SALVETERRA

Systematic Analysis of Variables for Strategic Territorial Planning and Risk Assessment

Dr. Allan Astorga Gattgens
Feb. - 2019
Systematic Analysis of Variables for Strategic Territorial Planning and Risk Assessment
(SALVETERRA System)

Allan Astorga Gättgens

1. Introduction

In 2018-2019, three alarms were raised by the UN in regard to the state of the environment of Eco Sphere Earth. The first one refers to the great vulnerability in the face of Climate Change, which includes disaster development. The second one is related to the exponential loss of biodiversity which occurs in all ecosystems of the planet and plunges into the Sixth Great Extinction of Species (the first one resulting from anthropic causes). Lastly, the third one is the threat of reaching a Point of No Return and the start of the extinction of Humanity itself, due to the loss of fertile soils for agriculture and the lack of hydric resources which in turn will cause lack of food (both from land and sea sources) for an increasingly numerous human population, especially in the developing world.

The decarbonization derived from the Convention on Climate Change (UNFCCC) and the Paris Accords of 2015 is not sufficient to avoid the Point of No Return. Much more is necessary. The damage to ecosystems, the pollution and the larger part of the very serious environmental problems which we now face have occurred at a local scale, in other words, at local government level. Thus, the solutions to these problems also should start at a local level. There is no magic formula which will fix things quickly and painlessly. But there is indeed a need to start working on systemic actions.

In face of this situation, the author—as a specialist in Environmental Territorial Planning for local governments—has proposed to use this tool as the means to jumpstart action at the level of local governments in order to avoid the Point of No Return (which will occur between 2030 and 2050) and revert the great environmental problems which we now face and which will only worsen in the coming years.

As things stand, this article tries to explain how SALVETERRA can serve as a strategic tool to avoid the extinction of life on Eco Sphere Earth and save humanity itself.

---

1 Former Professor of Sedimentary and Environmental Geology at the Central American School of Geology of the University of Costa Rica. Degree in Geology from the University of Costa Rica. Doctor of Natural Sciences from the University of Stuttgart, Germany. International Consultant in Environmental Land Management, Environmental Impact Assessment, Strategic Environmental Assessment, Preventive Risk Management, Environmental Hydrogeology and Integral Environmental Management. Scientific collaborator of the System for the Integration of Central America and the Dominican Republic (SICA, CEPREDENAC, CCAD) within the framework of the Joint Declaration SICA - NASA. Scientific Collaborator of the AmeriGEO Disaster Commission. Mail: a.astorga.g@gmail.com, Tel: +506 88268551, www.allan-astorga.com. San José, Costa Rica.
2. ¿What is Environmental Territorial Planning

Environmental Territorial Planning (ETP, or OAT in Spanish) “consists of the inventory, diagnostics and definitions of the natural conditions of the environment in a given geographical space, with the purpose of defining its usage limitations and its aptitude conditions for the development of determined human activities. For practical purposes ETP means to analyze all the set of variables that are derived from a given environment and define from an integral analysis thereof a distribution or division of said geographical space according to the natural aptitudes of said space and according to the limitations it sets upon the development of activities, works or projects” (MINAE, 2006).

ETP differs from conventional Land Use Planning as it does not place humans at the center of the process, instead the key element is its emphasis on Nature and its condition of environmental fragility, which is inversely proportional to its capability to receive an additional environmental load (meaning, human activities). From a macro point of view, ETP allows to identify fragile ecosystems which require protection or recovery and it also defines zones for agriculture and livestock with recommendations about its sustainable use and also urban development zones for the design of ecological and sustainable cities. ETP is particularly useful to define according to environmental criteria the agricultural border at the level of local governments.

The main instrument to implement ETP is the method of the Environmental Fragility Index (EFI, or IFA in Spanish) developed by the author in the late 90s (see Mende & Astorga, 2006 and Astorga & Milano, 2010) and it was donated to the Department of Environmental Issues and Energy of Costa Rica to be published in the year 2006, as a decree by the Executive Power in order to standardize the procedure of integration of the environmental variable within the land use planning for local governments. Thus, in Costa Rica there is already ample experience in the matter of the application of this methodology and of ETP, which has been already put in action in over 50 (out of 82) local government of the country. In Figure 1, an example is shown of the base map for ETP in the Canton of Limón on the Caribbean Coast of Costa Rica (see Astorga et al, 2019). The use of the EFI method allows to generate as one of its output products, the map of environmental macro zones, of three categories: Very High Environmental Fragility, High Environmental Fragility and Moderate Environmental Fragility. There are no zones of low, o very low environmental fragility. As part of Figure 1, there is also a text box that provides guidance on the human usage types that could be developed on the base of this zoning. The areas in red (which mark Very High Environmental Fragility) should be dedicated primarily to conservation and eco-system recovery. Areas in orange (High Environmental Fragility) should be used for sustainable agriculture and livestock activities and areas in yellow (Moderate Environmental Fragility) for ecologically sustainable urban development.
3. Basic elements of the Environmental Fragility Index (EFI, or IFA) Methodology

The EFI (IFA) methodology is a process for the identification of environmental factors by means of geospatial images (at a 1:25,000 scale) and field data. In Table 1 the whole set of 35 environmental factors used for generating EFI (IFA) maps are listed. As shown, an important percentage of these factors comes from the detailed interpretation of geospatial images. Many others must come from local information (locally published or through scientific journals) and from field work for the identification of geospatial unities.

The identified environmental factors are rated according to a standard established by the EFI (IFA) methodology (and bettered by the author for SALVETERRA) which has been tested in the field for almost 15 years in Costa Rica in over 50 municipalities. Each factor is rated according to the following scale: 1 (Very High Fragility), 2 (High Fragility), 3 (Moderate Fragility), 4 (low), 5 (very low). The rating of each factor automatically defines either an environmental technical limiting factor or to the contrary a technical potentiality. The generation of the maps is realized by means of a GIS (Geographical Information System) that generates maps for each factor and the combination of them generates the maps of the four EFI categories: Geoaptitude EFI (see Astorga & Campos, 2001), EFI Bioaptitude, EFI Edafoaptitude and EFI Anthropoaptitud (see Figure 2).
# Table 1. Key EFI Factors

<table>
<thead>
<tr>
<th>No.</th>
<th>DATA</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Delimitation of a geological unit</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>2</td>
<td>Name of a geological unit</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>3</td>
<td>Rock hardness</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>4</td>
<td>Consistency</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>5</td>
<td>Lineation factor</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>6</td>
<td>Soil layer thickness</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>7</td>
<td>Clay content</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>8</td>
<td>Porosity / Apparent permeability</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>9</td>
<td>Delimitation of a geomorphological unit</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>10</td>
<td>Slope</td>
<td>Satellite data process</td>
</tr>
<tr>
<td>11</td>
<td>Relative relief</td>
<td>Satellite data process</td>
</tr>
<tr>
<td>12</td>
<td>Drain density (km/km²)</td>
<td>Satellite data process</td>
</tr>
<tr>
<td>13</td>
<td>Importance of erosion processes</td>
<td>Field data (1:25.000)*</td>
</tr>
<tr>
<td>14</td>
<td>Importance of sedimentation processes</td>
<td>Field data (1:25.000)*</td>
</tr>
<tr>
<td>15</td>
<td>Drain density of permanent currents</td>
<td>Satellite data process</td>
</tr>
<tr>
<td>16</td>
<td>Hydrogeological profile index</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>17</td>
<td>Infiltration potential</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>18</td>
<td>Data of groundwater extraction wells</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>19</td>
<td>The top three rainy months of the years</td>
<td>Satellite data process</td>
</tr>
<tr>
<td>20</td>
<td>Slope direction vs. main lineation direction</td>
<td>Field data (1:25.000)*</td>
</tr>
<tr>
<td>21</td>
<td>Regional seismicity potential</td>
<td>Satellite data process**</td>
</tr>
<tr>
<td>22</td>
<td>Local seismicity potential (seismicity index)</td>
<td>Satellite data process**</td>
</tr>
<tr>
<td>23</td>
<td>Terrain liquefaction potential</td>
<td>Field data (1:25.000)</td>
</tr>
<tr>
<td>24</td>
<td>Geological fault-caused Surface fracture potential</td>
<td>Field data (1:25.000)*</td>
</tr>
<tr>
<td>25</td>
<td>Volcanic threat</td>
<td>Satellite data process**</td>
</tr>
<tr>
<td>26</td>
<td>Tsunami potential in coastal regions</td>
<td>Satellite data process**</td>
</tr>
<tr>
<td>27</td>
<td>Flooding potential</td>
<td>Satellite data process**</td>
</tr>
<tr>
<td>28</td>
<td>Vegetal coverage types</td>
<td>Satellite data process**</td>
</tr>
<tr>
<td>29</td>
<td>Biological corridor</td>
<td>Satellite data process</td>
</tr>
<tr>
<td>30</td>
<td>Bodies of water and drainage network</td>
<td>Satellite data process**</td>
</tr>
<tr>
<td>31</td>
<td>Soil types</td>
<td>Satellite data process**</td>
</tr>
<tr>
<td>32</td>
<td>Land use capacity</td>
<td>Satellite data process</td>
</tr>
<tr>
<td>33</td>
<td>Agriculture and livestock use</td>
<td>Satellite data process</td>
</tr>
<tr>
<td>34</td>
<td>Urbanistic use</td>
<td>Satellite data process</td>
</tr>
<tr>
<td>35</td>
<td>Archaeological sites, natural and scientific heritage</td>
<td>Satellite data process**</td>
</tr>
<tr>
<td>36</td>
<td>Annual maximum temperature projection data</td>
<td>Satellite data process</td>
</tr>
</tbody>
</table>

Key: (*) with the support of satellite images. (**) with the support of local data

Figure 3 shows the logic of the data process and the environmental fragility map generation for geospatial units, defined according to geological and geomorphological criterion (Mende & Astorga, 2006). This process generates environmental fragility maps that are used as the basis for the automatic generation of environmental territorial planning maps, which are defined by a system of algorithms that allow the generation of the Limiting Factors and Potential Use Table for each of the identified environmental fragility units.
**Fig. 2.** Analysis categories considered part of the EFI methodology and their different components. As it can be seen, all key elements of the physical, biological and human environment are taken into consideration.

**Fig. 3.** Brief synopsis of the logical flow of the application process of the Environmental Fragility Index for the identification of geospatial units and the development of environmental fragility zoning as base for its transformation into environmental territorial planning. The system can function automatically by a system of algorithms and AI.
Figure 4 shows the applied logic for the generation of thematic maps in SALVETERRA. First of all, systematic research is carried out on the information available in the field of study (scientific publications, reports, thematic mapping, historical record of disaster events, academic data, etc.) and is processed to obtain a base map of information. In addition, geospatial images are processed to complete research information. Thirdly, on this basis, a base map is obtained and field work is carried out.

During the fieldwork, a number of variables already standardized are obtained for each identified geospatial unit (see Table 2) and the corresponding values are set.

The dataset is processed using a geographic information system to generate thematic maps for each component of the EFI (Environmental Fragility Index)

![Flowchart](image)

**Fig. 4. Methodological procedure for the generation of EFI maps, for each environmental factor.** Previously published data or retrieved from different institutions is compiled and combined with the interpretation of geospatial images and complemented with field-work. Finally, everything is integrated and a thematic map is generated along with its corresponding EFI map (see Figure 5)

Figure 5 shows an example for the canton of Limón in the Caribbean region of Costa Rica. The geological map of Limón shows the respective geological profiles, as well as the geospatial units identified (geology – geomorphology) with the values set for the different factors. Figure 6 shows the resulting map of the Litopetrophysical Factor of the EFI Geoaptitude. This factor is, in a practical way, linked to the supporting capacity of the plot of land for the development of human activities. The system uses five levels of environmental fragility: from Very high to very low.
Fig. 5. Geological map of the canton of Limón in Costa Rica and its corresponding geological profiles. Below it is rating of the environmental factors according to the EFI methodology. The resulting EFI map is shown in Figure 7.
Fig. 6. EFI Map of Lithopetrophysical Geoaptitude generated as a product of the geological map of the canton of Limón in Costa Rica (see Figure 6). This map measures the geomechanical behavior of the geological units and allows a better understanding since it only uses types of environmental fragility rating.
Following the logic discussed above, the rest of the set of EFI maps are generated for the different factors. Table 2 shows the main maps with their different direct uses and which have been produced by the application of the EFI methodology and extended as the SALVETERRA system.

**Table 2.**
Main maps generated from the application of the EFI methodology and their direct uses

<table>
<thead>
<tr>
<th>No.</th>
<th>Thematic map</th>
<th>EFI map</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Geology</td>
<td>Lithopetrophysical Geoaptitude</td>
<td>Determines geomechanical behavior such as support load</td>
</tr>
<tr>
<td>4.</td>
<td>Hydrogeology</td>
<td>Hydrogeological Geoaptitude</td>
<td>It establishes the existence of aquifers in the higher subsoil. Determines the hydrogeological vulnerability to pollution. Determines the sites of potential drilling for wells for the extraction of groundwater. Determines the areas for aquifer recharge and discharge.</td>
</tr>
<tr>
<td>5.</td>
<td>Slope stability</td>
<td>Slide Geoaptitude.</td>
<td>Identifies unstable slope zones susceptible to slides generated by hydrometeorological events or seismicity.</td>
</tr>
<tr>
<td>6.</td>
<td>Natural hazards</td>
<td>Integrated Natural Hazard Geoaptitude</td>
<td>Map that integrates all areas susceptible to natural hazard conditions, for simplicity categories of Very High and High Hazard are used. Determines the degree of vulnerability and defines buildings and infrastructures in conditions of High and Very High risk</td>
</tr>
<tr>
<td>7.</td>
<td>Local and Regional Seismicity</td>
<td>Seismicity Geoaptitude</td>
<td>Determines the susceptibility of the geographical space to the seismic activity produced by regional or local sources. Maximum intensities and seismic acceleration.</td>
</tr>
<tr>
<td>8.</td>
<td>Surface fracture potential caused by active geological faults</td>
<td>Neotectonic Geoaptitude</td>
<td>It categorizes faults as active, potentially active or inactive. It fixes safety zones for the active and potentially active geological faults.</td>
</tr>
<tr>
<td>9.</td>
<td>Liquefaction potential</td>
<td>Liquefaction Geoaptitude</td>
<td>Defines geospatial units with liquefaction potential and restricts soil use.</td>
</tr>
<tr>
<td>10.</td>
<td>Flooding potential</td>
<td>Fluvial flooding or mudslide path Geoaptitude</td>
<td>Defines areas of High or Very High Risk of flooding and mudslide path or any flow that descends by a fluvial basin.</td>
</tr>
<tr>
<td>No.</td>
<td>Thematic map</td>
<td>EFI map</td>
<td>Uses</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>11</td>
<td>Coastal zone Tsunami potential</td>
<td>Tsunami Geoaptitude</td>
<td>Defines the zone with the higher potential effects for Tsunamis based on historical registries for the area.</td>
</tr>
<tr>
<td>12</td>
<td>Volcanic Hazard Potential</td>
<td>Volcanism Geoaptitude</td>
<td>Defines the sites with the higher potential effects caused by volcanic activity from a localized emission center located within a 30km radius.</td>
</tr>
<tr>
<td>13</td>
<td>Geoaptitude</td>
<td>Integrated Geoaptitude EFI</td>
<td>Defines the areas of higher Geoaptitude fragility and its technical limiting factors. Also it identifies the sites with a better Geoaptitude in order to locate human activities of potential high impact as long as it does not affect other environmental factors.</td>
</tr>
<tr>
<td>15</td>
<td>Present soil types</td>
<td></td>
<td>Based on edafological data and the integration with geological and geomorphological data. Defines the soils with higher agricultural fertility and the ones with lesser potential. It delimits desertification areas.</td>
</tr>
<tr>
<td>16</td>
<td>Land Use Load Category</td>
<td>Edafoaptitude</td>
<td>It delimits the zones of forest aptitude and the minimal area that should have forest cover or vegetation eco-systems. It limits the agricultural border, according to land use load.</td>
</tr>
<tr>
<td>17</td>
<td>Agricultural uses</td>
<td></td>
<td>Determines the types of crops present in the geographical space.</td>
</tr>
<tr>
<td>18</td>
<td>Urban uses</td>
<td></td>
<td>Determines the different usage categories according to constructions, including industrial areas, urban areas, commercial areas, etc. It can highlight strategic infrastructure: hospitals, schools, etc.</td>
</tr>
<tr>
<td>19</td>
<td>Transit infrastructure and road networks</td>
<td></td>
<td>It delimits and categorizes all the existing road network and their conditions. It identifies strategic infrastructure such as bridges, airports, ports, oil pipelines, chemical plants, etc.</td>
</tr>
<tr>
<td>20</td>
<td>Scientific or cultural interest areas</td>
<td></td>
<td>Archaeological sites. Cultural and scientific heritage sites. Geotopes and Geosites.</td>
</tr>
<tr>
<td>21</td>
<td>Landscape map</td>
<td>Landscape EFI</td>
<td>It defines landscape units according to topographical criteria and land use thereof.</td>
</tr>
<tr>
<td>22</td>
<td>Integrated actual use map</td>
<td>Anthropoaptitud EFI</td>
<td>It locates the different existing land uses and rates then environmentally.</td>
</tr>
<tr>
<td>No.</td>
<td>Thematic map</td>
<td>EFI map</td>
<td>Uses</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>23.</td>
<td>Integrated EFI Map</td>
<td></td>
<td>Identifies and limits the macrozone of environmental fragility to define guidelines for land use.</td>
</tr>
<tr>
<td>24.</td>
<td>Sub classified EFI Map</td>
<td></td>
<td>Identification of all existing environmental fragility zones in the geographical space. Each zone is accompanied with a technical Table of Limiting Factors and Potentialities, along with the potential use recommendations based on environmental criteria. The environmental conditions are fixed.</td>
</tr>
<tr>
<td>25.</td>
<td>Actual environmental overuse map</td>
<td>Overlay of the actual use map over the EFI Sub classified Map</td>
<td>It established the balanced environmental use zones. It identifies the overuse zones and the reasons that generate said overuse. It defines two categories of intermediate use and critical use. It established the corrective measures to apply. In some cases it fixes the guidelines so high impact activity is relocated to a site of lesser environmental fragility.</td>
</tr>
<tr>
<td>26.</td>
<td>Base Environmental Map</td>
<td>Combines the EFI Sub classified Map and the Actual Environmental Overuse Map</td>
<td>It is the base map for the Environmental Territorial Planning of the geographical space.</td>
</tr>
<tr>
<td>27.</td>
<td>Land or soil use zoning Map</td>
<td>Environmental Territorial Planning Map</td>
<td>Defines geospatial units with the use of natural and non-artificial limits. It determines the maximum use for land for human, urban and agricultural activities. It limits the agricultural border. It established the conservation areas and the ecosystem enhancement guidelines.</td>
</tr>
<tr>
<td>28.</td>
<td>Technical and juridical environmental land use restrictions map</td>
<td></td>
<td>Conforms a layer that is overlaid to the zoning map and it established the technical-juridical restriction to the land use for human activities.</td>
</tr>
<tr>
<td>29.</td>
<td>Potential overuse map</td>
<td>Overlay of the Environmental Base Map over the Land use zoning map</td>
<td>Allows to identify the conformity of the environmental territorial planning and it establishes the required corrections when necessary.</td>
</tr>
<tr>
<td>30.</td>
<td>Climate scenarios map</td>
<td>Establishment of annual maximum temperatures on the map of environmental fragility and land use proposal</td>
<td>It allows establishing scenarios of affectation and adaptation to climate change.</td>
</tr>
</tbody>
</table>

4. **SALVETERRA and local governments**

Local governments play a key role; given that they are the entity that defines the guidelines that determine strategic decisions regarding land use in their jurisdictions. They define what the urban development areas are; the agricultural areas and livestock activity zones and they can even intervene in the definition of areas for the protection of eco-systems and their recovery. The delimitation of the agricultural border is a field of action of local governments, which should be the first state institution to take action on the topic of environmental protection. Also, local government should manage other topics such as hydric resource management, recovery of ecosystems and degraded basins, preventive risk management, landscape management, cultural use of geotouristic resources and archaeological heritage, among others.

On the other hand, it is relevant to pinpoint the damage notices by the UN for terrestrial ecosystems which has occurred at a local level and has been cumulative. Thus the process to stop this damage and revert it in the short timeframe before the Point of No Return (2030 to 2050 according to UN reports) must be implemented at a local level, where local governments play a leading role.

Local government also play a key role in the implementation of some of the measures, that recently over 11,000 scientists of 153 countries published in an open letter in which they warn that to avoid “incalculable suffering due to climate change” dramatic changes must be made to society. Scientists have a moral obligation to clearly warn humanity of any catastrophic threat and to tell things as they are, as is pointed out in *BioScience Magazine* (BBC News, 10.11.2019).

Within these urgent actions recommended to be implemented at a local level by local governments the following can be highlighted:

- **Polluting agents:** It is necessary to eliminate or limit emissions or production of methane, hydrofluorocarbons and soot. By limiting these contaminants, the short term tendency to warming to be cut by a 50% within few decades.

- **Nature:** The destruction of forests must be stopped, also forest areas, prairies and mangroves must be restored. These measure will raise CO2 trapping from the environment.

- **Food:** a great change in diet is urgent. We all must consume a higher part of plant-based food and reduce food of animal origin such as red meat. It is also imperative to reduce food waste.

- **Economy:** Decrease the economy's dependence on fossil fuels. The economic
approach relentlessly pursuing growth needs to be changed. It only measures the Gross Domestic Product (GDP) as an indicator.

- **Population**: the world populace is growing at a pace of 200,000 births each day. It is recommended to reduce the growth pressure of the world population through ethical measures such as encouraging and guaranteeing the education of girls and young women. Several studies have shown that the higher the education level of women, it usually goes hand in hand with a reduction in the number of children.

These actions must be supported, as possible, from local governments with concrete plans over land use and specific management actions within their jurisdictions. State or national governments may develop general policies but actions required the intervention of everyone and local governments and the communities that comprise them are fundamental as they function as autonomous cells and that can collaborate directly and function synchronically with other cells, other local governments.

As part of the ETP, comprehensive environmental education process is being envisaged in various components. One includes learning to "live with risk" and others are aimed at environmental protection, pollution control, improving eating habits and guidance on entrepreneurship and development of diverse micro-enterprises as a product of the environmental information generated. An example of this is Geotourism or the use of non-metallic mining resources, particularly with regard to the use of semi-precious stones for the development of handicrafts and other activities.

5. **Fulfillment of the 2030 Sustainable Development Goals**

At the United Nations Sustainable Development Summit in September 2015, the UN Member States approved the 2030 Agenda for Sustainable Development which includes a set of 17 Sustainable Development Goals (SDGs) to end poverty, fight against inequality and face climate change. The SDGs, commonly called World Goals, are based upon the Millenium Development Goals (MDGs): eight goals in the fight against poverty that the world set to complete by 2015. The MDGs were adopted in the year 2000 encompass objectives such as the reduction of poverty, world hunger, disease, gender inequality and raising access to potable water and sanitation. Huge progress was made in regard to the MDGs, which shows the value of having a unifying agenda supported by concrete goals and objectives. In spite of this success, poverty has not been eradicated for all. Within this framework, and with a direct link with the Environmental Territorial Planning, there are at least two objectives with their respective guidelines. These are as follows:
Goal 11. Sustainable cities and communities

Make cities and human settlements inclusive, safe, resilient and sustainable.

- By 2030, increase inclusive and sustainable urbanization and the capacity for a participatory, integrated and sustainable planning and management of human settlements in all countries.

- Strengthen efforts to protect and safeguard the world’s cultural and natural heritage

- By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

- By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

- By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older people and people with disabilities

- Support positive economic, social and environmental linkages between urban, peri-urban and rural areas by strengthening national and regional development planning

- By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels

Goal 15. Life on Earth

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

- By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

- By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and
By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.

By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development.

Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.

Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as agreed internationally.

Take urgent action to end poaching and trafficking in protected species of flora and fauna and address illegal demand and supply of wild products.

By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species.

By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and recording data on the evolution of poverty.

Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems.

Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation.

Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities.

It is possible to conclude that to comply with the above quoted goals and the vast majority of its guidelines it becomes imperative to implement Environmental Territorial Planning at a sufficiently detailed scale (1:25,000) so that local governments can perform concrete actions to fulfil these guidelines.

The Sendai Framework for Disaster Risk Reduction was adopted at the third United Nations World Conference celebrated in Sendai (Japan) between March 14th and March 18th, 2015. It is a successor instrument to the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters.

In order to support the evaluation of global advancement in attaining the goals and targets of the present framework seven global goals have been defined. These goals are measured at a global scale and will be complemented with work destined to prepare the pertinent indicators. The goals and national indicators also will contribute to obtain the result and targets of the Framework:

a. Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality rate in the decade 2020-2030 compared to the period 2005-2015.

b. Substantially reduce the number of affected people globally by 2030, aiming to lower average global figure per 100,000 in the decade 2020 -2030 compared to the period 2005-2015.

c. Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030.

d. Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030.

e. Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020.

f. Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this Framework by 2030.

g. Significantly increase the availability and access to multi-threat early warning systems as well as to information and disaster risk assessments provided to people and access to the same by 2030.

As part of the priorities set by the Sendai Framework, the following are noted:
Priority 1: Understand the risk of disasters.
Priority 2. Strengthen disaster risk governance to manage such risk.

Priority 3: Investing in disaster risk reduction for resilience.
Priority 4: Increase disaster preparedness to provide an effective response and to “better rebuild” in the areas of recovery, rehabilitation and reconstruction.

Correct risk management, especially in preventive action, must be based on the Environmental Territorial Planning. Figure 8 presents the list of existing GeoRisks in the nature of many countries, particularly those located within areas of active tectonic margins.

In the topic of preventive risk management, it is essential to map natural threat sources (GeoRisks) on an appropriate scale (1:25,000 or more detailed) in order to set land use (or soil) rules that will allow to establish safe sites to develop human activities or at least to establish designs and constraints that provide more security to the infrastructure works that are developed.

In this regard, the EFI Geoaptitude component provides all the spectrum of necessary information to be able to carry out a correct preventive risk management (see Figures 9 and 10).

Figure 9 shows the Integrated Geoaptitude EFI Map, Natural Threats factor of the canton of Limón, in Costa Rica. This map was obtained from the sum of the following natural threat maps:

- Map of unstable slopes and potential landslides.
- Map of Threat of seismic events.
- Map of Seismic acceleration.
- Map of active geological faults with surface fracture potential.
- Map of areas with liquefaction potential.
- Map of Flood zones.
- Map of Tsunami threat in coastal areas.
- Map of Volcanic threat.

All of these maps individually or in sum have a great usage potential.
**Fig. 8.** Spectrum of geological risks or (geo-risks) that exist in Nature and their respective characterization in relation to risk management. It is emphasized in the “Prevention” column in the sense that in 95% of the cases, preventive action can be done through land use ruling, in other words, through Environmental Territorial Planning (ETP).
Figure 10 shows a practical way of applying the natural threat maps to generate risk maps. In this case, the Great Metropolitan Area of the Central Valley in Costa Rica is shown. About 60% of Costa Rica’s population (approximately three million inhabitants) is agglomerated.

The environmental fragility mapping works were done according to the framework of the studies of the Territorial Environmental Base for the Urban and Rural Planning of the Great Metropolitan Area (PRUGAM, see Astorga et al., 2008).

The uppermost map indicates the high and very high threat areas (to different sources) identified at 1:10,000 scale for the nearly 2 thousand km² of GAM in Costa Rica. The map in the center indicates all areas where there is human infrastructure within the GAM. This map is derived from the so-called Current Soil Use Map. It is worth mentioning that this map is the sum of an extensive series of layers that were identified.

This current map of land use can be segregated in different sectors and activities:

- Residential areas of high population density.
- Medium density residential areas.
- Low density residential areas.
- Industrial zones.
- Commercial areas.
- Institutional areas with strategic infrastructure such as health centers, education centers, government offices, etc.
- Railway infrastructure.
- Strategic road infrastructure (bridges, roads).
- Airport infrastructure, etc.
- Diverse crop areas

Thus, when we overlap the set of layers of the various uses on the threat map, it is possible to obtain the maps of the infrastructure not only at high, but also at very high risk conditions. The lower map in Figure 10 shows this complete superposition. Data obtained for Costa Rica’s GAM indicate that approximately 30% of the total infrastructure is at high and very high risk conditions of different types of natural threats.

With this information it is possible to issue specific guidelines to carry out Preventive Risk Management, and in addition, development of Parametric Insurance and Environmental Education in order to coexist with the risk. This way, the Natural Threats – Risk component of the SALVETERRA System – fully complies with the primary objectives of the UN Sendai Framework, including with the potential to develop a systematic approach, i.e. by productive sector or strategic infrastructure.
Fig. 9. Synthetic maps of the natural hazard susceptibility for the canton of Limón in Costa Rica. It matches the sum of the maps of landslides (unstable slopes), seismicity, local seismic acceleration, surface fracture potential due to active geological faults, liquefaction, flooding, tsunamis in coastal regions and volcanism. Obtaining this cartography at a 1:25,000 scale or higher detail allows local governments to perform preventive risk management at a local scale which is crucial to be able to save live and perform corrective actions such as education to inhabit with risk, emergency plans, early alert systems and even develop parametric insurance development and resilience insurance against Disasters. The development of this cartography also allows to identify strategic infrastructure which is located in conditions of High to Very High risk.

<table>
<thead>
<tr>
<th>Landslides</th>
<th>Seismicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seismic acceleration</td>
<td>Geological faulting</td>
</tr>
<tr>
<td>Liquefaction</td>
<td>Flooding</td>
</tr>
<tr>
<td>Tsunamis</td>
<td>Volcanism</td>
</tr>
</tbody>
</table>
Fig. 10. Example of the products that are generated in matters of Risk Management: a) Map of unstable slopes, b) Map of urbanized areas and c) Map of urbanized areas on unstable slopes in high to very high risk. Area of study: Greater Metropolitan Area of San José, Costa Rica (based upon Astorga et al., 2008).
The case of Quebrada Lajas in Escazú is an unfortunate example that should not happen again. The night of November 10, 2010, there were 23 people who died in this place. For 5 years, in 2005, the author and his collaborators had drawn the map of threat of landslides and avalanches that can be seen in the image above on the left. The black box indicates the area of Quebrada Lajas where the disaster event occurred. In the map drawn up in 2005, it was identified that the avalanche passage area would have an approximate width of 80 meters, which can be observed in the photograph presented to the right of the image. As part of the Report that the author and his collaborators delivered to the Municipality of Escazú in 2005, the fact that there were constructions (houses) within the very high risk area was stressed, so it was of great importance to inform residents to develop and apply, if necessary, an emergency plan linked to the avalanche path. The guidelines were not fulfilled and human lives were lost. Something that should never happen again. More than 50 cantons in the country have such information. It is estimated that one third of all buildings in the Greater Metropolitan Area and possibly the population (about one million people) are in conditions of High and Very High Risk. The country's legislation and, also, the international agreements signed by the country, such as the United Nations Sendai Framework, force the Costa Rican State to take measures to save lives and manage risk. One of the most efficient ways is to have a disaster insurance policy generated as a product of the environmental knowledge of the territory.
7. New UN Urban Agenda

The New Urban Agenda (NUA) is a document resulting from the United Nations Conference on Housing and Sustainable Urban Development (HIII) held in October 2016 in Quito, Ecuador. This document, which aims to serve as a guide for urban planning and development over the next two decades, raises this concern: "The global urban population will double by 2050. This brings enormous sustainability problems in housing, infrastructure, basic services, food security, health, education, decent jobs, security, and environment, among others."

The studies done by the UN indicate that, as early as 2006, the housing deficit in Latin America and the Caribbean was of 18.7 million urban households. By 2011, The ECLAC reported it to be of 22.7 million. As the urban population doubles, the deficit will grow significantly. Additionally, governments will require over $310 billion to cover the cumulative deficit, and US$70 billion each year to meet the annual demand for 2 million homes in low-income sectors. As the population doubles, annual demand will double too and will not be met, so the cumulative deficit will continue to grow. If we incorporate the variable of vulnerability to natural threats such as earthquakes, hurricanes, floods, droughts, extreme hydrometeorological phenomena and climate change, we reveal an even worse reality: the numbers are increasing significantly.

We can add up the fact that two-thirds of Homes in Latin America have been "self-built" by their inhabitants without any technical support; so they do not have enough structural capacity to withstand natural threats. Taking this situation into account, the deficit is much larger than the one officially assessed and is closer to two-thirds of the region’s total homes.

UN studies also indicate that in the absence of financial and institutional resources to meet this growing demand, the poor in Latin America will continue to generate their own housing solutions as well as the city habitat. This is the harsh reality, and in order to face it, it is necessary to achieve a deep and efficient change in urban development policies, and in visions and methods of government. The New Urban Agenda is addressing the attention towards this tough problem.

It is necessary to emphasize the danger that this represents from a risk point of view since our observations in various places in Latin America show that this unplanned urban development of vegetative growth is located, almost always, in high-end sites of very high threat to different sources of GeoRisks and Climate Crisis events. In other words, they are automatically installed in High and Very High Risk conditions.
According to the UN, the New Urban Agenda (NUA) has three fundamental objectives: to promote quality of life; an inclusive and competitive economy; resilient and sustainable urban development. Based on these objectives, this document sets out a series of challenges that seek to guide institutions to achieve an inclusive and people-oriented vision, in other words, on Sustainable Human Development. The following is the summary of these challenges:

- Attention to the needs, services and quality of life (for people’s development).
- Knowledge, training, entrepreneurship and productive development (to combat exclusion).
- Development of networks and associative capabilities (incentive to participation and association).
- Development of entrepreneurship and productivity for people’s economic growth.
- Institutional and governance strengthening (regulations, decentralization, participation), among others.
- Housing, infrastructure, urban planning (planning and execution of projects).
- Environment and disaster risk reduction

ETP generates very useful environmental information for the implementation of the New UN Urban Agenda. Not only in terms of identification of high and very high threat sites, but also the identification of areas of better environmental fragility and suitable for a sustainable, resilient and safe urban development (see Figure 11).

![Figure 11](image1.jpg)

**Fig. 11.** Tegucigalpa, Honduras. Urban development in a mountainous relief area of high threat of landslides. Photo of Allan Astorga (2019). It is estimated that in Central America and the Dominican Republic (SICA Region) about 20 million people live in conditions of high and very high risk to the natural threats caused by GeoRisks and the effects of the Climate Crisis.
8. Protection of the Right to a Healthy Environment


The following are the most relevant aspects developed by the Inter-American Court strictly related to the right to a healthy environment:

"The right to a healthy environment has both individual and collective connotations. In its collective dimension, it constitutes a universal interest, which is due to both present and future generations, while infringement in its individual dimension can have direct or indirect repercussions on people due to their connection with others rights, such as the right to health, personal integrity or life, among others, to the extent that environmental degradation can cause irreparable harm to human beings, so a healthy environment is a fundamental right for the existence of humanity" (Paragraph 59).

The right to a healthy environment is an autonomous right that, unlike other rights, protects environmental components, such as forests, rivers, seas and others, as legal interests in themselves, even in the absence of certainty or evidence of the risk to individuals. It is a right included in the economic, social and cultural rights (DESCA), protected by article 26 of the Convention. This right protects nature and the environment not only because of its usefulness to human beings, but also because of its importance to other living organisms with whom the planet is shared with and which deserve self-protection. To this end, the Court notified the global tendency to recognize legal capacity and, therefore, rights to nature not only in court judgments but even in constitutional ordering" (Paragraph 62).

"The rights that are particularly linked to the environment are classified into two groups: (a) substantive rights, such as the right to life, personal integrity, health or property, and b) procedural rights, including: freedom of expression and association, information, participation in decision-making and an effective resource" (Paragraph 64).

"The right to a healthy environment as an autonomous right is different from the environmental content arising from the protection of other rights particularly vulnerable to environmental impacts, for example, the right to life, personal integrity, private life, water, food, housing, participation in cultural life, right to property, right to move and the right not to be forcibly displaced by environmental deterioration" (Paragraphs 63 and 66).

"In order to comply with the obligation of prevention, each States should regulate,
check and monitor all activities that may cause significant harm to the environment; conduct environmental impact studies where there is a significant risk of environmental damage; establish a contingency plan, in order to have safety measures and procedures to minimize the possibility of major environmental accidents; and mitigate the significant environmental damage that would have occurred, even if it had occurred despite preventive actions of the State” (Paragraphs 141 to 174).

In this way, the application of this Sui Generis right also favors the issue of the realization of a local correct Environmental Territorial Planning, since it is the most effective way to protect the right to a healthy environment.

9. Salvation and recovery of the Earth’s Ecosphere as a strategic step

The Terrestrial Ecosphere is in serious danger. The three red alerts given by the UN confirm this. It is highly necessary to apply simultaneous and global mitigating and preventive measures.

One of the biggest problems we have to raise awareness of this planetary crisis is that the negative effects of the three UN alerts occur during several years or even decades. Thus, the routine problems of the economy, taxes, the cost of living, education, health and others are much more important. Not only for ordinary people, but also for the press and the government authorities themselves, both central and municipal. It seems that nothing is happening, but actually there are changes taking place and in a much accelerated way.

While there are global measures to be taken which can mitigate our planetary crisis, such as the Paris Accords of 2015, there are other urgent measures that can be taken now and the more direct and effective way to implement them is in the local scale, through local governments. Thus, the huge importance placed on the fact that local governments and local communities take conscience of the urgency to rank actions and execute them.

Every local government represents a cell of a huge living organism that composes the Earth’s continental Ecosphere. Just as cells have their own autonomous function and survival system, so local governments must function within their territories to revert the damage caused by humankind. It is the only reasonable way, there is no magical solution. It requires a lot of work at a local scale with great compromise from local authorities, mayor, educators, businesspeople and producers, academia, independent professionals and the general population. As we have pointed out the key steps to be taken are:
• Environmental Territorial Planning at a detailed scale (1:25,000)
• Soil use categorization: urban, agriculture and farming, conservation with a clear balance between the three components
• Recovery of degraded territories with strategic and natural reforestation for the betterment of ecosystems
• A quick transition from the productive model of agricultural and livestock activities to a vision of non-polluting and state of the art technology-based regenerative agriculture and livestock
• Environmentally sustainable urban development, nonpolluting and with incentives for sustainable production that offers opportunities of economic development to human communities to eradicate poverty and mend the social breach.
• Correction and prevention of pollution
• A rapid transition to the use of more sustainable and safe energies such as geothermal
• Strategic planning of development focused in a raise of human and natural resilience

The advantage of taking action with all these measures, as soon as possible, is that it allows every local government to raise its resilience and promote a natural and human development in a more accelerated manner, and also environmentally sustainable at the same time.

The individual action of every local government in the same direction will allow our Ecosphere to heal “cell by cell” and that we can avoid the point of no return. As we can see it is a job for all of us, and we need local authorities clearly conscious and responsible of the urgent tasks ahead.

National and planetary actions: the central government authorities must promote strategic actions that facilitate the local governments to take measure as soon as possible. It is necessary that the same government authorities take a more proactive action in the tasks that must be developed to save Ecosphere Earth. Policies must be based on technical criteria that allow to make strategic decision in very brief timeframes.

In many cases the juridical framework must be updated to adapt to the crisis conditions we face today. The same strategic measures mentioned before, must apply to a national framework that defines a management policy to save Ecosphere Earth.

On a global level, strategic action is also needed. One of the most important is to save the oceans and ocean base life. It is vital, because the marine ecosphere is also in grave danger. The Principle of Environmental Sustainability (see, https://allan-astorga.com)
must be integrated into the economy, because to the contrary, the economic system will become a major global obstacle in the struggle to avoid the Point of No Return.

UN Actions and programs must be bolstered and accelerated, such as the Sustainable Development Goals 2030. Greater investment is necessary in these global programs. Less investment in weapons and war, and a much bigger investment in saving the planetary Ecosphere.

10. The Environmental Territorial Planning Strategy

Taking up the example of the canton of Limón in Costa Rica, with the application of the ETP and the development of the Environmental Base Map (see Figure 12), it is possible to go into the implementation of concrete actions to comply with the guidelines of the United Nations aimed at mitigating the effects of climate change and working for the recovery of the Terrestial Ecosphere, without neglecting the need for humanity to progress, but in an environmentally sustainable way.

Figure 12 shows an environmental zoning map generated by the ETP as a strategic element for the Territorial Planning of a given geographical area, in this case the canton of Limón, in Costa Rica. The map includes the identified areas of environmental fragility and, in addition, the current environmental overuse zones, which correspond to areas where a degree of environmental deterioration was identified and which needs to be corrected. From this basis, it is possible to generate concrete actions.

Figure 13 shows the Strategic Environmental Planning Map of the canton of Limón with the socio-environmentally sustainable development guidelines called MUNICIPAL ORDINANCES. In this case, there are four ordinances to promote sustainable human development, urban (Resilient and Ecological Limón City), Industrial - Port, and two ordinances for urban tourism development in the coastal and Limón’s railway corridor.

The Principle of Environmental Sustainability states that: "Human activities of any kind must be environmentally sustainable over time, in an effective way, so as to ensure ecological balance without significant environmental effect, i.e., without the natural balance being altered above its capacity to assimilate additional environmental load." (Allan Astorga Gättgens, Diario Extra 12.12.2016).

SALVETERRA SYSTEM - DR. ALLAN ASTORGA GATTGENS
Fig. 12. Environmental Base Map derived with the SALVATERRA methodology for strategic planning of the canton of Limón in Costa Rica. It includes areas of environmental fragility and current overuse that need to be improved environmentally.
Fig. 13. Canton of Limón in Costa Rica. As a result of the strategic territorial planning generated by the Territorial Environmental Management, it has been possible to generate a system of municipal ordinances aimed at contributing locally in saving the Terrestrial Ecosphere and, in addition, to promote sustainable human development within the framework of the 2030 Planetary Goals and the New Urban Agenda.

Two of ordinances of great importance have been added: a) the Forest and Ecosystem Recovery Ordinance, which aims to regenerate and rehabilitate 350 km2 of forests and ecosystems – a contribution from Limón to the Earth's Ecosphere and 1 billion quota of forest hectares that need to be developed by the year 2025 across the planet, in order to decrease the CO2 of the atmosphere and extend the tipping point or non-return point and; (b) the Ordinance of the Environmentally Sustainable Agricultural and Agricultural District, which corresponds to 400 km2 of soil territory suitable for sustainable, ecological, non-GMO and mainly biological production.

In this way, the SALVATERRA generates the natural limit of the agricultural frontier with scientific criteria and on an environmental basis, and in turn defines the areas of ecosystems that must be regenerated to save the Earth's Ecosphere.

Figure 14 presents the set of municipal ordinances prepared for the canton of Limón in the field of PREVENTIVE Risk Management.
Based on the identification of all sources of identified natural threats cartographically, it was possible to take preventive action with the development of specific municipal ordinances for these different types of threats identified.

They shall be applied for buildings and people in high and very high risk conditions, with the use of parametric insurance and emergency plans for the new constructions so the designs can adjust to a Resilient condition.

Detailed knowledge of the populations and infrastructure in high and very high risk conditions allow to initiate a whole series of preventive management procedures, starting with direct environmental information and education processes as pilots and with the use of high-tech applications on mobiles to give information to users about their sites of residence or work and even real-time mobilization.

Fig. 14. Canton of Limón in Costa Rica. Based on the cartographically identification of all sources of natural threats, it was possible to take preventive action with the development of specific municipal ordinances for the different types of threats identified. They will be applied for buildings and people at high and very high risk conditions, with the use of parametric insurance and emergency plans for new constructions so that the designs adjust to a resilient condition.
11. Moving forward into Artificial Intelligence

The experience acquired in Costa Rica by the author and his collaborators, over the last 20 years has given ample opportunity to test and perfect the methodology and to give a step forward to transform the processing of data and the map generation and soil use guidelines to develop a set of algorithms handled by artificial intelligence (SALVE TERRA program), at least in relation to the greater macro zones of soil use. We consider that this is indispensable in order to guarantee the generation of quick and simultaneous products, in a transparent way.

The author considers that the application of artificial intelligence would eliminate human factors that have contributed to the deterioration of the system, particularly corruption, influence peddling and other elements that distort the system, which is not convenient in any way, and less in conditions of planetary urgency to save the life of the planet.

12. References


