for water is punctual – mainly when the system is implemented - and the production does not rely on natural factors: droughts and floods can't ruin the yield. Besides, this practice could also be used in areas depending on overfished watercourses, which would give some respite to fish populations. Aquaponics system then provides a sustainable, local and nutritional source of food. Pilot projects in Kenya have already proven to be successful (AMSHA Africa Foundation).

2.2.4. Biogas production

Methane-rich manure from livestock is used in Cameroon rural areas as a "new" source of energy for heating and lighting. This method provides a free and sustainable combustible. Besides, it enables to cut the consumption of wood coal, addressing in turn the issues of deforestation, GHG emissions and soil fertility. It also has direct positive benefits on the well-being of farmers by enabling them to spend more on medical care and education and to increase the animal stock as the costs for biogas energy production technology is relatively low and doesn't constitute a big financial burden for traditional farmers. Eventually, even dried after combustion, manure can still be used as a natural fertilizer for crops (Ngalame).

2.3. Relevant data to be researched in that field

AGRICULTURE INDICATORS	Providing information to assess…
Number of agriculture-dependant poor	The link between poverty and agriculture
Total revenue from agriculture	The economic dependence on agriculture
Number of HIV positive farmers	The link between health issues and agriculture
Number of GMO-crops farmers	The link between food security and agriculture
Percentage of women in the labor force	The potential of change in agricultural practices
Cattle production (beef, goat, chicken…)	The spatial distribution of livestock
Average Livestock share for self-consumption	The reliance on livestock for food security
Total revenue from cattle production	The economic dependence on breeding
Dairy production	The importance of dairy-revenues for farmers
Livestock race spatial distribution	The biodiversity of livestock and the potential of adaptation to climate change
Livestock diseases	The spatial distribution of animal diseases (correlated to human poor health?)
Average Precipitations per year	The variability of water availability

Droughts-stricken areas	The most stricken areas
Floods-stricken areas	"

FISHERIES INDICATORS	Providing information to assess…
Number of fisheries-dependant poor	The link between poverty and fisheries
Total revenue from fisheries	The economic dependence on fisheries
Number of invasive species	The external threat of a region and its vulnerability to it.
Coral cover	The level of ecosystems disturbance
Overfished sites	"
Oxygen in water	Water quality
Nutrients in water	"
Water temperature	The effect of climate change
Cyanide fishing practice	The use of harmful fishing practices
Dynamite fishing practice	"
Bleach fishing practice	"
Authorized fishing areas for foreign boats	The participation of foreign boats to the national depletion of fish stocks (food security issue)
Percentage of catches for foreign-markets	The share of seafood sent outside the country (food security issue)

Note: The identification of such data can also point out lacks in governmental/ organizational/ institutional database which could be worth filling and monitoring for further research.

3. Water Resources

Water certainly stands for the most important natural resource of all. As such, measures regarding its conservation, monitoring, distribution and use must be part of any development project. Indeed, water is a vital resource to any and every human-being and the lack of management or the mismanagement of water resources can have disastrous consequences. This is even truer in the current context of climate change, which affects the global hydrological cycle.

3.1. Main environmental issues linked to Water Resources

3.1.1. Water quantity and quality

An important thing to understand is that very few regions face a real lack of water issue. The problem is rather linked to its availability across time and space as well as to its quality. And both

of these situations can generally be addressed through a better management of land and activities thanks to “best practices”. There are two main sources of water: surface water and groundwater.

- Pollution and drying of surface waters (rivers and lakes)

LDCs face major issues of surface water contamination, mostly due to the lack of proper sanitation system and wastewater treatment. Other causes may include agriculture or industrial activities like oil and mining. From this point of view, the best way to control pollution is to regulate these activities and the effluents entering the surface waters. Two complementary actions are therefore needed: first, eliminating or decontaminating the effluents as much as possible and second, restore the ecosystems providing environmental services for water: mainly wetlands and forests. Regarding water quantity, the use and pumping of water have to be minimally controlled in order not to reach a point of non-return, like it happened in the Aral Sea for instance. Ecological Water Management aims at respecting at least the minimum natural flow required for ecosystems to function and provide the environmental services the communities need (Groenfeldt).

- Depletion and pollution of groundwater

Groundwater or aquifers represent another important source of water. However, available data about their status (how much is pumped up and how much is still available and where) are often poorly documented or not updated. Hence, a first step towards a better management of groundwater would be to constitute a database of these resources. Here again, if water abstraction exceeds the natural renewal of water, depletion occurs. The recharge of aquifers depends on climate conditions (precipitations, temperature), geologic material (soil permeability) and terrain (rural or urban).
Sources of groundwater pollution can be industrial, residential or agricultural and is due to chemicals and microbial matter entering the soil by percolation (Harter). It can also be due to below-the-surface installations like pipelines or wells. However, the source of pollution can also be “natural”. Indeed, some constituents are naturally present in groundwater. This is actually the situation Bangladesh is facing with arsenic where the installation of tube wells inserted at 200m of depth maximum were not preceded by water testing. The tube wells enabled contamination to spread and distribution of poisoned water is still ongoing (Smith, Lingas and Rahman).

3.1.2. Depletion of wetlands

Wetlands include mangroves, marshes, swamps, bogs and fences and often constitute the water towers of countries. They would then require a particular protection. Indeed, wetlands provide several environmental services which are indispensable to a healthy environment. They provide a natural filtration of water, they act as a buffer against natural disasters (floods, tsunamis, winds and storms…) or as a sponge during the wet seasons (then they progressively release water during the dry season), they are a source of food and can be a source of revenue as well. This is why LDCs must take action to protect their wetlands as part of their development strategy. This approach

is recognized as being cheaper than introducing technologies or purchasing goods to provide the same services nature is doing "for free".

The RAMSAR Convention is an international treaty dedicated to the protection of wetlands of international importance. It has established a Small Grant Fund to help developing countries implementing the principles of the Convention (Ramsar).

3.1.3. WASH: Water, Sanitation and Hygiene

The issues of lack of sanitation system and safe drinking water are crucial in LDCs, as it directly affects and threatens not only the ecosystems but human lives and wellbeing as well. Target 7C which aims to "halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation" (UNDP) perfectly illustrates the urgency of the situation. In 2006, 1.2 billion people did not have access to safe drinking water while 2.6 billion people did not have access to sanitation with the greatest majority living in LDCs or developing countries (UNDP). This situation is a direct symptom of poverty and has social, environmental and economic effects with inherent issues on health, education and food security.

- <u>The water privatization issue</u>

The situation of LDCs is partly due to the privatization phenomenon that has been going on since around the 1970s after the decolonization process in Africa and Asia. It has led to the implementation of private companies, including foreign ones, to exploit the distribution of water and sanitation services, i.e. wastewater collection and treatment. Unfortunately, the financial goals of these companies are most of the time not compatible with both the financial situation of the populations and the scarcity and sustainability of water resources. Besides these projects are often accompanied with IMF "conditionalities", which on the long-term do not benefit the countries (Mcafee).

- <u>The importance of small and local projects</u>

Since most individuals living in LDCs cannot afford the services of multi-national companies like Veolia, governments and even communities should turn to projects of smaller scale, using "soft-path" measures vs. costly hard-path infrastructures. Here are some examples:

-*Regarding availability and/or consumption reduction: Rainwater harvesting and water recycling.* Not all systems or activities require potable water. These two solutions can help provide water for other purposes than drinking water, hence significantly alleviating the need of potable water.

- *Regarding efficiency of use: drip irrigation.* This refers to the famous "more crop per drop" motto, which tends to increase the "water productivity": most crops do not need to be "inundated" to grow. In water-scarce countries, this can contribute to make a difference. Besides, we can also

note that the crop choice is very important too: selecting plants adapted to the regional climate is essential (Wolff and Gleick).

- *Regarding quality: Protection of natural wetlands and construction of artificial wetlands.* As natural water filters, wetlands constitute a good alternative to treatment plants, particularly in countries where they cannot be afforded. Experiments of artificial wetlands in tropical countries show the potential of such installations and give hopeful results of seeing them being implemented more systematically (Kivaisi).

- *Regarding hydroelectricity: run-of-the-river installations*. Instead of big dams with reservoirs, "micro-hydro" systems could be implemented without interrupting the water flow and disrupting the hydrological cycle, thus improving water distribution (and quality) along the rivers.

- *Regarding water installations: decentralization and participatory approach.* With local and "simple" infrastructures (e.g. rainwater capture and storage facilities), water users can participate in the water management, operations and maintenance, which make them more cost effective (Wolff and Gleick).

3.1.4. Hydroelectricity and Big Dams

The construction of big dams for hydroelectric purposes poses a threat to rivers ecosystems. Indeed, dams have for effect of "cutting" the river into several pieces, altering the distribution, availability and quality of water through space and time, therefore affecting the activities and livelihood of communities living on their banks or depending on their subsidiaries which are impacted too. The filling of reservoirs also requires the inundation of entire lands which often have a great agricultural value, hence weakening the food security. Eventually, from a cultural point of view, losses are irrecoverable when villages are submerged.

Therefore, big hydroelectric dams are not the best solution for LDCs, even if they provide them a source of energy. Alternatives like wind power, biomass and biogas-powered generator, solar energy, or even "micro-hydro" should be further exploited to meet the energy needs of LDCs.

3.1.5. Floods, Droughts and Climate Change

Floods and droughts are the two main extreme climatic events directly linked to water resources with potential disastrous outcome and which are likely to intensify in the years to come because of the effects of climate change, particularly in LDCs. Adaptation to these events is necessary and directly linked to the issue of food security.

Floods are natural events which regularly happen and are part of ecological processes, including the recharge in nutrients of lands. However, the reasons that turn a flood into a disaster are generally not due to nature but rather to human activities, settlements and mismanagement.

Indeed, as soon as we have started to try "taming" rivers with engineering and to allow settlements in floodplains in the meantime, floods became more and more destructive in both human and financial terms. As mentioned earlier, other mismanagement of ecosystems like deforestation, wetlands deterioration or rivers damming, also exacerbate the flood impacts on lands, as natural barriers and buffers are weakened or even destroyed. The shift of thinking from engineering solutions to soft-path solutions should be exploited by LDCs especially as the effects of climate change are increasingly felt in these countries.

There are three types of droughts: meteorological, hydrological and agricultural droughts. The first happens when there is an extended period of time with below-average precipitations; the second when there is a deficiency of water supply in surface and/or ground waters; and the third when the crop production is affected.

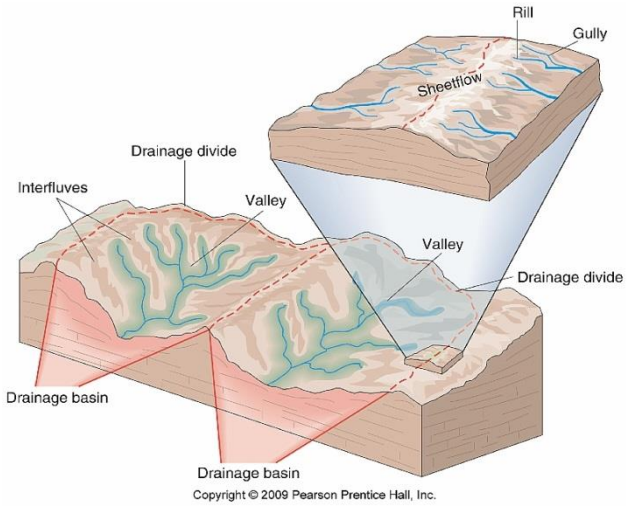
3.2. Examples of projects and best practices

The diversity of projects and best practices to improve water resources management is vast and evolving. However, there are some mainstream approaches which constitute a good basis and which are presented here along with some interesting projects around the world addressing the different issues water management is facing.

3.2.1. Integrated Water Resources Management (IWRM)

IWRM is defined as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP). It is based on the collaboration of all the stakeholders – farmers, industrials, individuals, governments, NGOs, etc. - in the decision-making process.

IWRM can be done at several scales: national, regional, local or at the watershed level. This is the option that is most commonly recommended. To better understand this approach, the definition of a watershed (or river basin, or drainage basin) should be given: "that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community" (U.S. EPA). It can also be illustrated by the following diagram:



From this picture, it is clear to understand why water management should preferably be done on this basis: use of/or impacts on the river upstream affect water characteristics (quality, flow, biodiversity…) downstream. Therefore, communication between the different water users must be established to allow an equitable and sustainable use of water along the river. However, in the case of transboundary rivers, this may also imply negotiations with other countries. The use of GIS maps to provide a better understanding of the situation through a visual tool is therefore interesting to exploit.

3.2.2. Wetlands Management through the use of GIS: "Mapping a better future for Uganda"

This project aimed at identifying the importance and value of wetlands for communities in Uganda: up to 24 products extracted from wetlands were identified to be used by a single community. The combination of data on the status of wetlands with poverty-related data on a single map enabled to provide information for decision-making. In this case, no clear correlation was established between the state of wetlands and poverty indicators. However, this may not always be true in other regions or countries. Two main benefits can be drawn from this kind of project: first, identifying the most impacted wetlands to protect them and ensure the sustainable production of their products and services; second, identifying the under-exploited wetlands to provide a sustainable source of revenue to communities. Here, the harvesting of papyrus following sustainable practices was proposed as a way to alleviate poverty in the region (WRI).

3.2.3. TAK: Cheap, simple and effective techniques to cope with droughts and soil erosion[5]

- **Terracing**

[5] For explaining clips, see : http://www.youtube.com/watch?feature=player_embedded&v=RQkiv_U5AoU and http://www.youtube.com/watch?v=b9Z_wYJyBCE&feature=player_embedded

This practice traditionally led by women helps to both reduce erosion and preserve moisture. Lands quality is therefore enhanced as roots can more easily grasp in soil and grow, and plants can go through the dry season thanks to the moisture held in soil (IIED).

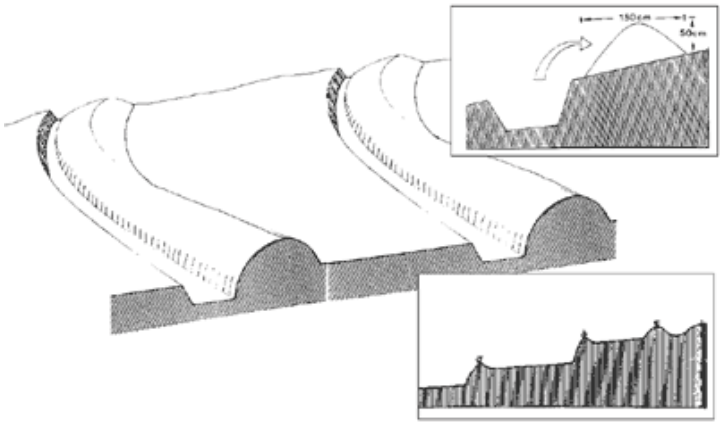


Photo Credit: http://practicalaction.org/farming_techniques

- **Stone lines**

This other traditional practice aims at slowing water runoff and retaining it in the soil when heavy rains occur to provide homogenous moisture throughout the crops, even during dry seasons (FAO).

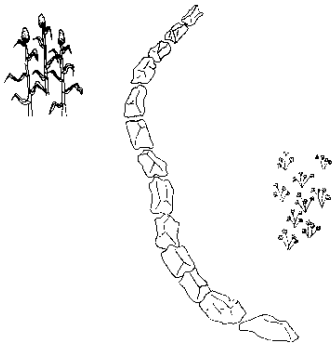


Photo credit: (FAO)

- **Agro-forestry**

The two previous techniques can also be combined with the planting of grass to enhance the efficiency. And once the soil has recovered, the planting of trees is possible. These trees would play the role of buffer, and protect the crops from extreme climate events while retaining moisture and provide shelter for biodiversity, which in turn can increase the crop productivity.

- **"Wadis"**

These earth basins also enable to retain water, reduce soil erosion and improve land quality for agricultural purpose during both dry and rainy seasons (FAO).

Photo credit: (FAO)

3.2.4. Cambodia: the success of Phnom Penh's public water company

In 1997, the authorities took the challenge to modernize the whole water system of the city in order to achieve by 2015 the Millennium Development Goal of halving the number of people who lack drinking-water and sanitation. The public company now provides 24h drinking water service, the poorest customers are subsidized and they're never cut off if they do not (or cannot) pay their bill, which is the case of only 1% of the population of the inner city. The networks are being expended to the neighbouring areas, with the priority given to the poorest communities. This success relies on different factors: the support from the government and donors, the independence of the company, the monitoring of customers' satisfaction, the "spirit of ownership" and the emphasis on capacity building among staff (Chan).

3.3. Relevant data to be researched in that field

WATER QUALITY INDICATORS	Providing information to assess…
Color of water	Purity of water
Temperature of water	The potential of bacteria development
Presence of coliforms	The level of contamination/drinkability
Presence of cysts	"
Presence of Heavy metals	"
- **Arsenic**	"
- **Lead**	"
- **… [other]**	"
Oxygen-rate	The quality of water for biodiversity

WATER ECOSYSTEMS INDICATORS	Providing information to assess…
Distribution of permanent wetlands	Year-round provision of water/products
Distribution of seasonal wetlands	Seasonal provision of water/products: are alternatives needed?

Watersheds limits	The surface of land and number of people depending on the same source of water
Aquifers limits	"
Floodplains limits	Current areas threatened by flooding
River limits over time	Potential areas threatened by flooding
Biodiversity index	The health of the ecosystem
Number of aquatic species upstream	The health of the ecosystem upstream
Number of aquatic species downstream	The health of ecosystem downstream

CLIMATE CONDITIONS INDICATORS	Providing information to assess…
Average precipitation	The average amount of water received
Precipitation during the rainy seasons (at different periods of time)	The evolution of the amount of water received
Average duration of the dry season	The distribution of water over time
Average duration of the wet season	"
Average temperature	The rate of evaporation and evapotranspiration (from vegetation)
Floods most stricken areas	The most vulnerable areas to floods
Droughts most stricken areas	The most vulnerable areas to droughts

WATER-USE INDICATORS	Providing information to assess…
Dams spatial distribution	The level of disturbance of water courses
Households having access to sanitation	The level of water contamination due to non-wastewater-treatment
Households having access to drinking water (TOTAL): At home, in the near neighbourhood, outside the town or village	The vulnerability of people to water-borne diseases
Cultivated surface area (total)	The need of water for agricultural purposes
• **Rain fed surface area**	The level of reliance on climate for food production
• **Irrigated surface area**	The amount of water needed for food production
Industries spatial distribution	The potential level of pollution
Mines spatial distribution	"
[Any effluents-releasing sites]	"
Use of aquifers	The rate of depletion of the resource
Use of surface-water	"

4. Coastal Zones & Deltas

Risks faced by the population and biodiversity living in these areas are mainly due to climate change through habitat loss and/or deterioration, which in return have impacts on food security and livelihood for both human beings and wildlife.

4.1. Main environmental issues in coastal zones and deltas

4.1.1. Why are coastal zones sensitive areas?

While most lands are facing the sole power of wind and precipitations, coastal zones also face the power of the sea, including the tides and waves. Besides they are often the most populated areas, because of the resources they provide in terms of food security.

The main hazards, and their link with climate change, are:

- Sea-level rise

The level of water naturally fluctuates in the short term with tides and in the long term when the shape of the oceans changes following an underwater volcanic eruption or when the volume of water changes – during glacial periods for instance, the level and volume of water in the ocean are lower. However, climate change is also affecting these characteristics at a faster rate: as ice melts and water becomes warmer, the volume of water increases, thus raising the sea-level (Nelson). This phenomenon will impact the coastal populations by forcing them to build dykes system in the short-term and either to move away from the coasts or even to leave them. This is the case of several low-lying Small-Island States, which are condemned to be submerged in the future. Besides human population, biodiversity is also affected by sea-level rise, particularly coral reefs which are very sensitive to changes of the surrounding conditions (depth, temperature, acidity…). This side-effect is making the populations relying on seafood to survive even more vulnerable.

- Storms and hurricanes

Storms are generally the most powerful and devastating on coastal zones because they took all their strength at the surface of water with no barriers to stop them until they reach the coasts. Tropical storms take their energy from warm waters and with climate change, the ocean's temperature is warmer. More powerful hurricanes are therefore to be expected in the years and decades to come (Webster, Holland and Curry). Eventually, it is important to recall that besides gusts of wind and rain, they are also responsible for erosion and floods.

- Tsunami

This natural disaster is not linked to climate conditions. However climate change does make the coasts more vulnerable to tsunamis because of the coastal erosion, the deterioration of coral reefs by warmer and more acidic water and the deterioration of barrier islands by stronger storms.

- Landslides

This phenomenon is the result of erosion driven by sea-level rise and storms as mentioned above. Cliffs are particularly exposed because of the constant action of waves on their surface. Massive landslides can also generate tsunamis (Nelson).

4.1.2. Why are deltas sensitive areas?

Deltas are the geographic areas formed at the mouth of rivers before entering the sea. Deltas' lands are very fertile but also very vulnerable to floods. With climate change, this risk has amplified. Another element of vulnerability of deltas, which actually can have larger geographical implications, is the salt intrusion from seawater. This phenomenon is amplified by the mismanagement of groundwater resources. Indeed, when freshwater is excessively pumped out the remaining water is not dense enough to keep salted water out of the aquifer. As a result, freshwater is contaminated and needs to be treated before being used for consumption or irrigation. Finally, dams built upstream affect the flow and the supply of sediments downstream, which directly threatens the availability and quality of water in deltas, as well as the activities occurring there.

4.1.3. Settlements in Low-Elevation Coastal Zones (LECZ)

Numerous LECZs are found in LDCs, more particularly the Small Islands States, Bangladesh, Nigeria, Liberia, Mauritania, Djibouti… These zones are also often the most populated, originally attracted there for agricultural purposes. Besides, today LECZs are more likely to host large urban populations. These last two demographic elements (density and urbanity) make the LECZs' populations particularly vulnerable to coastal risks and climate change. Looking to the future, the most vulnerable areas should be identified as priority in the country's NAPA. The strategy should include mitigation, migration and modification. Moreover, at a national level development strategies and support measures should put the emphasis more on inland urban settlements to balance the settlement scheme. Market and strictly economic decisions cannot lead adaptation. Social as well as environmental dimensions should be taken into consideration to support a sustainable development (MacGranahan, Balk and Anderson).

4.2. Best practices for a sustainable use of lands and resources

4.2.1. Integrated Coastal Zone Management

The objectives of ICZM are to establish integrated and sustainable strategies regarding disaster prevention planning, land-use planning and natural resources management in order to address the risks, pollution and over-exploitation of resources in coastal zones. They include the management of impacts on freshwater supply, fisheries and agriculture, coastal residences, commercial buildings, wetlands, drylands (forests), human health, culture and heritage sites, tourism.

This approach is based on steering committees gathering representatives of the stakeholders such as: industries, mining fisheries, agriculture, landlords, tourism professionals, environmental

NGOs, energy sector (oil and gas, hydroelectricity), public authorities and services, wetlands users, forestry…

The "integrated" part refers to the integration of: economy, environment and society; the different sectors of activities; responsibilities between the different levels of governance; stakeholders; elements of management; and disciplines (Bower and Turner).

4.2.2. "The Use of Remote Sensing and GIS in the Sustainable Management of Tropical Coastal Ecosystems"

This is the title of an article demonstrating the possibilities offered by the use of new technologies to help identifying species and areas from a fundamental point of view, or for indicating the prioritary importance for protection and conservation, for development, or for sustainable exploitation. A multidisciplinary approach gathering experts from different but complementary fields of work is also recommended as well as a better integration of the biocomplexity in the decision-making not to overlook the interdependencies between the ecosystems, the biodiversity and human populations and activities, which tend to be very complex in these areas of the world. A balance has to be found to reach a sustainable model of development (Dahbouh-Guebas).

4.2.3. Eutrophication: Recommendations for action

Eutrophication is a phenomenon characterized by an over-enrichment of waters by nutrients. The main source of nutrients in LDCs is wastewater from human sewage. Other sources may include: urban runoff, industrial effluents, agriculture and fossil fuel combustion. The first impacts are the excessive growth of phytoplankton, micro-algae and macro-algae. Side effects are diverse and may include: loss of biodiversity and dominance of jellyfish, coral reef damage, harmful algal blooms like cyanobacteria, and hypoxia, i.e. oxygen depletion.

In Asia, Africa, and Latin America, environmental agencies or coastal authorities should:

> "1. Undertake systematic and routine assessments of coastal areas, particularly those exhibiting symptoms of eutrophication.
>
> 2. Develop transparent and public reporting procedures for tracking the occurrence of eutrophication and hypoxia, as well as monitoring their impact on ecosystem health.
>
> 3. Develop and adopt decision-support tools—such as nutrient budgets and water quality models—that can facilitate the development of appropriate local and regional responses to eutrophication." (Selman, Greenhalgh and Diaz)

4.2.4. Examples of adaptation measures applied to coastal zones

Several countries have already begun their adaptation process and implemented a certain number of actions. Here are some examples of initiatives in LDCs (Kato):

- Liberia: Reducing coastal zones urban areas' vulnerability
- Cambodia: Community mangrove restoration and sustainable use of natural resources

- Bangladesh, Central African Republic, Guinea Bissau, Sierra Leone: Enhancing education and capacity building
- Cambodia: Development and rehabilitation of flood protection dykes
- Maldives: Sustainable building designs

4.3. Data Required for Coastal Zone Information

BIO-PHYSICAL INDICATORS	Providing information to assess…
Land elevation: 0-3m; 4-7m, 8-10m, <10m	The vulnerability to flooding
Type of habitat: Estuaries, Sea grass, Macro algae, Inter-tidal, Salt-marsh, Mangroves, Waders, Rookeries, Shellfish	The vulnerability to natural disasters, potential of exploitation (threat to ecosystem)
Type of coast: Sandy Beach, Rocky beach, Rocky cliff, Inter-tidal, Mangroves, Salt marsh	The vulnerability to natural disasters, vulnerability of infrastructures
Type of seabed: Sand, Hard clay, Rock, mud shell, Coral reefs	The vulnerability to climate change and pollution
Bathymetry: < 2 m, **,** < 5 m**,** < 10 m**,** Inter tidal**,** Spoil dump	The level of accessibility of aquatic resources and their vulnerability to it
Benthic Flora: Sea grass**,** Seaweed**,** Coral	The type of species, the vulnerability to climate change and pollution
Temperature of water over time	The effects of climate change and pollution
PH of water over time	"

ANTHROPOGENIC INDICATORS	Providing information to assess…
Sources of pollution: Oil spills, Oil treatment, Dispersant use, Disposal sites, Domestic sewage, Industrial waste, GHG emissions, Agricultural and Urban runoff	The level of contamination and identify the priority sites of action
Type of transports: Major and Minor Roads, Ports, Harbours, Boat ramps, Airports, Navigation channels	The level of accessibility to coastal ecosystems
Type of infrastructures: Residential, Industrial Commercial, Recreational, Mooring, Intakes, Outfalls, Fresh water, Power generation, Hinterland, Education and Medical facilities	The density of infrastructures and their pressure on the environment

RISK-MANAGEMENT INDICATORS	Providing information to assess…
Water-management infrastructures: Dykes, Levees, Dams, Sustainable buildings	The type and level of adaptation to water-related disasters
Emergency sites and infrastructures: assembly points, fire station, alarms…	The level of preparedness of local authorities
Salted-water intrusion?	The vulnerability to climate change, the management of water resources (over-exploitation)

Signs of Eutrophication side-effects? loss of biodiversity, dominance of jellyfish, coral reef damage, harmful algal blooms (cyanobacteria, rhodophyta), hypoxia	The vulnerability of coastal ecosystems to nutrients, water quality, threat to seafood (contamination, depletion, migration…)
Major disasters-stricken areas: floods, hurricanes and storms, tsunamis	The most vulnerable areas to natural disasters
Economic losses from natural disasters	The economic vulnerability to natural disasters
Population's awareness of natural disasters	The level of education of the population on the subject and their vulnerability to it
Population's awareness of climate change	"

COASTAL ACTIVITIES INDICATORS	Providing information to assess…
Tourism: Beaches, Tourist facility, Harbours, Marinas, Fishing, Diving, Moorings, Boat ramps	The pressure on coastal ecosystems
Fisheries: Commercial, Recreational, Aquaculture, Leases, Fishing Ports, Spawning ground	"
Proportion of urban/rural population	"
Proportion of people depending on tourism, fisheries, agriculture, wetlands exploitation and products, forestry	The economic dependence of population over coastal ecosystems, the threat of anthropogenic activities on the ecosystems

5. Other Environment-related Data

5.1. Environmental Education

Environmental education of both children and adults plays a crucial role in the accomplishment of better natural resources management in LDCs. People must be aware of the benefits brought by healthy ecosystems, rich biodiversity and quality of natural resources, of the threat ecosystems bear, what are the consequences and links between environmental degradation and their livelihood and how they can participate to release that pressure through their habits and activities.

Environmental education data can be related to NGOs working in that field in particular areas. It can also be sensitization projects, training centers, school programs which would help assessing the level of awareness of environmental issues and the tools and means available to the local population.

5.2. Energy & GHG emissions

Energy is central to almost every aspect of everyday life, including access to water, agricultural productivity, health care, education, gender equity and environmental sustainability. Unfortunately, LDCs have in general little to no flexibility in choosing their source of energy.

According to UNDP, “it is estimated that worldwide there are 2.5 billion people who rely on traditional fuels such as wood, charcoal, and dung as their principal source of energy for cooking and heating” and “almost 1.6 billion people have no access to electricity” (United Nations Ministerial Conference of the Least Developed Countries).

Data regarding the production and consumption of energy will help identifying the population’s needs in order to identify potential alternatives and/or mitigation measures to increase energy efficiency and reduce GHG emissions.

5.2.1. Fossil fuels

Data may include information regarding the industrial, commercial, governmental and domestic production and consumption of fossil fuels - oil, gas, and coal - but also any accidental event related to these extraction activities.

5.2.2. Unsustainable sources of Renewable Energy

Wood from deforestation: As stated earlier, the use of wood is widespread in LDCs. But this practice has serious effects in terms of deforestation and biodiversity and ecosystems degradation, as it was explained in the first section. It also has impacts on soil quality for agriculture and climate change both from the carbon-sink destruction –forests- and from the combustion of wood itself. Data regarding this issue may include, households’ access to electricity, source of energy, cooking habits…

Biofuel: This practice is not recommended because of the large surface of crops needed to ensure its production, which directly competes with the production of food. It is therefore an issue in terms of food security as it is susceptible to induce both a lack of food and increases in prices. It is also a practice encouraging deforestation, like the palm oil industry, with effects on carbon-capture natural processes and eventually on climate change.

Hydroelectricity: Although classified as a renewable energy, hydroelectricity can have such environmental damages affecting the economic, cultural, agricultural components of a region that it is not considered a sustainable source of energy, unless it is made at a small scale with no interruption of the river flow. In fact, reservoirs are even responsible of some GHG emissions (methane essentially) due to water stagnation.

5.2.3. Sustainable sources of Renewable Energy

Organic sources: domestic waste and livestock manure produce methane that can be used for heating or producing energy. Any information related to these two components could help assess the potential of exploitation of these resources: amount of waste produced, landfills location, livestock production, manure utilization…

Technical sources: There is a wide range of existing technologies using renewable sources of energy. However, some are more developed than others like solar and wind energy. Although, it

may seem to be too expensive a technology, more conventional combustibles like kerosene are very expensive themselves in these countries. Pay-as-you-go systems enable household to have access to electricity at a moderate price (Bullis). Alternatives renewable energies include: geothermal energy, tidal energy, wave energy, offshore wind farm, hydro-mills, ocean thermal energy conversion …. Although, most of these technologies are not profitable yet and require more research and development, they might constitute serious alternatives in the future, especially for islands and coastal zones.

5.2.4. GHG emissions

Green House Gas emissions constitute a major issue, because of their effects on climate change and the side-effects it induces and which were mentioned in the previous sections (on water resources, fisheries, agriculture, coastal zones, wetlands…) but also because of their effects on human health. Therefore, the correlation between health and energy indicators would also be interesting to explore so that mitigation efforts would also be part of the poverty alleviation strategy to reach the MDGs.

Data related to GHG emissions may include:

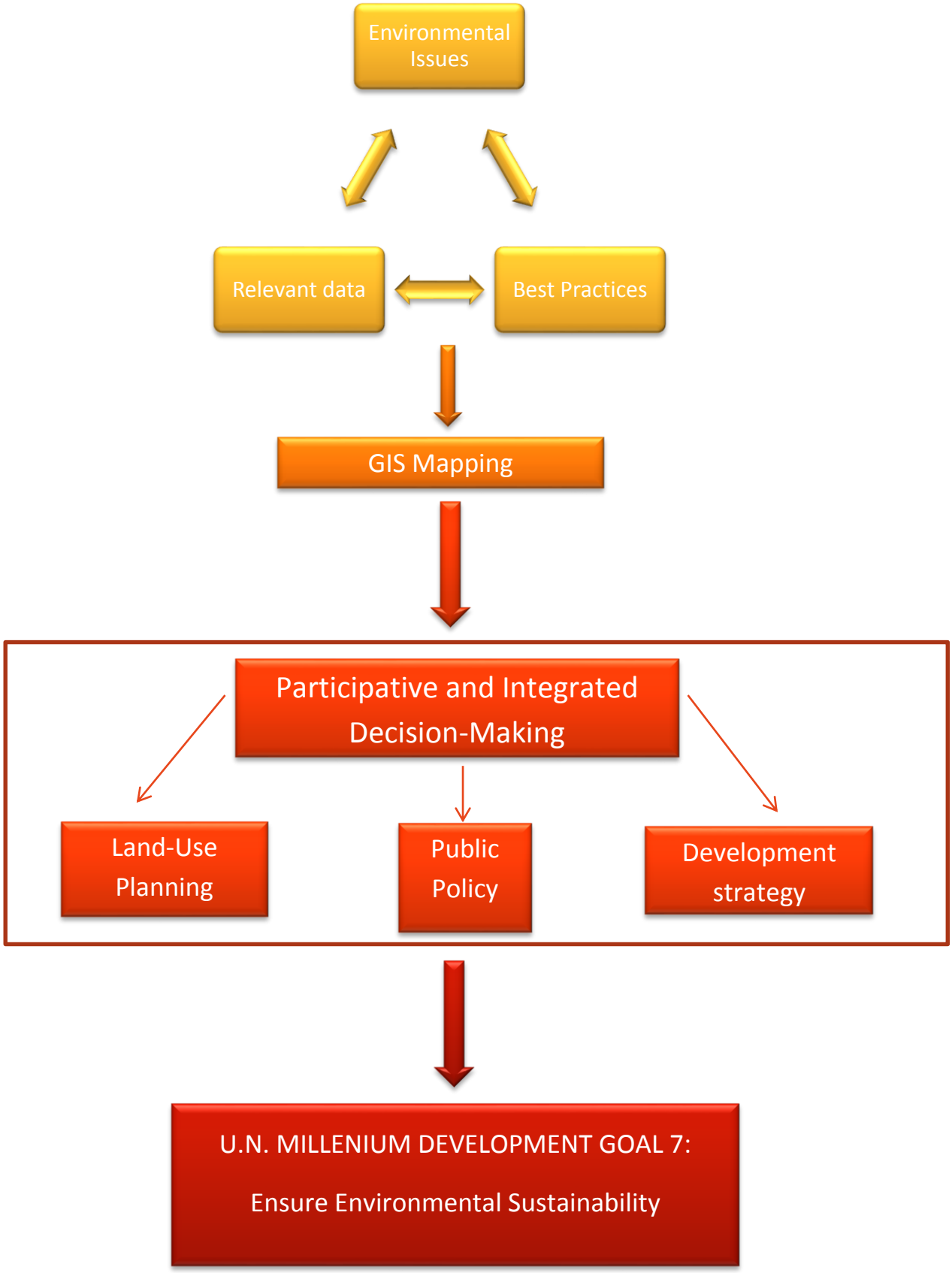
- figures of emissions themselves, commonly carbon dioxide (CO2), methane (CH4), nitrous oxide (NO2), Persistent Organic Pollutants (POP), Chlorofluorocarbons (CFC),
- information regarding sources and consumption of energy: coal, oil, hydroelectric dams…
- information regarding installations emitting GHG: factories, landfills,
- information regarding depletion of natural carbon sinks: deforestation, wetlands over-exploitation
- information regarding agricultural practices, more particularly regarding livestock and the use of chemicals

6. Synthesis

An understanding of environmental issues towards better land-use planning and resources management thanks to GIS

Linking the sections and sub-sections together enables to provide a universal picture of the issue, what might be the solutions for it thanks to the presented examples and the clues that would help highlighting the environmental elements towards which efforts must be directed. By taking into consideration the environmental issues mentioned throughout the guidelines, decision-makers should be able to establish priorities in the management of national natural resources to integrate sustainable practices in their development strategy. Indeed, when environmental data are added to the GIS maps, decisions regarding Land-Use Planning can be made in an integrated way. The participation of local populations is also highly recommended in the process in order to ensure the effective implementation of the measures.

The next diagram illustrates the links between these guidelines and the final objective towards the reaching of MDGs:



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