Designing oil and gas plant siting alternatives

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General

- This presentation describes the challenges related to the implementation of a SMCA having the aim of selecting priority areas for locating Oil and Gas plant and facilities on the West African coast, in the conceptual stage of a project.

- Multicriteria analysis (MCA) is generally defined as “a decision-aid and a mathematical tool allowing the comparison of different alternatives or scenarios according to many criteria, often conflicting, in order to guide the decision maker towards a judicious choice” [B. Roy, 1996].

- Spatial refers to the use of geographic information and elaboration
Scope of work

- Preliminary identification and description of Environmental, Social and Health sensibilities and criticalities for the study area to support the choice of the facilities localization.

- The study consider the following facilities:
  - Gas Processing plant (CPF, approx. area 500x800 m)
  - Accommodation Camp (AC, ~ 300 people, permanent)
Study area

- Boundary definition
- Main features
Pictures from logistic survey

Seasonally flooded areas
Pictures from logistic survey

Seasonally flooded areas (dry season)
Pictures from logistic survey

permanently flooded areas
Pictures from topographic survey

Inland fishery
Pictures from topographic survey

ecotourism
The purpose of the analysis is to individuate multiple alternative inside the study area.

The technique utilized is called **SMCA to design alternative** and it adopt a continuous method. It corresponds to a high or infinite number of decision alternatives, represented by rasters.

The starting point of continuous methods is

- a set of objective functions and
- a set of constraints.
The multicriteria analysis decomposes the decision elements into a hierarchy of more easily understandable sub-elements, each of which can be analyzed independently.

The elements of the hierarchy can relate to any aspect of the decision problem, tangible or intangible, carefully measured or roughly estimated, or anything at all that applies to the decision at hand.

<table>
<thead>
<tr>
<th>Macro-Objective</th>
<th>Objective</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conceptual steps of SMCA

- Evaluation criteria definition
- Quantification of criteria
- Standardization of the criteria values
- Criteria weights
- Constraints definition
- Decision rules
- Sensitivity analysis
We set up a panel of specialists composed of:
- Geologist
- Biologist
- Naturalist
- Environmental Engineer
- Health & Safety Engineer
- Sociologist
- GIS Analyst
Evaluation criteria definition

- In the spatial context, evaluation criteria are associated with geographical entities and relationships between entities, and can be represented in the form of maps.
Evaluation criteria definition

Valuable for who?

“Ecosystem services valued by humans are often underpinned by biodiversity ..... Impacts on biodiversity can therefore often adversely affect the delivery of ecosystem services. As a matter of priority, the client should seek to avoid impacts on biodiversity and ecosystem services.”

(IFC Performance Standards on Environmental and Social Sustainability, Performance Standard 6, Biodiversity Conservation and Sustainable Management of Living Natural Resources)

“To achieve greater progress toward biodiversity conservation to improve human well-being and reduce poverty, it will be necessary to strengthen response options that are designed with the conservation and sustainable use of biodiversity and ecosystem services as the primary goal.”

(Millennium Ecosystem Assessment, Ecosystems and Human Well-being, Biodiversity Synthesis)
The supporting and, often, the regulating ES are not valued by local stakeholders, that don’t see the indirect relationship between them and the supported functions (mainly provisioning) they value most.
Evaluation criteria definition

ES and biodiversity values shall be considered in terms of beneficiaries. For this project we identified different stakeholders placing different values to the same habitat.....

Example: wetlands have high value for global community as supporting and regulating service, while having low value for local community as provisioning service (inland fishery)
The experts shall have a **clear picture** of the social and environmental components, their **relationships** and the **value** attached to the function each component plays.

*Do we have at this stage of the project the necessary information for a clear picture?*
A matter of timing

- In current practice, the EIA procedure, and the related socio/environmental data collection, begins once project design is almost complete.
A matter of timing

**PROJECT PHASES**

**CONCEPT SELECTION**

**DEFINITION OF ALTERNATIVES**

**CONCEPT DEFINITION**

**ESHIA PHASES**

1. SCREENING
   - High level ESH impacts assessment based on secondary data
   - Preliminary ESHIA

2. SCOPING
   - Definition of information and data gaps; Focus on key ESH impacts; Definition of methodology
   - Term of Reference for ESHIA

3. BASELINE & FIELD SURVEY
   - Definition of Baseline conditions of the area (including field surveys)
   - ESHIA: Baseline Study
look where the money is........

- What kind of data engineering and logistic base their decision on?

**Engineering**
- Geology
- Geotechnics
- Geomorphology
- Hydrology
- Hydrogeology
- Meteorology
- Topography

**Logistic**
- Infrastructures
- Morphology
- Soil use
- Settlements
- Communities

Examples:
- Engineering prepared a thorough flood risk study, with complete information on flooding regime, land use and geomorphology
- Logistic have a complete map of Communities
Look where the money is........

- Plenty of information, already. Lack of data on the biosphere, may be....

**Engineering**
- Geology
- Geotechnics
- Geomorphology
- Hydrology
- Hydrogeology
- Meteorology
- Topography

**Logistic**
- Infrastructures
- Morphology
- Soil use
- Settlements
- Communities

**Socio/Environment**
- Communities
- Soil use
- Hydrology/hydrogeology/geomorphology
- Biology (flora/fauna)
- Ecosystems
Baseline data

Remember that sometimes not getting what you want is a wonderful stroke of luck.

Dalai Lama

soul-to-souls.com
Baseline data

- The (traditional) topographic survey was incomplete due to the presence of thick vegetation and swamps.
- We proposed to survey the area via drone (Unmanned Aerial Vehicle, UAV). The advantages were twofold:
  - Acquired topo surface of the area
  - Derived ground truth data on vegetation cover and flooding data
UAV photogrammetric survey

Resolution 5 cm\pixel

Blurr (Wind)
UAV photogrammetric survey
UAV photogrammetric survey
UAV photogrammetric survey

- Ground-level profile extracted after processing
Evaluation criteria definition

- So far so good for the environmental/physical sphere. We identified 3 objectives, and the criteria to value them with respect of the main beneficiaries:

<table>
<thead>
<tr>
<th>Macro-Objective</th>
<th>Objective</th>
<th>Criteria</th>
<th>Beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Habitat conservation</td>
<td>Naturality level of the ecosystem</td>
<td>Global, national</td>
</tr>
<tr>
<td></td>
<td>Fauna conservation</td>
<td>Protection of nesting sites</td>
<td>Global, national</td>
</tr>
<tr>
<td></td>
<td>Maintenance of flooding regime</td>
<td>Presence and nature of flooding</td>
<td>Global, national, local</td>
</tr>
</tbody>
</table>
Local beneficiaries

- For the values given by local communities to provisioning and cultural ES we referred to the logistic survey performed one year earlier, when the team met with fishing communities and local governments.
Example of stakeholder consultation sheet during logistic survey

<table>
<thead>
<tr>
<th>Local Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>This area aims at describing the macroeconomic context of the area where the operations will take place. It is necessary to know the main economic sectors, the structure of the labour market, the country's resources and which are the most sensitive issues in the economic sector. It is also important to understand if and how the access to natural resources is regulated.</td>
</tr>
</tbody>
</table>

1. What is the current unemployment rate (%)? Are there differences in unemployment according to gender and age? If yes, in what order?

2. Which are the primary occupations of the community?
   - Farming
   - Hunting
   - Fishing
   - Food processing
   - Trading
   - Lumbering/timber works
   - Wood gathering
   - Company employment
   - Industrial employment
   - Civil/public service
   - Artisanal/craftsmanship
   - Tourism and tours
   - Others (please specify)

3. Is it common to have a secondary occupation? If yes, of what type?

4. Are many primary occupations of mainly a subsistence nature?

5. Which are the main typical professional skills possessed by the community population?

6. What crops & cultivations present in the community present?

7. What is each of their percentage distribution on total crop-types present?

8. What distance is covered on average in order to reach ones field? (Km or Minutes/Hours)

9. How has the yield been in recent years? What do you think is the reason for any change in yield?

10. What is the current cost of land? Has it increased or decreased in the last 5 years?

11. Is animal husbandry practiced in the community?
   - If yes, which livestock are kept?

12. What proportion of the community has fishing as its main occupation?

13. Where do these people fish?

14. Is aquaculture developed in the community?
   - If yes, how many persons does this sector employ?

15. Is hunting commonly practiced?

16. Are medicines, biocides, and other biological materials derived from ecosystems employed for commercial or domestic use?

17. How would you say is the community land territory sub-divided between agricultural uses, forests, hunting grounds, fishing grounds, pastureage, and uninhabited areas? (Express in % distribution)

18. List the type of economic activities present in this area:

   - Manufacturing Enterprises
   - Construction Enterprises
   - Transportation Enterprises
   - Agricultural production Enterprises
   - Oil exploration Enterprises
   - Communication Enterprises
   - Trading Enterprises
   - Banking & Financial Enterprises
   - Public Sector establishments
   - Bakery
   - Wood and woods production
   - Textiles production
   - Building materials production
   - Grain milling
   - Food processing
   - Motor & auto repairs
   - Commercial fishing
   - Agricultural production for commercial use
   - Blacksmith
   - Welding
   - Pottery
   - Construction activities
   - Tourism agencies and resorts
   - Other crafts (please specify)

   Subsistence economic activities:
   - Fishing
   - Farming
   - Hunting
   - Wood gathering
   - Fruit picking
   - Other (please specify)
With respect to local communities well-being maintenance and promotion, we identified 3 objectives, and the criteria to value them.

<table>
<thead>
<tr>
<th>Macro-Objective</th>
<th>Objective</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td><strong>Maintenance</strong> of Provisioning ecosystem services</td>
<td>Food from Crops, Biomass Fuel, Coastal Fisheries, Inland Fisheries values</td>
</tr>
<tr>
<td></td>
<td><strong>Respect</strong> of Cultural ecosystem services</td>
<td>Eco-tourism potential, Ethical/Spiritual Values</td>
</tr>
<tr>
<td></td>
<td><strong>Maximize</strong> synergy between local community and the new infrastructures</td>
<td>Distance from existing roads and villages. (Only roads for CPF evaluation)</td>
</tr>
<tr>
<td>Macro-Objective</td>
<td>Objective</td>
<td>Criteria</td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------------------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Environment</td>
<td>Habitat conservation</td>
<td>Naturality level of the ecosystem</td>
</tr>
<tr>
<td></td>
<td>Fauna conservation</td>
<td>Presence of nesting sites</td>
</tr>
<tr>
<td></td>
<td>Maintenance of flooding regime</td>
<td>Presence and nature of flooding</td>
</tr>
<tr>
<td>Social</td>
<td>Maintenance of livelihood means</td>
<td>Food from Crops, Biomass Fuel, Coastal Fisheries, Inland Fisheries</td>
</tr>
<tr>
<td></td>
<td>Respect the Cultural life\values of communities</td>
<td>Eco-tourism potential, Ethical/Spiritual Values</td>
</tr>
<tr>
<td></td>
<td>Maximize synergy between local community and the new infrastructures</td>
<td>Distance from existing road and villages</td>
</tr>
</tbody>
</table>
### EVALUATION TREE

- We added the Health and Safety criteria, and the constraints

<table>
<thead>
<tr>
<th>Results</th>
<th>Macro-Objective</th>
<th>Objective</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Habitat conservation</td>
<td>Naturality level of the ecosystem</td>
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<td>Protection of nesting sites</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintenance of flooding regime</td>
<td>Presence and nature of flooding</td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>Maintenance of Provisioning ecosystem services</td>
<td>Food from Crops, Biomass Fuel, Coastal Fisheries, Inland Fisheries values</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Respect of Cultural ecosystem services</td>
<td>Eco-tourism potential, Ethical/Spiritual Values</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximize synergy between local community and the new infrastructures</td>
<td>Distance from existing road and villages. (Only roads for CPF evaluation)</td>
<td></td>
</tr>
<tr>
<td>H-S</td>
<td>Safeguard of workers and local people</td>
<td>Distance from potential sources of accident</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Health protection of workers and local people</td>
<td>Distance from noise sources*</td>
<td></td>
</tr>
</tbody>
</table>

### Constraints (no-building zone)

- Law constraints (for safety)
- Secure damage area in case of incident
- Distance from noise sources*
- Noise disturbance threshold value

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Suitability maps (identifying priority areas)

Creating suitability maps enabled us to obtain a suitability value for every location on the map. Once we have created the necessary layers for each objective, we ranked each layer by how suitable it is as a location for a new facility, according to the map’s criteria. Having all measures on the same numeric scale gives them equal importance in determining the most suitable locations. Standardizing the criteria permits the rescaling of all the evaluation dimensions between 0 and 1. This allows between and within criteria comparisons.
HABITAT

- CRITERIA: HABITAT VALUE

- DATA SOURCE: VEGETATION MAP

- CLASSES:

  Habitat
  
  - Built ground
  - Bare soil
  - Plantation
  - Grassland
  - Thicket
  - Wet forest
  - Swamp and mangrove forest

- VALUE FUNCTION based on habitat loss
Habitat – standardized value map
FAUNA

- CRITERIA: NESTING SITES AND IMPORTANT BIRD AREA (IBA)
- DATA: TURTLES NESTING SITES AND IBA MAP
- CLASSES: TURTLES NESTING BEACHES, WET FOREST, MANGROVES, MANGROVES BUFFER
- VALUE FUNCTION based on POTENTIAL NESTING SITES
Fauna – standardized value map

Legend

- 0.00 Not suitable
- 0.25
- 0.50
- 0.75
- 1.00 Suitable
FLOODING

- CRITERIA: FLOODING CLASSIFICATION
- DATA: DTM, VEGETATION, GROUNDWATER TABLE, GROUND WETNESS
- CLASSES: WATER BODIES- PERMANENTLY FLOODED – SEASONALLY FLOODED – MOSTLY DRY LAND
- VALUE FUNCTION based on MAINTENANCE/DISTURBANCE OF THE NATURAL HYDROLOGIC FLOW
Flooding – standardized value map

Legend
- 0.00 Not suitable
- 0.25
- 0.50
- 0.75
- 1.00 Suitable

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ECOSYSTEM SERVICES (ES)

- CRITERIA: ES LOCATION AND VALUE
- DATA: TOURISM SITES, SPIRITUAL SITES, TURTLE NESTING SITES, (CULTURAL ES), VEGETATION, FISHING ZONES, FLOODED AREAS & PONDS (PROVISIONING AND REGULATING ES).
- CLASSES: FOOD FROM CROPS, BIOMASS FUEL, COASTAL FISHERIES, INLAND FISHERIES, ECO-TOURISM, ETHICAL/SPRITUAL VALUES

- VALUE FUNCTION based on SERVICES PROVISION TO LOCAL PEOPLE
### Ecosystem services– value functions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irreplaceability</td>
<td>1</td>
</tr>
<tr>
<td>N° beneficiaries</td>
<td>0.2</td>
</tr>
<tr>
<td>Community perception</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ecosystem Service</th>
<th>Irreplaceability</th>
<th>N° beneficiaries</th>
<th>Community perception</th>
<th>Weighted sum</th>
<th>Normalised value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food from crops</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>1.54</td>
<td>0.7</td>
</tr>
<tr>
<td>Biomass for fuel</td>
<td>0.1</td>
<td>1</td>
<td>0.2</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Coastal fisheries</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Inland fisheries</td>
<td>0.3</td>
<td>0.6</td>
<td>0.5</td>
<td>0.92</td>
<td>0.4</td>
</tr>
<tr>
<td>Ecotourism</td>
<td>0.7</td>
<td>0.4</td>
<td>0.4</td>
<td>1.18</td>
<td>0.5</td>
</tr>
<tr>
<td>Ethical and spiritual values</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td>0.68</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Ecosystem services location overlay map

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Ecosystem services– standardized value map

- The Ecosystem Services Suitability map describes that to an area where there is a high **local community dependency** (due to irreplaceability, perception and n° of beneficiaries) on a specific ecosystem service, corresponds a low suitability for project facilities’ location.
Ecosystem services– standardized value map

The presence of two or more ecosystem services in a location results in decrease in suitability.
Ecosystem services vs Habitat

Habitat standardized value map

Ecosystem services standardized value map

Legend
Not suitable
Suitable

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Often for a high suitability in terms of ecosystem services corresponds a low suitability in terms of habitat and vice versa. This is mainly due to the high value attributed by local stakeholders to plantations for their function as ecosystem service providers, and their low value as a habitat type.
Provisioning services from abandoned plantations
SYNERGIES

- **CRITERIA:** ACCESSIBILITY

- **DATA:** ROADS, HUMAN SETTLEMENTS, EXISTING FACILITIES

- **CLASSES:** DISTANCE FROM EXISTING INFRASTRUCTURES*

- **VALUE FUNCTION:** proportional to the distance

---

* Double classification has been performed to differentiate the criterion for AC or others facilities
Synergies for CPF—standardized value map
Weights factors were attributed to objectives on the basis of the following parameters:

- Existence of alternatives to affected areas
- Receptor areas’ resilience (ability to recover or adapt to change without interventions)
- Data reliability (lower weights are attributed where there is data uncertainty in order to decrease the possible marginal error in final decision).

- Different weighting techniques were used for each macro-objective.
- Weights were attributed during a brainstorming session among the panel of seven experts.
Weights and aggregations

- The pair-wise technique, also known as the Analytical Hierarchy Process (AHP), was used to elaborate the Environmental map and is based on objectives that are measured on a ratio scale. In AHP the decision maker has to make a comparison for every pair of objectives: first qualitative and then quantitative on a scale from 1 to 9 to make the method operational.

- The rank ordering weighting technique was used to elaborate the Social Map and the Health & Safety Map.

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### EVALUATION TREE

<table>
<thead>
<tr>
<th>Results</th>
<th>Macro-Objective</th>
<th>Objective</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Suitability</strong></td>
<td><strong>Environment</strong> 0,30</td>
<td>Habitat</td>
<td>0,67</td>
</tr>
<tr>
<td><strong>map</strong></td>
<td></td>
<td>Fauna</td>
<td>0,09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flooding</td>
<td>0,24</td>
</tr>
<tr>
<td></td>
<td><strong>Social</strong> 0,40</td>
<td>Ecosystem Services</td>
<td>0,70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Synergies</td>
<td>0,30</td>
</tr>
<tr>
<td></td>
<td><strong>H-S</strong> 0,30</td>
<td>Safety</td>
<td>0,67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Health</td>
<td>0,33</td>
</tr>
<tr>
<td></td>
<td><strong>Constraints</strong></td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
CPF - I level maps

- Environment

- Social

- H-S

Legend scale refers to discrete values.

Legend:
- 0.00 Not suitable
- 0.25
- 0.50
- 0.75
- 1.00 Suitable
CPF - II level Map (suitability)

- Environment = 0.30
- Social = 0.40
- HS = 0.30

Legend scale refers to discrete values
Constraint for CPF

- CRITERIA: No buildable area
- CLASSES:
  - Pipeline: sicuro danno (50 m South 100m North);
  - CPF: sicuro danno (350 m)
  - Villages and schools: 500m by law

- VALUE FUNCTION: 1-0
Final suitability map
CPF – Location Options

Option ranking:
1. Option 3
2. Option 4
3. Option 2
4. Option 5
5. Option 1

Suitability classes:
- Very low
- Low
- Medium
- High
- Very high
- Constraint
Mean values:
- Option 1 = 56
- Option 2 = 67
- Option 3 = 70
- Option 4 = 70
- Option 5 = 64
AC – Location Value

Suitability classes:
- Very low
- Low
- Medium
- High
- Very high
- Constraint

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AC– Location Option Value

Mean value 74

Map value distribution

AC suitability map value distribution

AC suitability map cumulative distribution

Suitability classes
- Very low
- Low
- Medium
- High
- Very high
- Constraint

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Sensitivity analysis results

- A sensitivity analysis have been performed to evaluate the stability of the results

- The sensitivity analysis consists to apply a weights variation to CPF suitability map calculation

- New weights are:

  Var 1
  - Environment = 0,28
  - Social = 0,61
  - HS = 0,11

  Var 2
  - Environment = 0,19
  - Social = 0,19
  - HS = 0,61

- Sensitivity analysis results confirm the validity of the adopted scenario
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- Environment = 0.19
- Social = 0.19
- HS = 0.61

Options ranking for var_1 hypothesis is the same as the result map.
Absolute value are bigger in var 1 than Result Suitability Map.
The RSM approach is cautious.
CPF- Comparison SMR – var 2

- Environment = 0,28
- Social = 0,61
- HS = 0,11

- Options ranking for var_1 hypothesis is the same of the result map
- Absolute value are lower in var 2 then Suitability Map Results (SMR)
- No critical values emerging from the analysis
Conclusion

- SMCA is a powerful tool for comparing different locations.
- One limit of the study is that it is based on experts' judgment. Direct involvement of the stakeholders leads to more accurate results.
- Often valuable information are available at the client’s different departments.
- Ecosystem services approach is highly effective in including global and local stakeholders' view into the analysis.
Questions?
Thank you
### Evaluation criteria definition

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>Habitat change</th>
<th>Climate change</th>
<th>Invasive species</th>
<th>Over-exploitation</th>
<th>Pollution (nitrogen, phosphorus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boreal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperate</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Tropical</td>
<td></td>
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<tr>
<td>Temperate grassland</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Mediterranean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical grassland and savanna</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desert</td>
<td></td>
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<td></td>
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<tr>
<td>Inland water</td>
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**Source:** Millennium Ecosystem Assessment

**Driver's impact on biodiversity over the last century**

- Low: Decreasing impact
- Moderate: Continuing impact
- High: Increasing impact
- Very high: Very rapid increase of the impact

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Designing oil and gas plant siting alternatives  
Vina del Mar, April 2014