ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

ENEA

ECOLOGICAL FOOTPRINT: STATE OF THE ART AND APPLICATION IN PARTNER COUNTRIES

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The term "environmental footprint" or, more appropriately, "ecological footprint", has become a household word, as well as a good practice, aimed at measuring the effects of our actions on the environment, in terms of the resources consumed and the pollution produced. This is true for both the general public and the public institutions, even involving entire nations. The Earth Overshoot Day marks each year the date when human demand of natural resources exceeds what the Earth can renew in an entire year, warning us that, if we continue at this rate, a single Earth may not be enough to meet the needs of the world's population.
International development cooperation has always factored in the functional relationship between the demand for natural resources and the basic needs of people. What is new today is that measuring environmental sustainability has become an unavoidably necessary step to ensure the compatibility of development with the regenerative capacity of ecosystems.

In recent years, the activities of the Italian Agency for Development Cooperation (AICS) have increasingly focused on environmental and climate change issues, and a process has been undertaken to develop several guidance and support tools to strengthen the integration of environmental sustainability in development cooperation actions.
Our Agency, in collaboration with the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), has prepared a document called Ecological Footprint: State of the Art and Application in Partner Countries, aimed at introducing a set of tools to calculate avoided emissions due to energy efficiency and self-production from renewable sources in development cooperation initiatives. Such tools can be used in both the design and monitoring phases.
The document also features a checklist for identifying all the elements that can contribute to assessing or reducing the ecological footprint of an initiative, during the project

design phase.
The purpose of this document is to provide guidance to the Italian Development Cooperation System operators working in Africa, Asia, Latin America and the Caribbean, with a special focus on cities and their urban development.

Il Direttore Vicario AICS

Leonardo Carmenati

INTRODUCTION

The global environmental criticalities clearly facing the scientific and general community today are largely the result of human overexploitation, over the years, of natural resources, such as fossil fuels, minerals, water, soil, among others, including biodiversity.

Growing evidence shows that the current prevailing model of economic development, based on high levels of resource exploitation, waste generation and pollution, is no longer sustainable in the long term. Much of the resources (which many countries are required to import) is in fact used on-ly for a short time, then disposed of in landfills or "downcycled", a form of recycling that produces materials of lower quality compared to the original material, resulting in a significant economic loss.

The unsustainability of the current system of production and consumption is well exemplified by the concept of "overshoot", in the sense of "excess", as for "Earth Overshoot Day", which conven-tionally marks the date when the global consumption of natural resources exceeds what the Earth can regenerate in that year. This date is coming earlier each year, reflecting an ever-increasing rate of consumption of resources, which are used up faster that they can be renewed, producing an ecological deficit, a condition whereby the stocks of local resources are depleted generating environmental impacts.

Against such a backdrop, the first fundamental step towards raising awareness – to define target-ed actions – consists of building our knowledge base by measuring this impact on the environment, through a variety of so-called "footprints", developed in recent years as an effective measure of the pressure of human activity on the environment and its components.

This technical annex provides, firstly, an overview of the principal and most common environmen-tal footprints and the methods used to assess them, such as "Life Cycle Thinking" and "Life Cycle Assessment," along with the relevant policies, directives and regulations. This is followed by a fo-cus on the Ecological Footprint, with an overview of the present state of the art related to the ge-ographical areas of interest in the partner countries (including a comparison with the global and European situations), and a review of the potential strategic actions/solutions for minimising the impact. Finally, there is a checklist designed to support the inclusion and/or facilitate the reduc-tion of the ecological footprint, in terms of international development cooperation activities and projects.

1 MEASURING IMPACTS THROUGH ENVIRONMENTAL FOOTPRINTS

Footprints are symbolic of human beings on the move and of their effects on the surrounding envi-ronment, which is why this concept is being adopted more and more as a metaphor of the "mark" of humans in terms of their environmental impact.

The first such "footprint" to be adopted was probably the "ecological footprint", which is also the most widely used tool to assess and report the impact humans have on the environment. This was followed, in recent years, by several other "footprints", used to measure the pressure of human activity on the environment.

The following paragraphs introduce the concept of ecological footprint and provide details on how it is measured, followed by a description of the most common environmental footprints and how they are related to the ecological footprint, as well as the method for their calculation based on the life cycle concept (Life Cycle Thinking and Life Cycle Assessment).

1.1 THE ECOLOGICAL FOOTPRINT (EF)

The concept of Ecological Footprint (EF) was first introduced in 1996, at the University of British Columbia, in Canada, by Wackernagel and Rees [1]. The EF is a synthetic indicator of environmen-tal sustainability, aimed at assessing the impact of humans on the environment, by calculating the area of land and water ecosystems required to produce the resources consumed and to absorb the emissions produced by a specific population in a given area. In order for development to be "sus-tainable", as established by UNEP, WWF and IUCN in their groundbreaking report "Caring for the Earth" [2], it must enable the ecosystems to regenerate the necessary resources, year after year, ensuring the well-being of people through natural means.

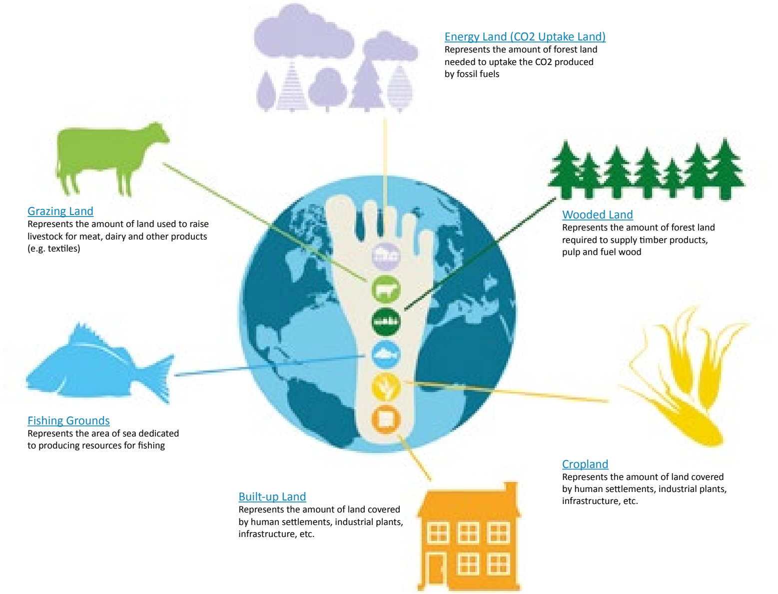

Figure 1. Land categories used to determine the Ecological Footprint.

The formula generally used to calculate the EF is based on the following six main land categories (Figure 1), namely:

1. **Energy Land (or CO_2 Uptake Land)** is the amount of land needed to sustainably produce the energy consumed, i.e. to obtain the biomass needed to produce sufficient fuel to replace fossil fuel. Wackernagel and Rees adopt a different definition, based on the amount of forest land required to absorb CO_2 emissions from fossil fuel (CO_2 Uptake Fuel). The results obtained from both approaches are of the same order of magnitude, so either one can be adopted. Moreover, the method proposed by [1] is useful for measuring the energy component of the EF, by focusing on GHGs and the problem of climate change, as well as to distinguish the impacts due to different fossil fuels (solid, liquid, gas).
2. **Cropland** is arable land (fields, gardens, etc.) used to produce food and non-food products of agricultural origin (e.g. cotton, jute, tobacco).
3. **Grazing Land** is land used for livestock farming and therefore the production of meat, dairy products, eggs, wool and, generally speaking, all animal husbandry products.
4. **Forest Land** are areas of modified natural systems dedicated to timber production (pulp, fire-wood).
5. **Built-up Land** also includes degraded, ecologically unproductive

land, used for building infra-structure, such as housing, manufacturing, service areas, communication routes, etc. (it is as-sumed that built-up land also occupies potentially fertile and, therefore, arable land).

6. **Fishing Grounds** are areas of the sea for fish resources.

To take into account both the direct and indirect impact of the specified population in a given re-gion, for the different types of productive land, the EF associated with consumption (EF_C) is calcu-lated by taking into account the footprints for both production (EF_P) and imports (EF_I) and exports (EF_E):

$$EF_C = EF_P + (EF_I + EF_E)$$

The various footprints can be assessed by applying the basic formula for the EF associated with product extraction or waste generation, as follows:

$$EF_P = \frac{P}{N} \cdot YF \cdot EQF \cdot IYF$$

Where:
EF_P = ecological footprint associated with the product/waste [gha];
P = total amount of product extracted/waste generated [t/year];
Y_N = national average yield for product extraction/waste absorption [t/nha*year];
YF = yield factor of a given soil type [wha/nha];
EQF = equivalence factor for the specific soil type [gha/wha];
IYF = intertemporal yield factor for the specific soil type [-];

Legend
gha = global hectares;
wha = world-average hectares (for a specific soil type);
nha = national-average hectares (for a specific soil type).

Dimensionally speaking, the YF is expressed as the ratio of the national to the world value of the yield for a given soil type, so the formula can be rewritten more concisely:

$$EF_P = \frac{P}{W} \cdot EQF \cdot IYF$$

with Y_W = world-average product yield/waste absorption [t/wha*year].

Equivalence factors (EQFs) are used to convert the land types, with their respective world average productivity, into the equivalent area with world average productivity (for all the land types), by weighing the different land areas according to their inherent capacity to produce biological re-sources useful to humans, and vary according to land category and year. Instead, the intertemporal yield factors (IYFs), also calculated for each year and land type, are used to take into account the variation over time of the world average productivity of each land type.
Furthermore, slight changes to the basic standard formula may occur for the six different soil types considered in the EF calculation (for the main

methodological details see [3] e [4]), whereby it should be emphasised that, given the normalisation of the different land category areas, based on their world average productivity, the calculated area no longer represents the actual area di-rectly or indirectly used by a certain population but the equivalent area, whose yield is equal to the world average required to produce the amount of product effectively used by the relevant pop-ulation.
Therefore, a global hectare (gha) – i.e., a hectare of land normalised according to the world aver-age productivity of all biologically productive land and sea areas in a given year – does not repre-sent a "physical" hectare used, but rather indicates that 1 equivalent hectare is needed to fulfil the specific function considered (supply of resources, uptake of carbon dioxide emissions, ...).

In order to assess whether the supply needs of the resources used (and the uptake of the emis-sions produced) by a given population, within a specific region, can effectively be met, the EF is normally compared with biocapacity (BC), which is the amount of biologically productive land and sea areas available for producing the resources (and absorbing the emissions). This makes it pos-sible to assess whether the equivalent available productive area is larger or smaller than the equivalent area needed to meet the needs, i.e., the EF (Figure 2).
The biocapacity of different soil types is calculated as:

$$BC = A \cdot YF \cdot EQF \cdot IYF$$

where A the area of the specific nation or region, YF the yield factor for the specific land and na-tion/region, EQF the equivalence factor for the specific land type, and IYF the relevant inter-temporal yield factor.

The "conventional" EF calculation procedure is generally applied at the global or national level and requires large amounts of information at either scale (i.e., production and trade statistics for in-dustrial sectors and economic activities that are rarely collected and available at the sub-national level). The resulting Global Footprint Network is used to produce the annual National Footprint Accounts, which are EF and BC assessments for individual countries (regions or territories), to gauge and monitor the use and capacity of ecological resources of countries over time, and to as-sess the overall sustainability of each, and hence to better understand the collective need of hu-manity to reduce its impact on nature. The National Footprint Accounts are intentionally based on United Nations statistics (recent editions use up to 15,000-point data for each country each year) to ensure neutrality, cross-country comparisons, and compatibility with international standards, but also to provide a sound framework for assessment aligned with the constantly changing and improving international statistics.

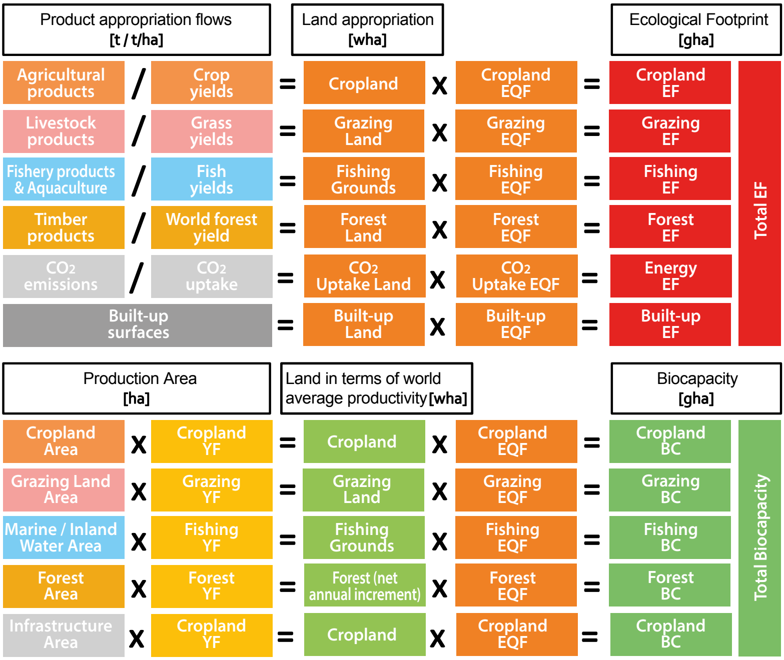

Figure 2. Diagram for calculating Ecological Footprint and Biocapacity (elaboration based on. [4])

Operationally, there are basically two possible approaches for calculating the EF at the local level, in applications of interest to International Development Cooperation:

- the "bottom-up" approach, which mirrors the "conventional" approach used for producing the National Footprint Accounts, with the same calculation steps but using data at the sub-national rather than national level. This approach is effectively a "component-based meth-od", in which the EFs of all products consumed at the specific (e.g., regional or municipal) level are first assessed individually and then aggregated;
- the "top-down" approach, a kind of sub-national adjustment of the national EF, based on relative differences between the national figure for a specific component and the corre-sponding sub-national figure. This approach consists of an input-output model for allocat-ing the national EF at the sub-national level, based on economic data and consumption patterns (e.g., average spending at the sub-national level).

In conclusion, the EF method has several limitations. Firstly, the use of a single measurement unit (global hectares of land area), besides involving many unavoidable approximations, could oversim-plify the assessment and distort the representation of complex and multidimensional problems. Moreover, when gauging the EF, the impact on the environment is examined exclusively in terms of CO2 emissions, neglecting other far from irrelevant aspects, such as radioactive waste from nu-clear power plants or waste generation, among others. It follows that, since many degrading fac-tors are not taken into account, the "actual environmental damage" is certainly greater than the EF value and, moreover, even a situation of equality between the consumption (EF) and availability (BC) of resources – a conventional comparison used in assessments – would not translate into a total absence of environmental problems.

Data availability itself can be identified as one of the most limiting factors of analysis. Indeed, a significant amount of data is required to calculate the EF, which means that, if no information is available, the possible options of using "weak" data, neglecting relevant aspects or making as-sumptions are inevitably reflected in the limited robustness of the outcomes.

The authors of the method themselves recognize its limitations, discussing them in detail in recent papers [5], while pointing out opportunities for improvement based on the criticisms levelled at the EF over the years.

1.2 OTHER ENVIRONMENTAL FOOTPRINTS AND THEIR LINKS TO THE EF

1.2.1 The Carbon Footprint

Climate change is now widely recognized as one of the most important challenges Governments, Organizations and Citizens will face in the coming decades, so the Carbon (or Climate) Footprint, has become increasingly popular and is now one of the most widely used environmental impact footprints.

The Carbon Footprint (CF) measures the impact of human activities on the global climate, express-ing it as the total sum of so-called "Greenhouse Gases" (GHGs) generated by a specific activity or product, taking into account all major GHGs, namely, carbon dioxide (CO_2), methane (CH_4), ni-trous oxide (N_2O), the group of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

The CF is expressed in terms of carbon dioxide equivalent (CO2eq), or as a cumulative value of the "climate-changing capacity" of all GHGs, based on their Global Warming Potential (GWP), which is the ratio of the warming caused by a specific GHG over a specified time (normally assumed as 100 years) to the warming caused over the same period by the same amount of CO2. Therefore, the GWP weighs the contribution of each GHG to global warming against the CO2 reference value, conventionally set at 1.

Therefore, the CF is the result of:

$$CF = E_i \cdot GWP_i$$

where:
E_i is the i-th GHG emitted (in units of mass) and GWP_i is the global warming potential of the same GHG (see Table 1).

Table 1. Global warming potential (GWP) of major greenhouse gases.		
Greenhouse gases	**Chemical formula**	**GWP100 [6]**
Carbon Dioxide	CO_2	1
Methane of fossil origin of non-fossil origin	CH_4	- 29,8 27,2
Nitrous oxide	N_2O	273

MEASURING IMPACTS THROUGH ENVIRONMENTAL FOOTPRINTS

Operationally, i.e. in terms of the applicable technical reference standards and calculation meth-od, we can distinguish between:

- the Carbon Footprint of a Product (CFP), which measures the total GHG emissions generat-ed by a product or service throughout its life cycle, based on the UNI EN ISO 14067:2018 standard [7], which specifies principles, requirements and guidelines for the quantification and reporting of the CFP, building on international reference standards for Life Cycle As-sessment (LCA) studies; and
- the Carbon Footprint of an Organization (CFO), which measures the total GHG emissions from all the activities across the organization, based on the UNI ISO 14064 standard, and, in particular, part one (UNI ISO 14064-1:2019 [8]), which specifies principles and require-ments, at the organization level, for the quantification and reporting of greenhouse gas (GHG) emissions and removals."

1.2.2 The Water Footprint

Another important area of environmental impact and resource consumption concerns water re-sources. Global freshwater use has grown sixfold over the past 100 years and continues to grow at an annual rate of about 1% since the 1980s, largely due to a combination of population growth, economic development, and changes in consumption patterns [9]. For some production sectors and some types of products, water consumption is obvious and easy to understand, such as irrigation for agriculture (primarily, but also for livestock breeding and aquaculture), which currently ac-counts for about 69% of water withdrawals worldwide. However, there are also less obvious forms of water consumption, which are also harder to understand, such as the industrial use of water in connection with power generation or for manufacturing and distributing products.

In order to bring these more "concealed" forms of water consumption into the light, and assess water use from a life-cycle perspective, a new indicator has been introduced and has become widespread in recent years, the Water Footprint (WF).

The WF is an indicator of direct and indirect freshwater consumption and is expressed as the total volume of total water consumed in relation to a specific activity or product. It largely represents the extension and furthering of a concept previously introduced in the scientific world called the Virtual Water Content (VWC), i.e., the volume of freshwater used in the production chain of a product/service and therefore incorporated into it. Compared to other accounting tools, and con-sidering the increasing use and scarcity of water, the WF has come to represent the most broad-ranging and comprehensive solution for measuring freshwater uses, as it includes both direct and indirect water use and considers both water consumption and pollution.

The WF is calculated as:

$$WF = WF_{blu} + WF_{verde} + WF_{grigia}$$

where:
WFblue is the volume of surface or groundwater used and not returned into the water system from where it came, WFgreen is the volume of rainwater used that does not runoff and replenish surface and/or groundwater resources, and WFgrey is the volume of water needed to dilute the input of pol-lutants and return their concentration to the natural value of the receiving water body (Figure 3).

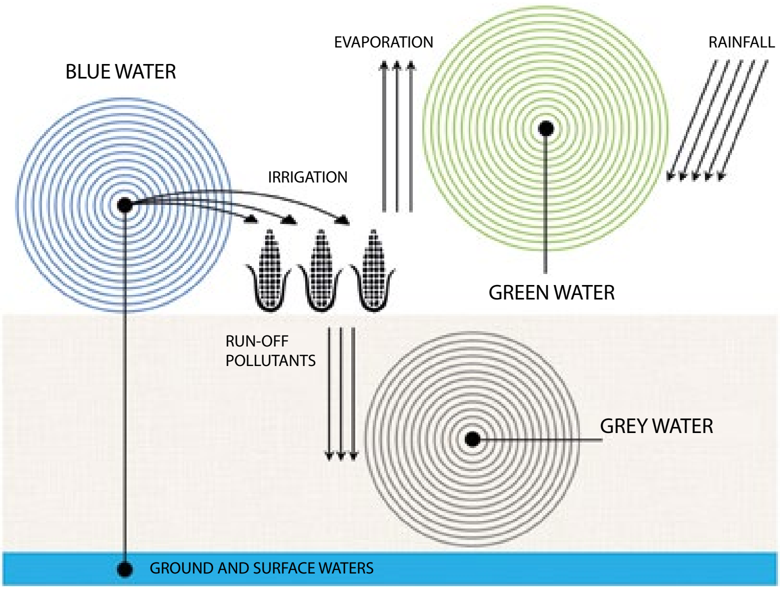

Figure 3. Diagram showing the Water Footprint components

The WF, calculated as the total volume of water consumed, however, does not measure the severi-ty of the local impact associated with the consumption and pollution of water. Its impact, in fact, depends on multiple factors, including the vulnerability of the local water system and the number of possible consumers and/or polluters.
Therefore, the reference standard for the WF, namely UNI EN ISO 14046:2016 [10] – which speci-fies principles, requirements and guidelines related to WF assessment of products, processes and organizations based on the LCA methodology – clearly introduces the concept of a water footprint profile, as a set of results of the various indicators relative to potential water-related environmen-tal impacts, closely linked to the water footprint

impact assessment (a stage of a water footprint assessment aimed at understanding and assessing the magnitude and importance of potential wa-ter-related environmental impacts).

1.2.3 Relationships among the footprints and possible applications

There is a clear methodological connection between the EF and CF. In fact, one of the land catego-ries considered for measuring the EF is energy land, i.e., the "energy" component directly related to the land for greenhouse gas emission uptake from consumption of fossil fuels. The calculation of the EF requires that the CO2 eq emissions associated with production, imports and exports are known, whereby the EF partly includes a carbon footprint calculation related to the consumption of resources. Furthermore, taking into account the calculation method proposed by Wackernagel and Rees [1], the EF also quantifies and incorporates a measure for offsetting the GHG emissions re-sulting from the consumption of fossil fuels, by quantifying, through the Energy Land component, the forest area needed to uptake the CO2 generated by consumption of these resources.
Carbon emissions from energy use (i.e., fossil fuel combustion) accumulate in the atmosphere with adverse effects on global warming, if a sufficient biocapacity for their uptake is not available. Therefore, when measuring the EF, the CF (i.e., the total tons of CO2 emitted) is expressed in terms of the productive area required for carbon sequestration purposes. This measurement ulti-mately provides an indication of the biocapacity needed to neutralize fossil fuel emissions from combustion, in the specific context, for EF assessment.

The WF can methodologically be considered as a complementary indicator to the EF. Among the land categories considered for measuring the EF is the biologically productive water area available for the production of resources. However, this component can only be considered partly related to the exploitation of water for the production of resources, as a result of which the WF comple-ments the EF by focusing not only on productive area but on water consumption in general, in rela-tion to the life cycle of the consumed products. Moreover, the WF can also be used to understand certain environmental effects that have direct and/or indirect impacts on the biological productivi-ty of the water area, through the assessment of specific impact profiles.
Although they can be confused, and perhaps even compared, the EF and WF are fundamentally in-dependent indicators. The EF does not and is not intended to measure freshwater flows, while the WF is an indicator of sustainable water use that measures the total volume of freshwater directly or indirectly used by the population. Each of the two indicators, therefore, provides different in-formation regarding sustainability, and instead of being seen as competing parameters, the EF and WF should be seen as complementary, in relation to human consumption of natural resources.

Generally speaking, although based on different methodologies, links between the different envi-ronmental footprints and the EF do exist,

primarily regarding their value as useful indicators for measuring and communicating the environmental performance of products, and also as important tools for guiding consumers toward the adoption of more sustainable lifestyles, with regard to food and eating. Since 2010, in fact, the Barilla Food Nutrition Centre [11] has introduced the con-cept of the Double Pyramid, which is a useful tool for choosing a sustainable diet. The Double Pyr-amid consists of the traditional food pyramid, which arranges food groups according to the princi-ples of a Mediterranean diet, with the addition of an environmental pyramid, which ranks different foods on the basis of their ecological footprint. Likewise, a WF-linked environmental pyramid has been identified, in which food groups are ranked according to the amount of water consumed throughout their production life cycle, expressed in liters/kg, and a CF-linked pyramid (climate pyr-amid), which ranks different food groups on the basis of their carbon footprint. The values are cal-culated based on the Su-Eatable Life project database .
This approach shows clear and important relationships between the footprints of foods with the largest environmental impact and of foods that should only be moderately or minimally consumed, as recommended by nutritionists. In particular, meats and cheeses are the foods with the largest impact on both people's health and the environment, while fruits and vegetables feature lower impact values, both in terms of their ecological footprint and of climate change and water con-sumption.
In addition to the global model, specific studies have been published for seven geo-graphic macro-areas (Africa, South America, South Asia, East Asia, the Mediterranean Area, Northern Europe and Canada, and the United States), highlighting culturally relevant foods and their links in terms of environmental impact and healthy eating. For example, in Africa, the includ-ed foods are cassava, sorghum and tilapia. In South America, quinoa, white corn and sweet pota-toes. In South Asia, foods such as lentils and rice are examined, and in East Asia, rice, soybeans, tofu, seaweed, and tuna. The Double Pyramid model can guide and encourage the adoption of healthier and more sustainable eating habits.
The evidence gathered clearly shows that a healthy diet also coincides with an environmentally sustainable diet and is in line with the holistic One Health concept that the health of people, ani-mals and the environment are closely interrelated [12].

[1] https://www.sueatablelife.eu/

1.3 FOOTPRINT CALCULATION METHODS: LIFE CYCLE THINKING AND LIFE CYCLE ASSESSMENT

It descends from the considerations contained in the preceding paragraphs that, in order to appro-priately assess the impact of a product or an activity through the "footprint indicators", we should first of all consider the many associated environmental aspects, as well as the entire life cycle of the product or activity. In fact, all stages of the life cycle of a product or activity require the con-sumption of energy and resources and generate various kinds of environmental impacts.
To analyse the life cycle of a product or activity, we must consider all the relevant stages, from the extraction and processing of the raw materials, to the manufacture of the product, followed by its transportation, distribution, use and possible reuse, collection, storage, recycling, recovery, and, ultimately, the disposal of the resulting waste.

Life Cycle Thinking (LCT) is a fundamental methodological approach for assessing environmental footprints, because it shifts the focus from the production process alone to the entire life cycle of the product or activity, providing for a "cradle-to-grave" assessment. Within the framework of Life Cycle Thinking, the environmental impacts to be analysed and acted on are related not just to the manufacturing stage but also to the activities upstream and downstream of production. The adop-tion of this approach prevents from shifting critical environmental issues from one component to another, eventually achieving a systemic result.

The Life Cycle Assessment (LCA) method, as the name implies, studies the environmental impacts of a product through the various stages of its life cycle, by measuring the consumption of energy and resource (e.g., water, soil), for the purpose of improving the product and its related activities. By adopting a lifecycle approach, we can learn how to close the loop and make products more cir-cular.

LCT-based methods, such as Life Cycle Assessment, are used to comprehensively analyse the re-quired resources and environmental effects associated with the entire life cycle of a product or ac-tivity, while methods such as the EF/CF/WF are more useful for focusing on specific environmental impacts and comparing production and consumption needs and patterns with the capacity of eco-systems.

1.3.1 The Life Cycle Assessment (LCA) approach

The LCA approach is based on the use of specific procedures to identify, measure and assess all the material, resource and energy inputs and outputs, and the related environmental impacts, as-sociated with a product throughout its lifecycle[2].

An underlying concept of life cycle assessment is product function. The focus of LCA, in fact, is not on a single product but on its function. For example, the function of drying hands can be per-formed by a towel, disposable wipes, or an electric hand dryer. Therefore, each LCA study is re-ferred to the functional unit, which is the measure of the functional performance of the outputs of the "product-related system". For example, if we want to compare the LCA of a PET bottle with that of a glass bottle, the functional unit at the basis of the study will be the amount of mineral water consumed in Italy annually per person (172 litres/person). Instead, the flow to which all the LCA-related values refer is the amount of product required to satisfy the function measured by the functional unit. In the example of the water bottle, the reference flow will be 115 PET bottles con-taining 1.5 litres of water each and 172 glass bottles containing 1 litre of water each.

LCA studies can be carried out in countless ways, which means that there is a need for standardi-zation based on the reliability, accessibility and representativeness of the data and results. The reference standard is UNI ISO 14040 [13], and related standards ([14], [15]), which describe the conceptual structure of Life Cycle Assessment, consisting of four separate and consecutive phases, as shown in Figure 4.

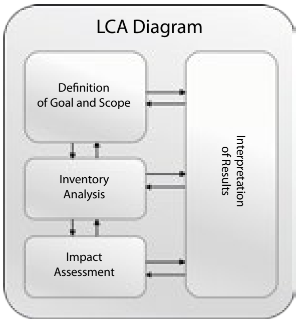

Figura 4. Structure of an LCA study

The four stages of an LCA study of a product (although the same considerations apply to any hu-man activity) are the following:

1. Definition of Goal and Scope
   This is the phase for establishing the intended applications and target audiences of the study, as well as the defining the goals, i.e., what we want to analyze. For example, we might want to com-pare two products or assess the relationship between a product and a reference standard (e.g., an environmental label). Another goal might be to improve a product environmentally or to design a new product. Finally, the study could also be used to answer strategic questions related to a com-pany's position on the market.

[2]In some cases, data regarding non-material emissions, such as noise, radiation, etc., may also be produced.

2. Life Cycle Inventory (LCI) Analysis
The LCI analysis looks at the environmental inputs (i.e., materials, energy, natural resources) and outputs (e.g., emissions to air, water, soil) of a product or service. It is the most critical stage of the LCA study and is very time-consuming. Indeed, the reliability of the outcome of the study will depend on the data used in this phase (documentation). This is the step during which the flowchart is developed, data gathered, impact allocation rules/problems are defined, and the col-lected data managed, generally with the assistance of dedicated software.
3. Life Cycle Impact Assessment (LCIA)
The purpose of this step is to analyse the extent of the potential direct and indirect environmental impacts associated with the inputs and outputs obtained from the LCI. The LCIA looks at how each inventory flow developed in phase 2 contributes to the environmental impacts, which are repre-sented by a set of parameters that define how the product behaves in environmental terms. This is a relative assessment because it is measured with respect to the functional unit.
4. Life Cycle Interpretation
In this phase, the results of phases 2 and 3 are verified and assessed to establish their consistency with the goals and scope, to ensure that the study is complete. Its results are expressed in the form of conclusions, recommendations and reports addressed to decision makers.
The results of an LCA can be useful for:

- describing the overall environmental impact of a product;
- comparing the environmental impacts of different products with the same function;
- identifying the lifecycle phase of a product with the greatest environmental impact;
- highlighting the strategies to be adopted for environmental improvement;
- obtaining a product label or certification;
- supporting the design of new circular products or services.

1.3.2 LCA applications

While LCA is thus a tool that businesses can use to develop and improve their products and ser-vices according to a circular perspective, it can also be used at the governance level to develop economic, legal and regulatory guidelines for minimizing the environmental impact of prod-ucts/services throughout their life cycle. LCA is an internationally widespread scientific method that also requires spaces for comparison and exchange. In Italy, an LCA Network has been set up with the purpose of disseminating success stories and applications in the country [16].
In order to simplify and reduce the use of the many environmental assessment methods, the Euro-pean Commission published its Recommendation 2013/179/EU on "the use of common methods to measure and communicate the life cycle environmental performance of products and organisa-tions" [17], which identifies the Product

Environmental Footprint (PEF) and the Organisation Envi-ronmental Footprint (OEF) as reference methods for communicating commitment to the improved environmental performance of products and services delivered by both the private market and the public sector (e.g., Green Public Procurement, GPP). These certifications also serve as useful reference tools for consumers to guide them toward more responsible choices in their purchases.

Table 2 below describes when to apply the LCA method and when other alternative methods are useful instead.

Table 2. Possible uses and non-uses of LCA.

USE THE LCA METHOD TO	DON'T USE THE LCA METHOD TO
Help identify, quantify, interpret, and assess the environmental impacts of a product, function, or service	Resolve problems related to the location of a work (use EIA)
Select relevant environmental performance indicators to compare products having the same function	Resolve problems related to a specific substance (use Substance Flow Analysis - SFA)
Compare the environmental impacts of a product with a reference standard (e.g., Ecolabel)	Resolve company's environmental problems (use Environmental Management Systems, EMS, e.g., ISO 14001, EMAS...)
Identify opportunities to improve the environmental aspects of a product by identifying the lifecycle stages that have dominant environmental impacts	Resolve problems of a specific production process (use Best Available Techonologies - BAT)
Assist the decision-making process of businesses and the public sector (e.g., strategic planning, prioritisation, design or redesign of products, processes or services);	Respond to safety and risk issues (use Risk Asses-sment - RA)
Scientifically support the communication of environmental information (e.g., Environmental Statement, EMAS) and marketing (e.g., eco-labels, advertising of environmentally friendly products).	Communicate the results of an LCA directly to consumers, as it is a complex study that is difficult for the end user to understand (better to use the Product Environmental Footprint - PEF).

2 BACKGROUND POLICIES AND REGULATIONS

The transition toward sustainability is one of the major challenges for policymakers, particularly in terms of the comprehensive assessment of impacts and measures needed to limit them. Policy-makers face increasingly complex challenges in which environmental and social and economic as-pects coexist.

Therefore, Life Cycle Thinking is a fundamental systemic approach integrating sustainability into the decision-making process, and, in recent decades, both the LCT and LCA methods are being in-creasingly implemented worldwide. Studies have also been developed to assess the level of im-plementation of LCA in policies [18], sometimes focusing on specific cases, which highlight that the implementation of stringent and mandatory lifecycle requirements is still relatively limited de-spite the EU's interest in the LCT/LCA methods and efforts to implement them in its policies.

Therefore, the European Commission, being aware of the fundamental role played by businesses in achieving sustainability goals, has focused its "moral suasion" policy on the adoption of voluntary measures aimed at reducing the environmental impact of production processes and eco-innovation.

2.1 EUROPEAN AND DOMESTIC POLICIES AND REGULATIONS

Application of the LCA method in European policies has increased enormously since the late 1990s, producing EMAS Regulation No. 1836, 1993 [19], one of the first European regulations on envi-ronmental management systems for businesses, the Ecolabel Regulation [20] and the Ecodesign Directive [221]. The Ecolabel Regulation formalised the first voluntary eco-label, to enhance the value of products with a reduced environmental impact; the Ecodesign Directive (2005/32/EC) also known as the EuP (Energy-using Products) Directive, introduced the first worldwide mandatory re-quirements for new products based on a lifecycle approach. By acknowledging its key contribution to sustainable development, a crucial role in paving the way for the development of policies that included the concept of a product's life cycle was played by the European Commission's "Integrated Product Policy" (IPP) approach,

contained in the "European Commission Green Paper on Integrated Product Policy" (2001) [22], which also assessed environ-mental degradation as a consequence of consumer behaviour, in addition to production activities (and which set the targets of environmentally friendly production and conscious consumption).
Another key milestone on the path to establishing LCA-based policies was the 2013 communication "Building the Single Market for Green Products" [23], which exemplifies the desire to achieve a single market for green products and recommends the use of methods ensuring comparable and reliable environmental information.

In the same year, the European Commission also issued the above-mentioned Recommendation 2013/179/EU, on the "use of common methods to measure and communicate the life cycle envi-ronmental performance of products and organisations" [17], with the aim of rationalising and uni-forming, as much as possible, the methods available until then, based on the use of the said PEF and OEF methods to measure or communicate environmental performance throughout the life cy-cle of products or organizations. The recommendation was not a binding piece of legislation but was intended to encourage businesses and organisations to improve their environmental perfor-mance, also with a view to increasing competitiveness. It was also based on the awareness that a review of production chain management systems according to an "ecological" perspective could become an important driver of competitiveness for businesses, with the possibility of convincing consumers to make more responsible decisions and adopt a more virtuous behaviour.

In Italy, the Ministry of the Environment (now called the Ministry of the Environment and Energy Security) had already promoted the Programme for the Environmental Footprint Assessment of Products/Services/ Organizations in 2011 [24], based on close public-private partnerships, for the large-scale optimisation, harmonisation and replicability of the methods for measuring environ-mental performance, specific to the peculiarities of different economic sectors. This initiative was aimed at encouraging businesses to assess and improve their environmental performance and re-duce GHG emissions consistently with the measures and policies contained in the Kyoto Protocol (1997) [25], subsequently confirmed by the Paris Agreement on Climate Change (2015), the "EU Circular Economy Package" (2015) [26], and, more recently, the set of legislative proposals con-tained in the EU's new "Fit for 55" package for a green transition [27].

In recent years, the proposed Environmental Footprint methods have been tested with more than 300 businesses in different sectors, including several agro-industrial supply chains, in order to ver-ify their effective applicability and reliability. This was a "pilot phase" that led to the issuing, on 30 December 2021, of the Commission Recommendation 2021/2279/ EU on the "use of the Envi-ronmental Footprint methods to measure and communicate the life cycle environmental perfor-mance of products and organisations" [28], which confirms the method proposed in the previous Recommendation, based on longstanding reliable, verifiable and comparable elements. The goal of the Recommendation is to effectively assist businesses to manufacture products with high levels of environmental performance and also contribute to the achievement of the European Green Deal targets [29]. Thus, the "standardisation" and widespread adoption of such tools are viewed as es-sential for establishing a policy framework based on sustainable production and business models.

3 EF ASSESSMENT BY REGION IN THE PARTNER COUNTRIES

This section provides data on EF (and BC) by region/sub-region, focusing on the total (gha) and per capita (gha/person) EF (and BC), to identify a specific context for a clear assessment of the current and potential status, in terms of sustainability, and functional solutions and technologies in the partner countries.
The reported assessments are based on data processed by the Global Footprint Network for the 1961-2018 period and which are available online in the Ecological Footprint Explorer [30] (note that the graphs below show total values in millions of gha and per capita values in gha).

3.1 AFRICA

The total data available for Africa show there has been increasing exploitation of resources over the years, at a rate faster than their capacity to be regenerated, although the EF per person is be-low the Western standards and the world average.

The data show how the total EF and BC have both increased over the years, with values of about 1.513 and 1.288 million gha in 2018, respectively, while at the per-capita level, an average EF of more than 1 gha/person is observed over the years (about 1.35 gha in 2018), compared with a re-duction in per-capita biocapacity from about 4.32 gha/person in 1961 to about 1.15 gha/person in 2018 (Figure 5). The data points to a situation in which, compared to the largely unchanged impact of each single inhabitant of the continent and a slightly increasing total BC, due to the steadily in-creasing population trend, the total EF has increased significantly and there has been a steady and rapid decrease in per-capita BC.

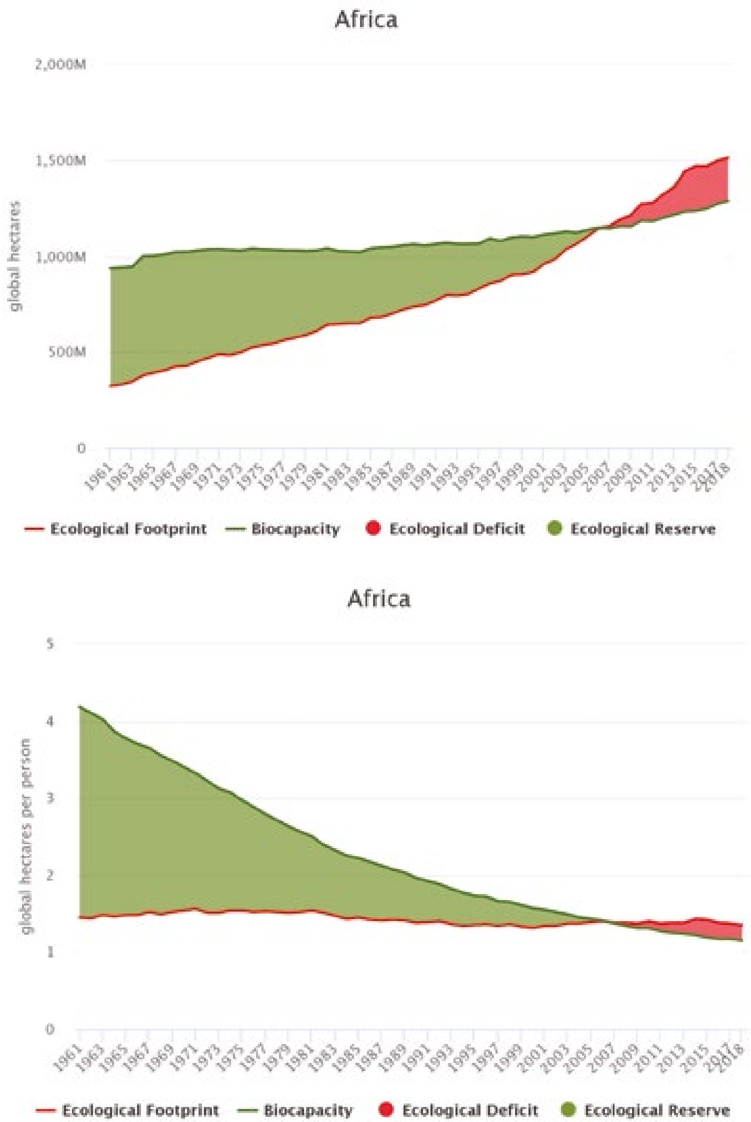

Figura 5. Africa – EF and BC trends (total and per capita) over the years

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Observing the total EF trend, we can see how it has increased from about 324.1 Mgha in 1961 to about 1,513.5 Mgha in 2018. In terms of the contribution of the 6 components (Figure 6), it can be seen that the largest EF by far is associated with cropland and CO2 uptake land, followed by EFs associated with forest land and grazing land. In general, there has been an increase in all the components over the years. In terms of per capita EF, as of 2018, it can be observed that, despite fluctuations over the years, the per capita EF associated with forest land (about -37%) and grazing land (about -56%) have decreased compared to 1961, while the per capita EF associated with built-up land (about +150%), CO2 uptake land (about +95%) and cropland (about +20%) have in-creased. Over the same period, the EF of fishing grounds has remained essentially unchanged.

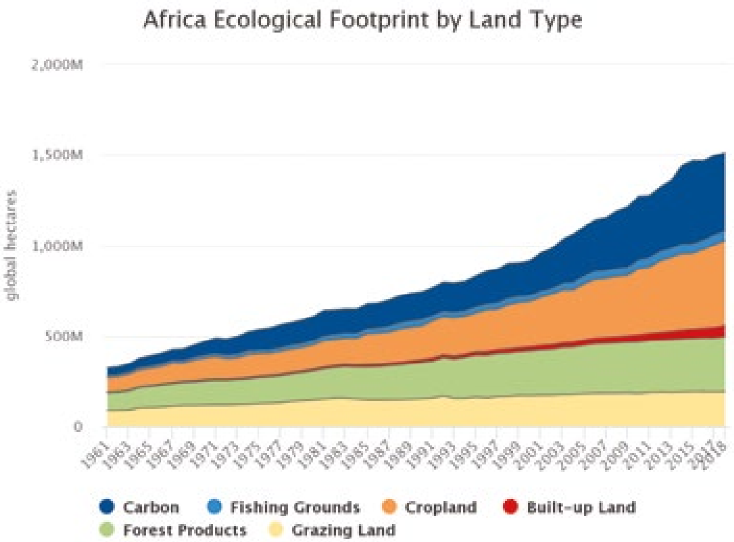


Figura 6. Africa - Trend over the years of EF (total and per capita) by component.

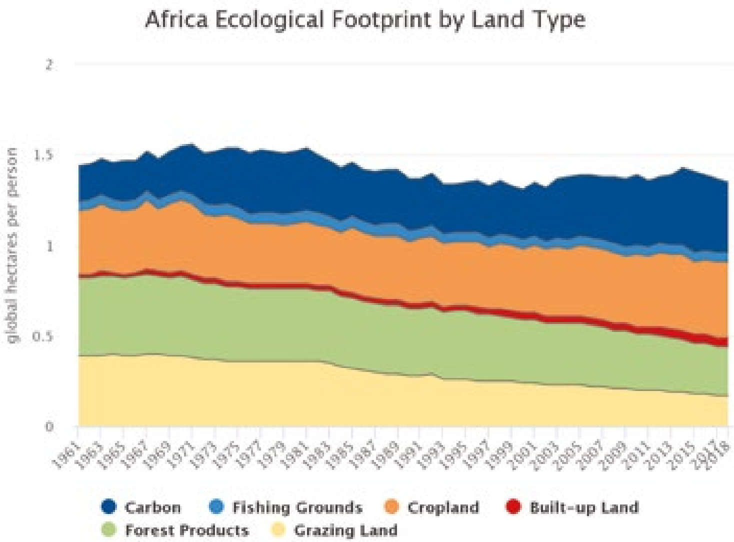
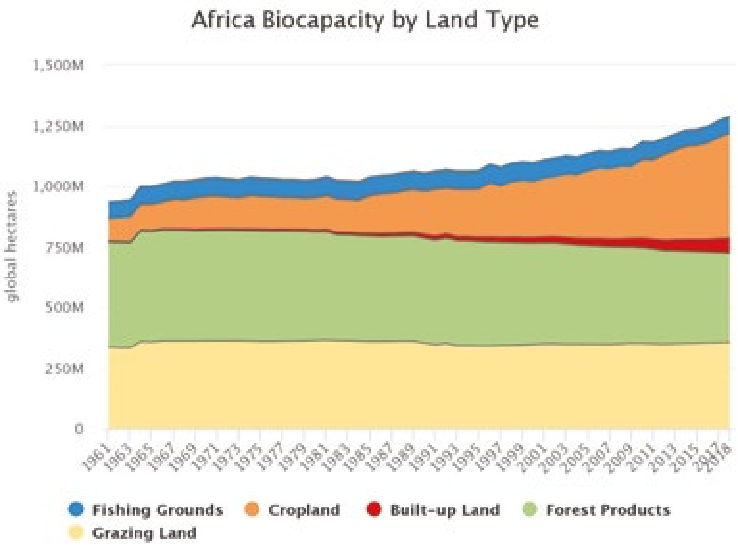


Figura 6. Africa - Trend over the years of BC (total and per capita) by component.

In terms of biocapacity (Figure 7), on the other hand, a decrease can be observed from about 936.8 Mgha in 1961 to about 1,288 Mgha in 2018, with three main contributions from cropland, forest land and grazing land. In terms of per capita BC, a more or less significant reduction is ob-served, across the board, for all 6 components. In detail, compared to 1961, the BC of cropland ap-pears to have decreased by about 5%, the BC of fishing grounds by about 81%, the BC of forest land by about 83%, while the BC of grazing land has dropped by about 79%. In contrast, the BC as-sociated with built-up land (equal to the relative EF) appears to have increased by about 150%, in accordance with the methodological assumptions.



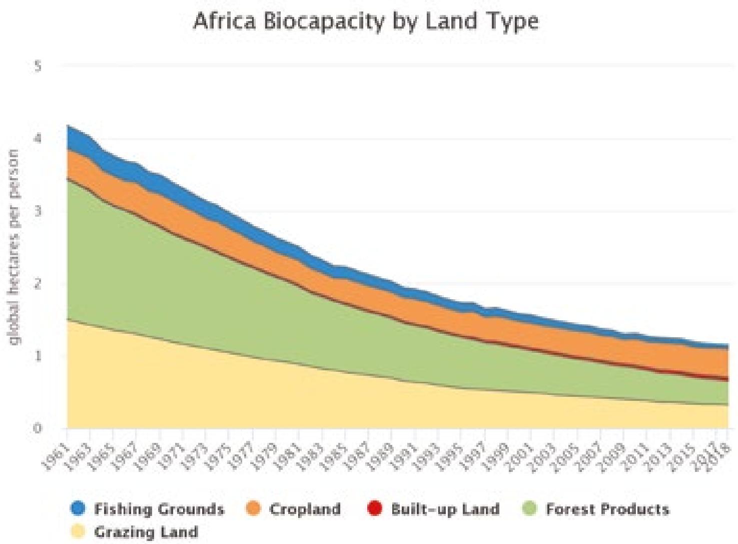
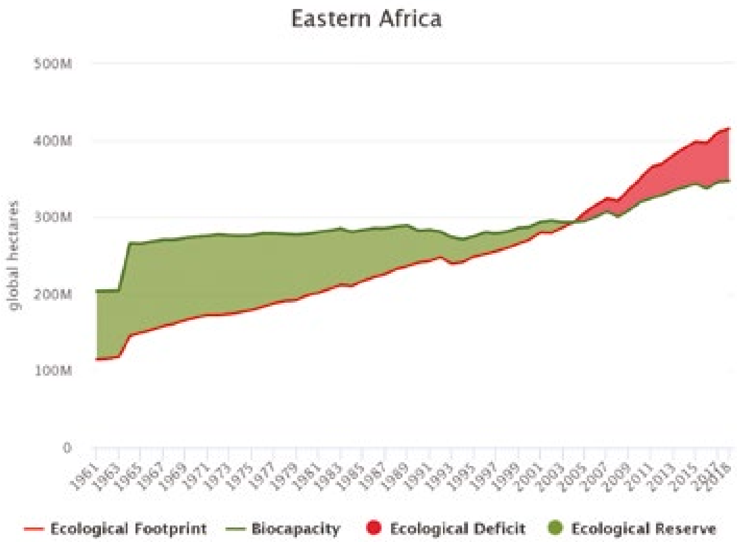


Figura 7. Africa – Trend over the years of BC (total and per capita) by component.

For a long time, Africa was characterised by a situation of "ecological surplus", but its margin of available biocapacity has gradually dwindled, to the point that it now finds itself in a condition of "ecological deficit", which means that demand now beats supply (the EF exceeds the BC). This sit-uation, as mentioned earlier, is largely due to population growth and the consequent need to meet its ever-increasing demands, i.e., a situation in which the increasing biocapacity (mainly due to growing agricultural production) has not kept "in step" with the increase in demand. However, the biocapacity of the African continent is also used for producing natural resources, which are ex-ported, legally or illegally, and a part of this biocapacity is included in the global common re-sources that, for example, are used for capturing carbon dioxide [31]. These factors could have in-fluenced the development of the situation in the continent as well. Furthermore, the increased bi-ocapacity could have occurred at the expense of other impacts, e.g. in terms of the WF, as an in-crease in productive cropland could be associated with the conversion of ecologically less produc-tive land to growing crops, resulting in greater use of water (but also energy) resources, which means that it is necessary to assess this indicator as complementary to the WF, in order to paint an overall picture of how the situation is developing in terms of impact/ sustainability.

To complete the picture, it should be mentioned that the situation in terms of average values is obviously not reflected in the individual countries or even in the sub-regions. In fact, while most of the continent is currently more or less in line with the situation of "ecological deficit" described above, there are regions of the continent that maintain a surplus situation, despite a trend similar to the illustrated trend (Figure 8).



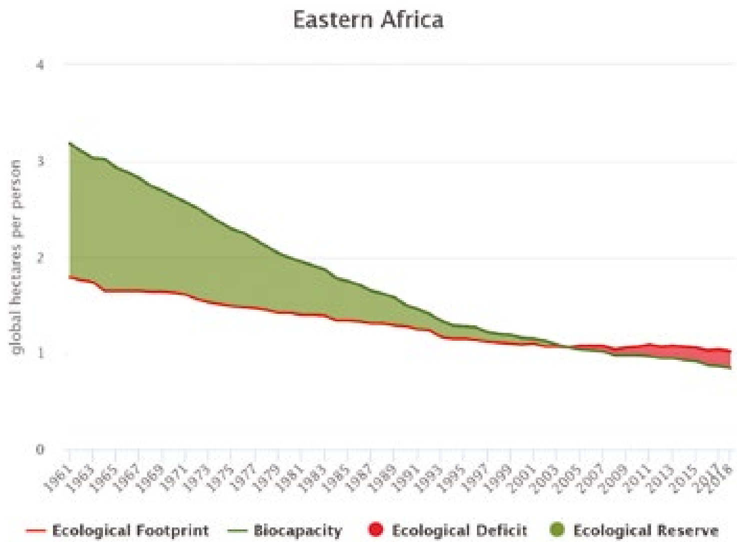
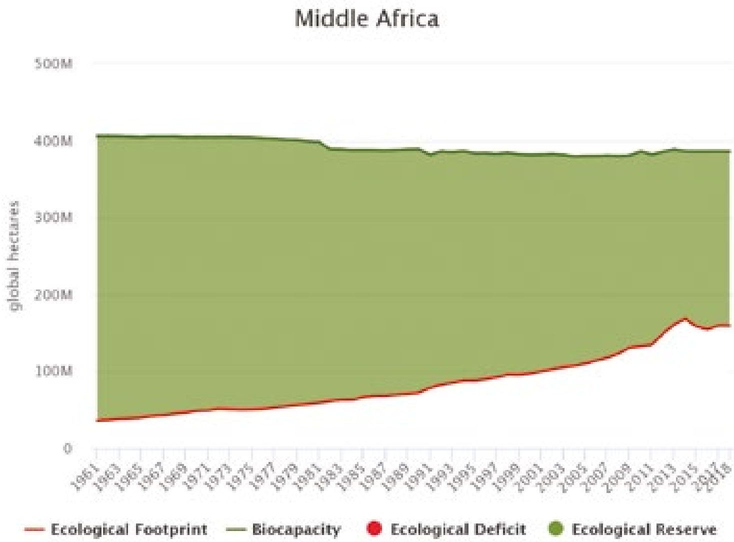


Figura 8. Africa - Total EF and BC trends over the years by region.



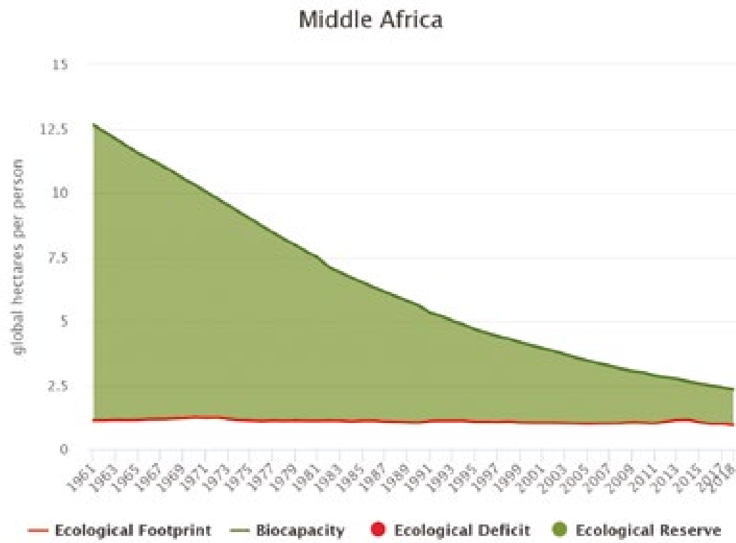


Figura 8. Africa - Total EF and BC trends over the years by region.

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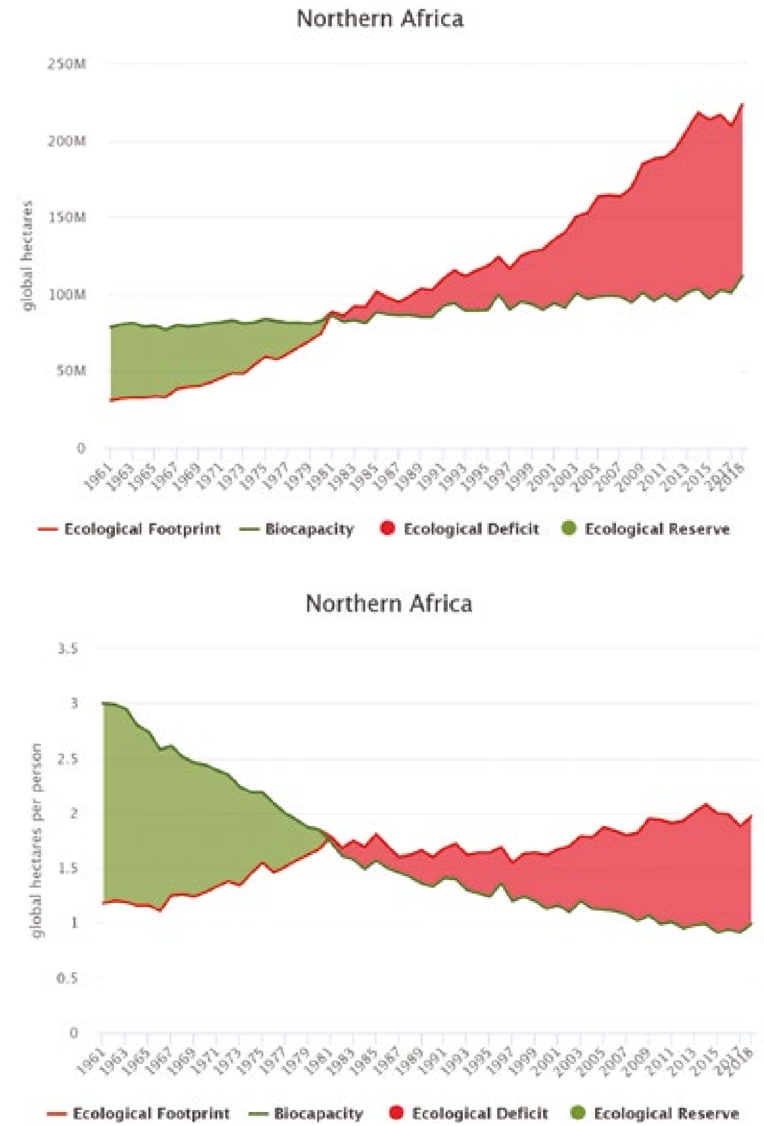
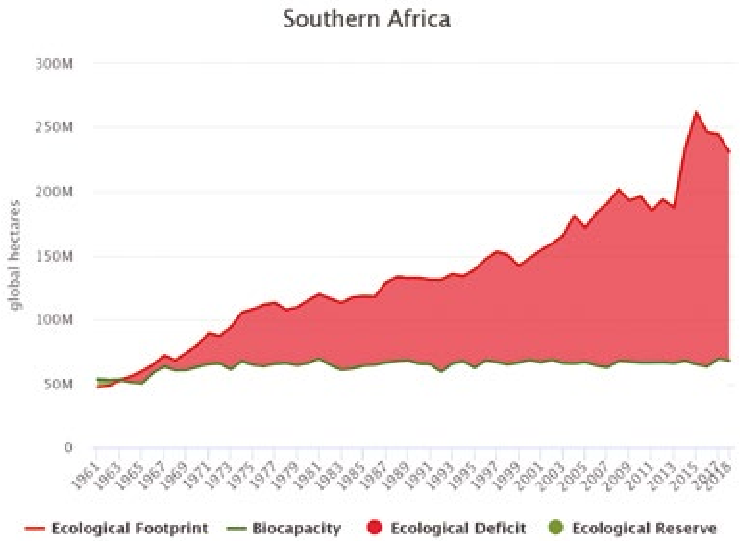


Figura 8. Africa - Total EF and BC trends over the years by region.



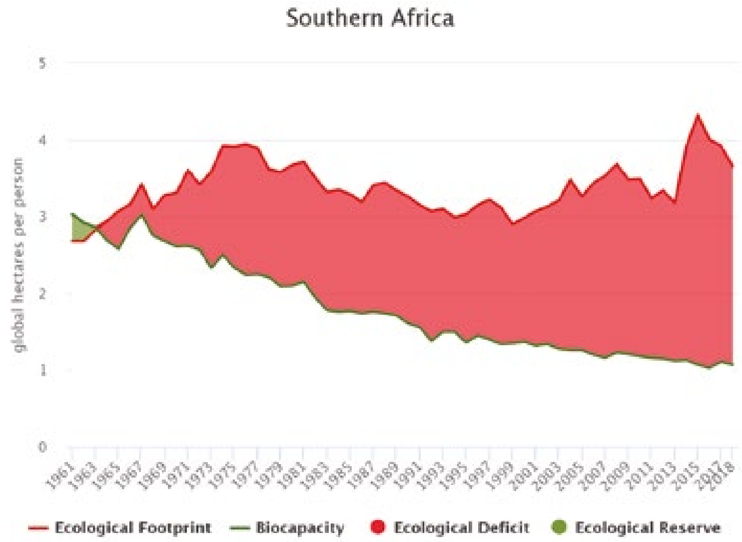


Figura 8. Africa - Total EF and BC trends over the years by region.

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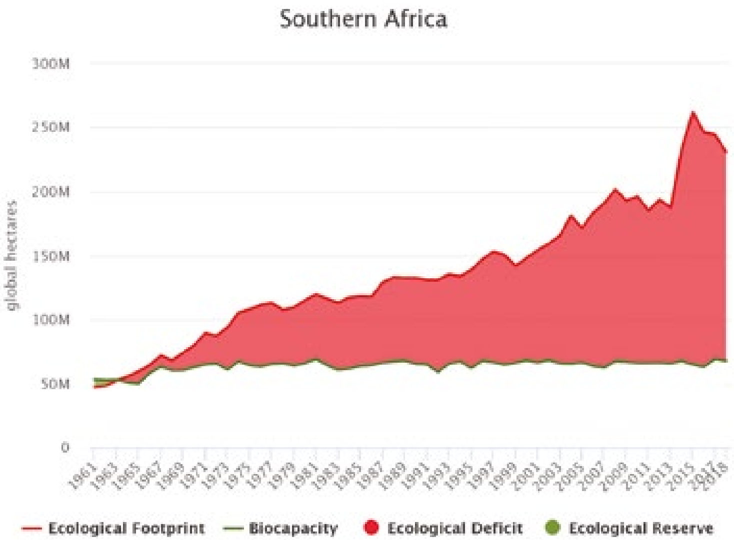


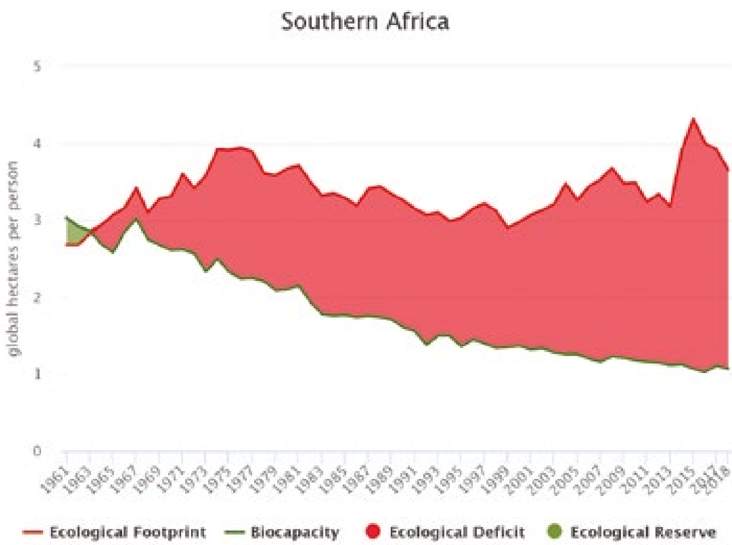
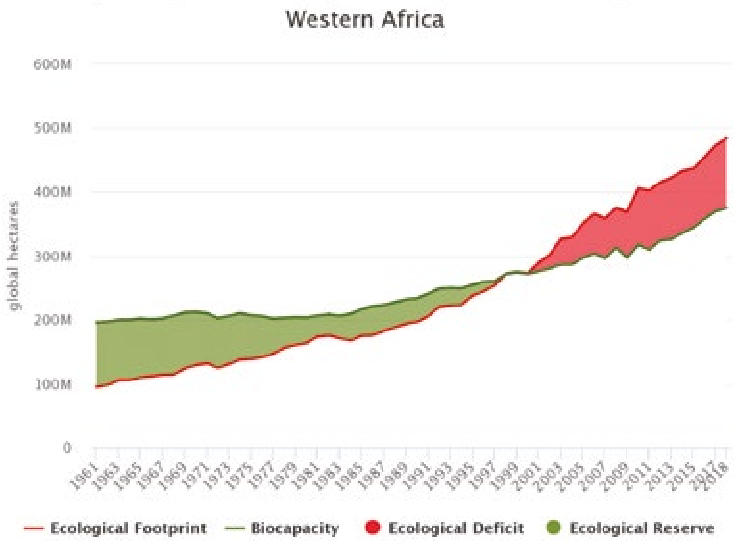


Figura 8. Africa - Total EF and BC trends over the years by region.



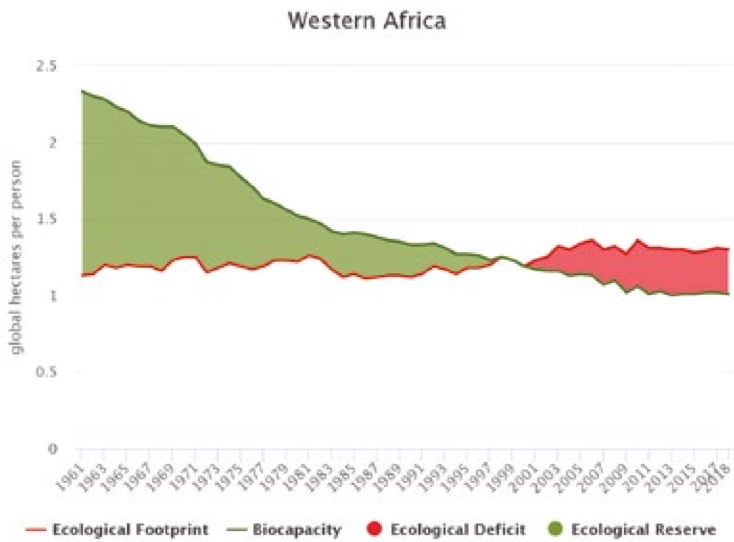


Figura 8. Africa - Total EF and BC trends over the years by region.

3.2 ASIA

Although the per capita EF is below the Western standards and the world average, the total data available for Asia show there has been an increasing exploitation of resources over the years, at a faster rate than their capacity to be regenerated.

The total EF and BC have both increased over the years, with values of about 10,774 and 3,317 mil-lion gha in 2018, respectively, while at the per-capita level the EF has increased from about 1 gha/person in 1961 to about 2.45 gha in 2018, compared with a reduction in per-capita biocapacity from about 1.06 gha/person in 1961 to about 0.75 gha/person in 2018 (Figure 9). The data point to a situation in which the impact of single inhabitants of the continent is clearly growing (probably as a result of changing lifestyles) and, consequently, the total EF is increasing even more so also as a result of population growth,. Conversely, compared to a slightly increasing total BC, there has been a steady decrease in per capita BC due to population growth.

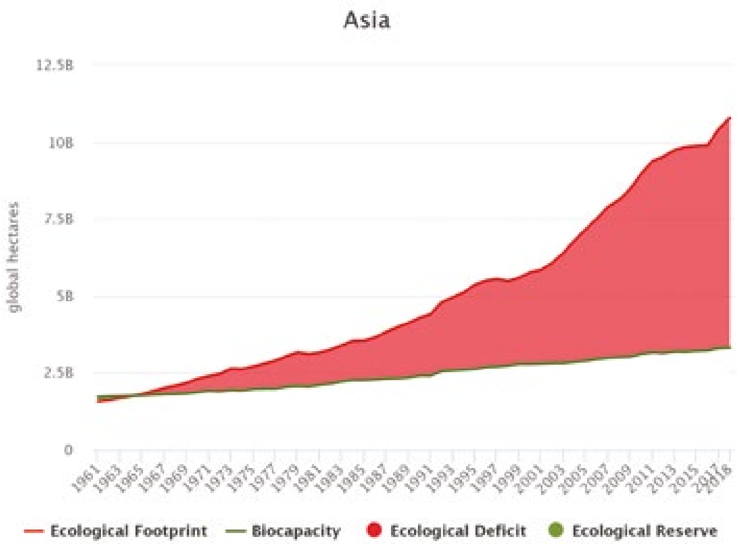


Figura 9. Asia - Trend in EF and BC (total and per capita) over the years.

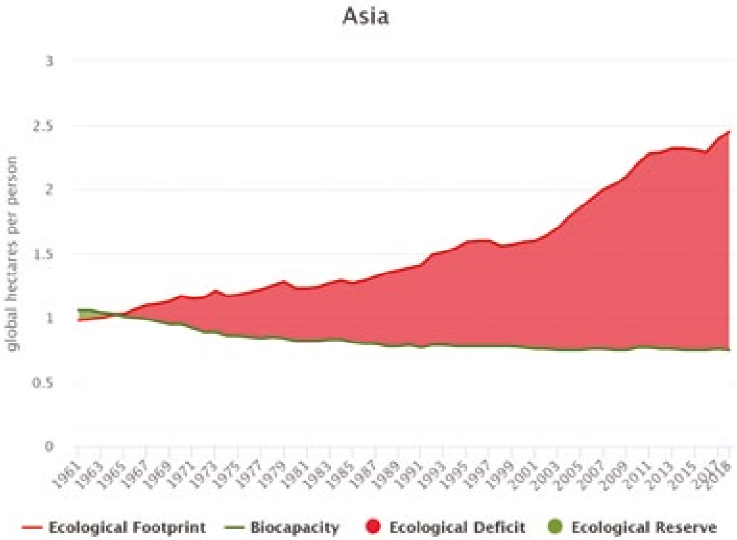
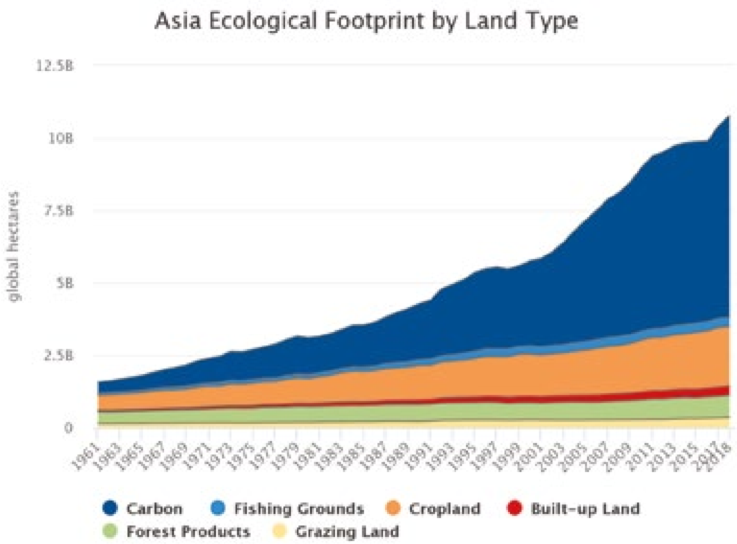


Figura 9. Asia - Trend in EF and BC (total and per capita) over the years.

Observing the total EF, we can see it has increased from about 1,576 Mgha in 1961 to about 10,774 Mgha in 2018. In terms of the contribution of the 6 components (Figure 10), it can be seen that while the largest EF by far is associated with CO2 uptake land, followed by the EF associated with cropland and smaller contributions from the other EFs, all the components have increased over the years. In terms of per-capita EF, there has been a significant increase in the per-capita EF related to built-up land (about +133%) and even more so in the EF related to CO2 uptake land (about +587%), which increased from about 0.24 gha/person in 1961 to about 1.58 gha/person in 2018. The per capita EF associated with cropland (about +44%) and fishing grounds (about +33%) were also found to have increased appreciably, while the EF related to forest land (about -28%) and grazing land (about -11%) decreased compared to 1961.



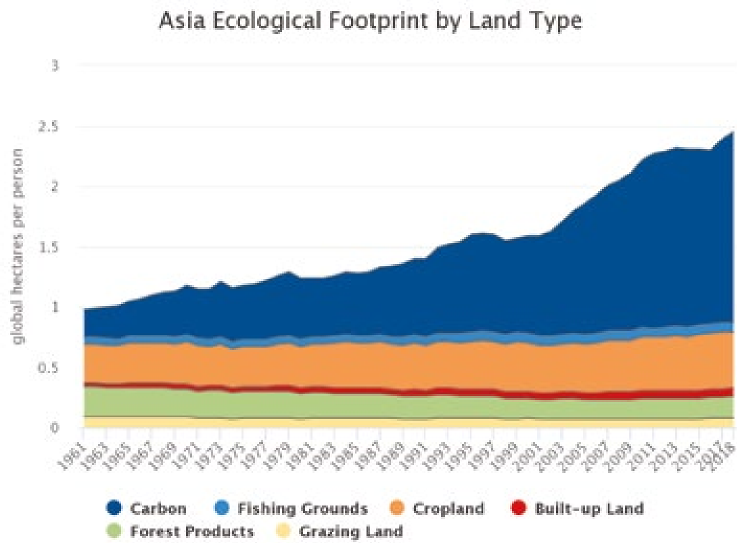


Figura 10. Asia - Trend over the years of EF (total and per capita) by component.

In terms of biocapacity (Figure 11), on the other hand, an upward trend can be observed from about 1,713 Mgha in 1961 to about 3,317 Mgha in 2018, with the main contribution from cropland, followed by forest land. In terms of per capita BC, a more or less significant reduction is observed, across the board, for different BC components. In detail, compared to 1961, the BC of fishing grounds appears to have dropped by about 62%, the BC of forest land by about 64%, and the BC of grazing land by about 45%. In contrast, the BC of cropland (about +30%) and, in accordance with methodological assumptions, the BC associated with built-up land (about +133%, equal to the rela-tive EF) appear to have increased.

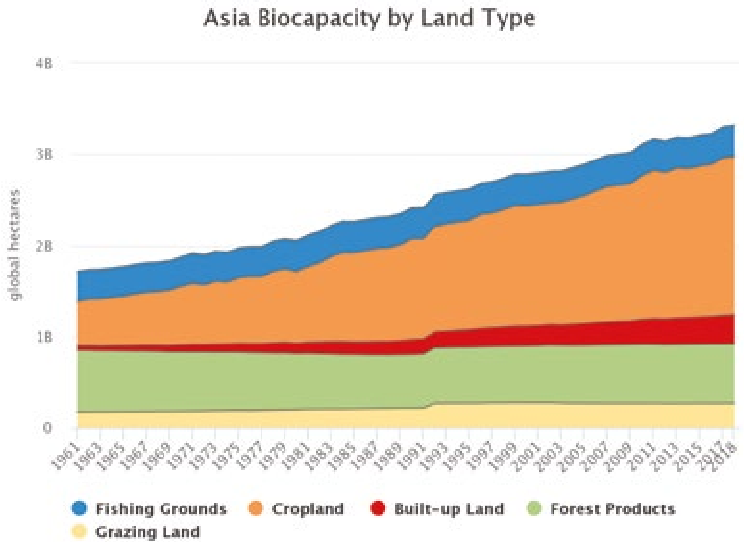


Figura 11. Asia - Trend over the years of BC (total and per capita) by component.

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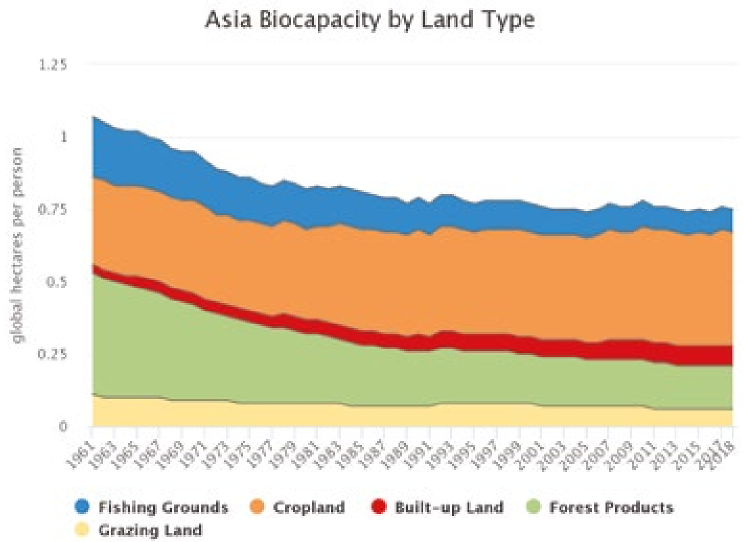


Figura 11. Asia - Trend over the years of BC (total and per capita) by component.

In the Asia-Pacific countries, the gap between EF and BC is widening, leading to a situation where the demand for natural resources is increasing at a faster rate than the environment's capacity to replenish them. Although there is a clear disparity between different countries, with most of the EF associated with just a few (China, Japan, India, and Indonesia), this situation can be attributed to a population growing at a faster rate than BC, but also to a rising new middle class and related lifestyle developments, which are boosting the demand for the energy, food, metals, and water needed to provide for the ever-increasing needs [32].

As mentioned before, the situation in terms of average values is not reflected in the individual countries or even the sub-regions. Although the "ecological deficit" is common to all regions, in fact, in some of them the gap is widening at a faster rate than in others (Figure 12).

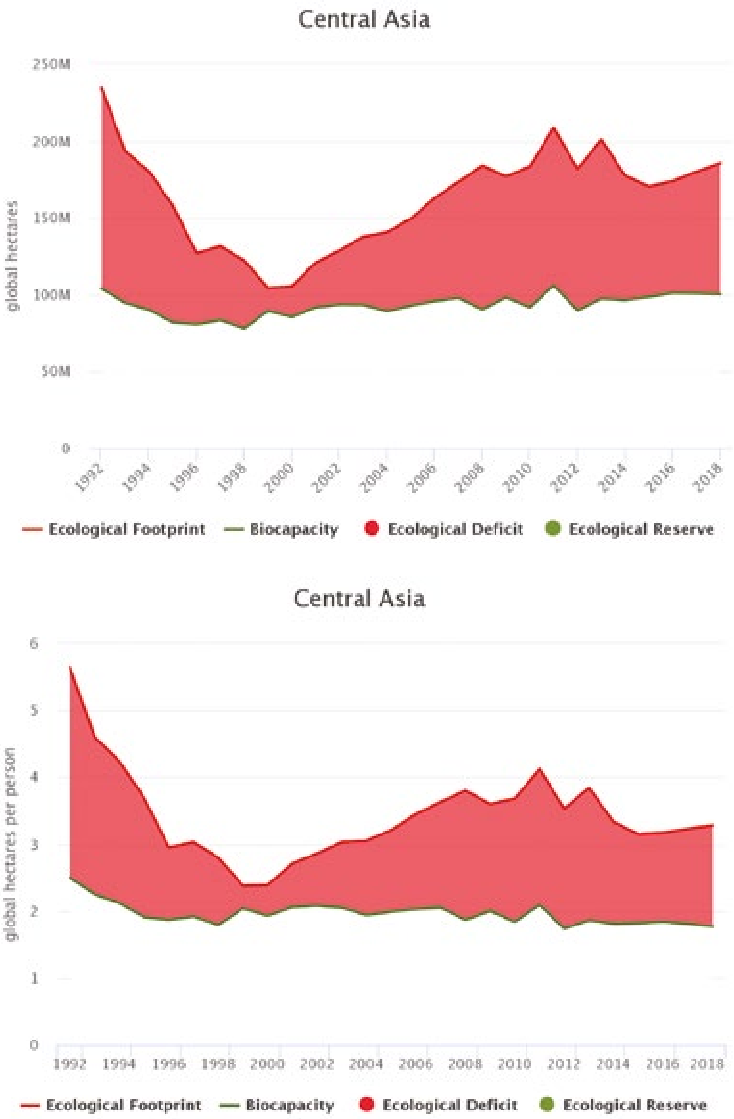
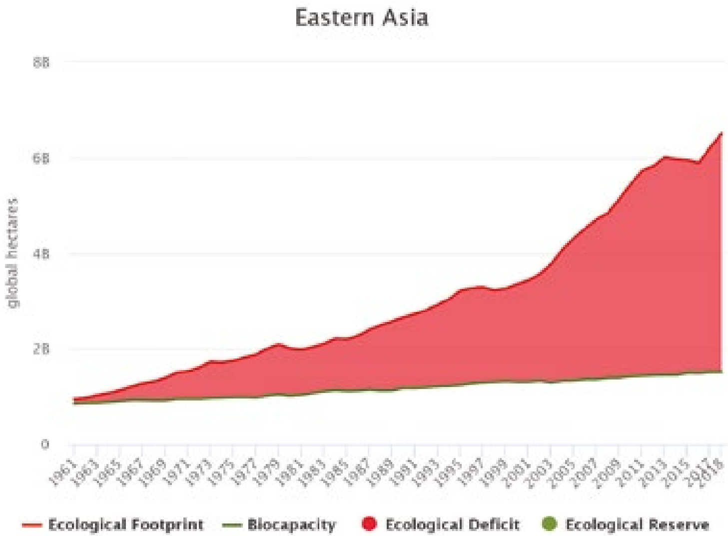


Figura 12. Asia - Total EF and BC trends over the years by region.



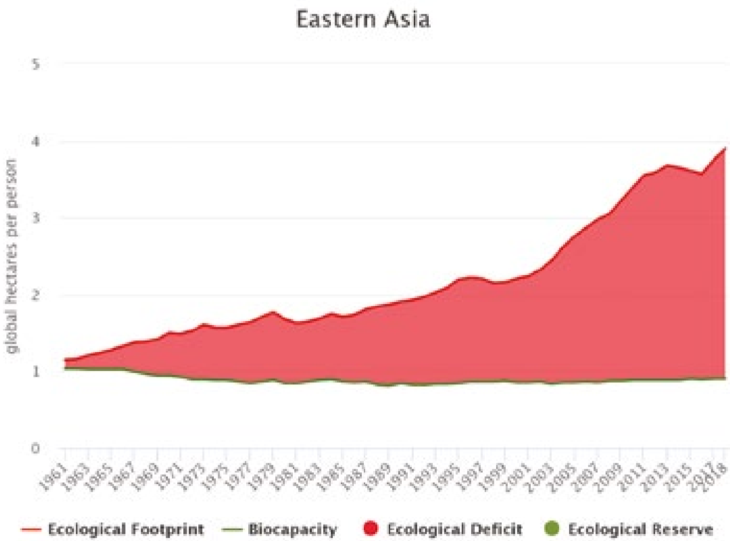
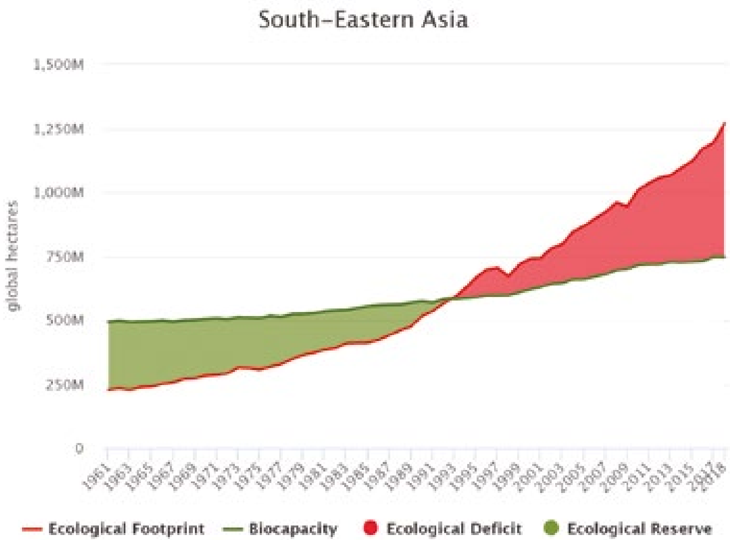


Figura 12. Asia - Total EF and BC trends over the years by region.



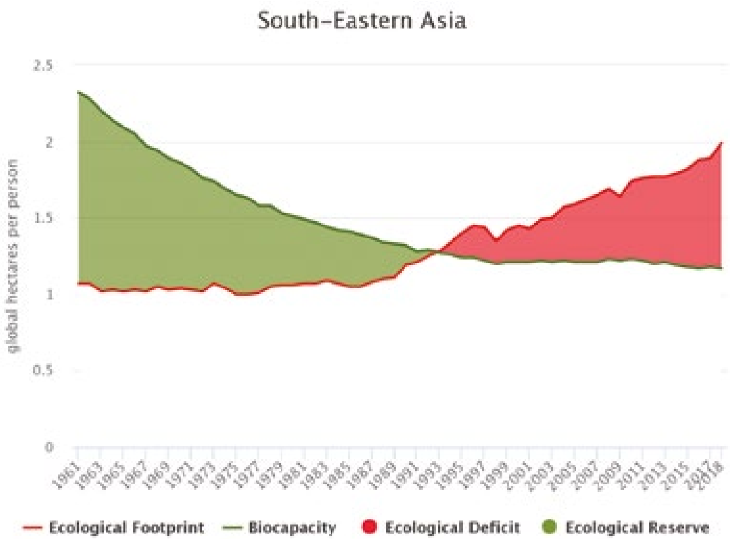
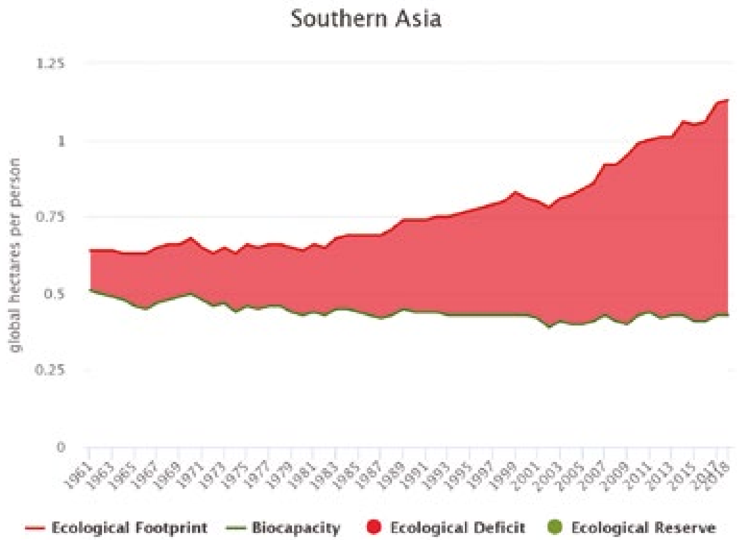


Figura 12. Asia - Total EF and BC trends over the years by region.



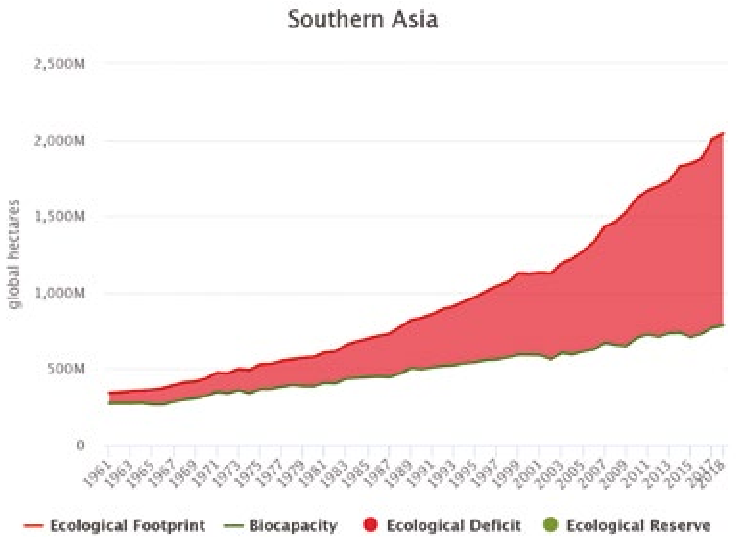
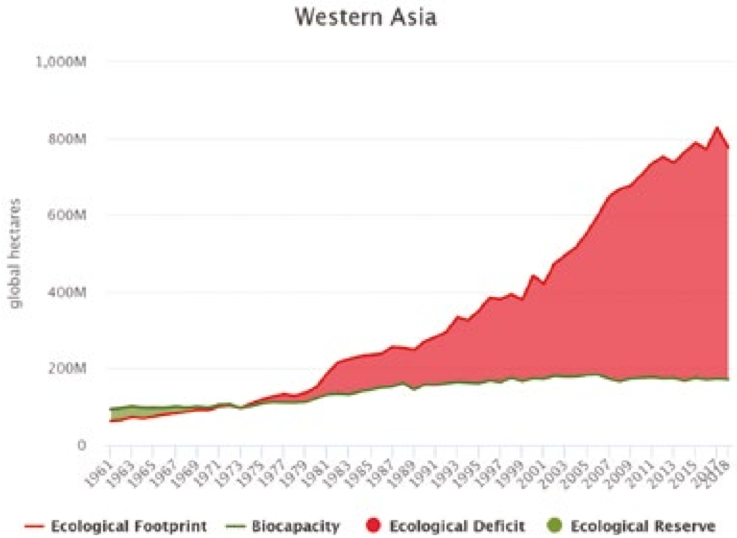


Figura 12. Asia - Total EF and BC trends over the years by region.



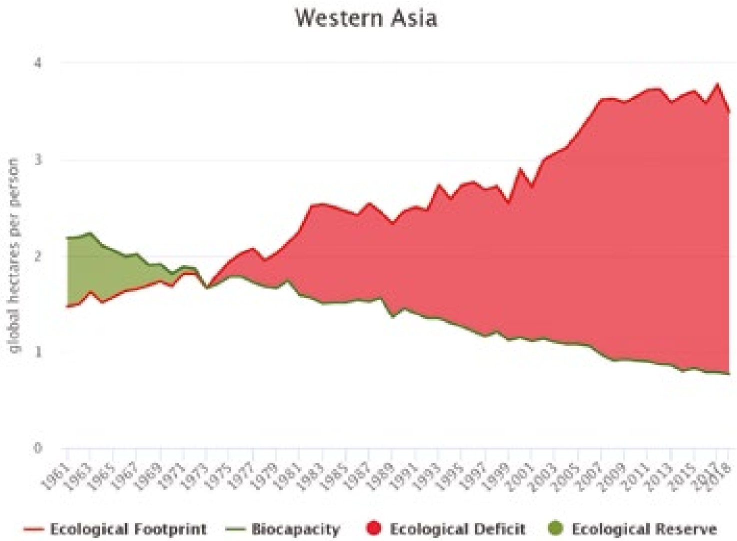


Figura 12. Asia - Total EF and BC trends over the years by region.

3.3 LATIN AMERICA AND CARIBBEAN

The total data available for Latin America and the Caribbean region show that the EF per person is in line with Western standards and the world average, with a general trend of resource exploita-tion increasing at a faster rate than the capacity of resources to be regenerated, although there is still a situation of "ecological surplus".

Examining the numbers in detail, we can see how the total EF is clearly growing (amounting to about 1,504 Mgha in 2018) and the total BC has remained basically unchanged over the years (amounting to about 3.094 Mgha in 2018), while the per-capita EF has increased from about 2.31 gha/person in 1961 to about 2.47 gha/person in 2018, compared to a reduction in per-capita BC from about 14.13 gha/person in 1961 to about 5.08 gha/person in 2018 (Figure 13). This points to a situation where the total EF has increased significantly and there has been a steady and rapid drop in the per capita BC, compared to a noticeable increase in the impact of each single inhabit-ant of the continent (probably as a result of changes in lifestyle) and a substantially stable total BC, due to population growth.

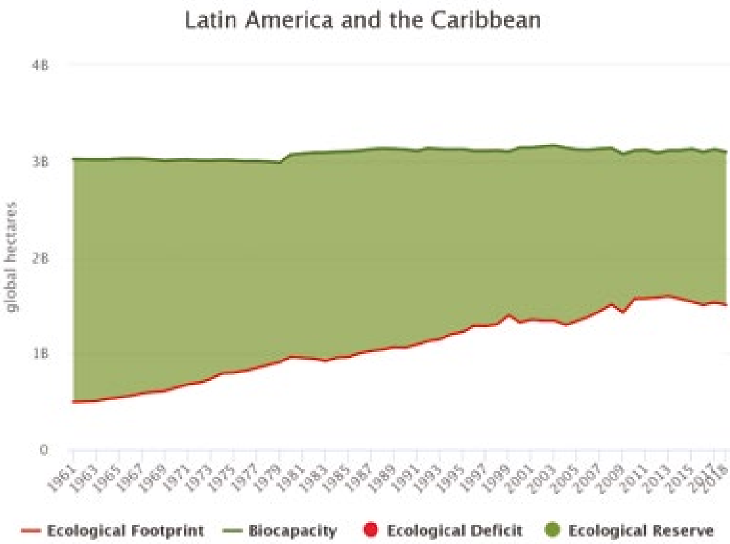


Figura 13. Latin America and the Caribbean - Trends in EF and BC (total and per capita) over the years.

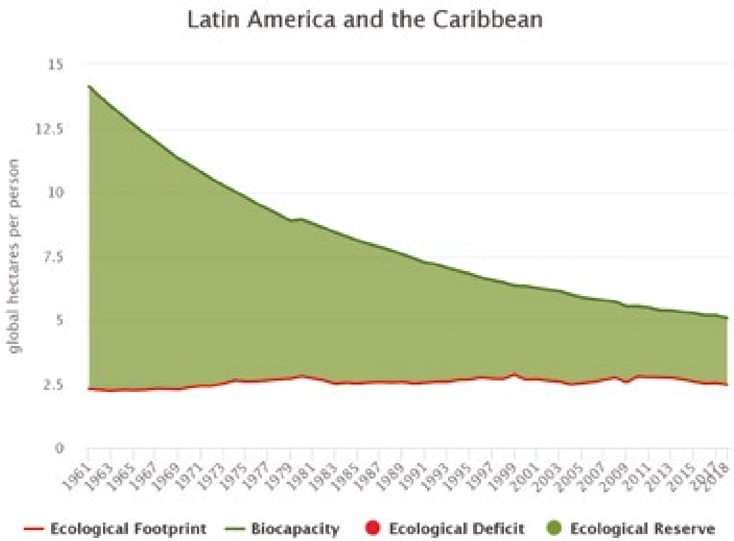


Figura 13. Latin America and the Caribbean - Trends in EF and BC (total and per capita) over the years.

Observing the total EF trend, we can see it has increased from about 494.56 Mgha in 1961 to about 1,504 Mgha in 2018. In terms of the contribution of the 6 components (Figure 14), the larg-est EF by far is the one associated with CO2 uptake land, followed by the EF associated with cropland and appreciable contributions from the EF associated with forest land and grazing lan. Moreover, there has been an increase in all the components over the years. In terms of per capita EF, there has been a significant decrease in per capita EF related to grazing land (-50%) and ap-preciable decrease in EF associated with forest land (-15%). In contrast, all other EFs have in-creased over the years by about +14% in the case of fishing grounds, about +29% in the case of cropland, +142% in the case of CO2 uptake land, and +167% in the case of built-up land.

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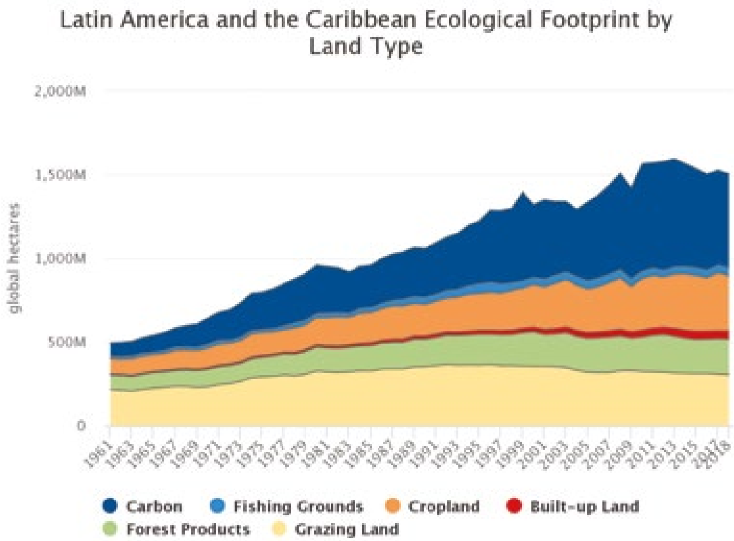

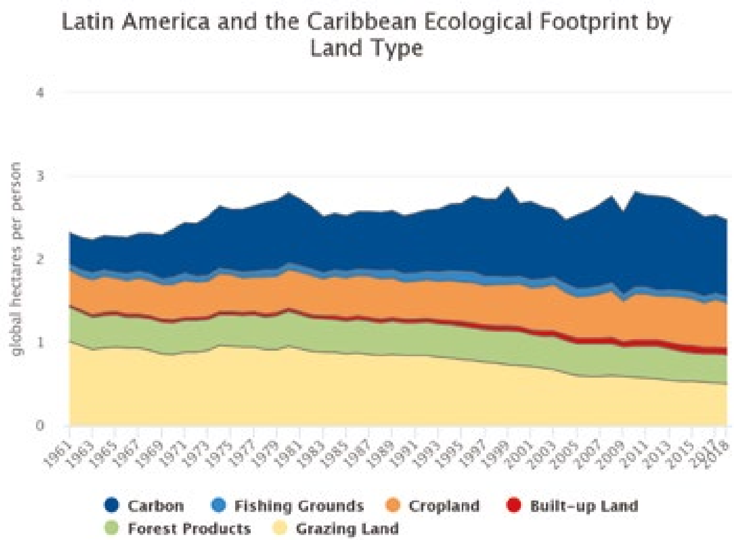

Figura 14. Latin America and the Caribbean - Trend over the years of EF (total and per capita) by component.

On the other hand, biocapacity has remained essentially unchanged (Figure 15), from about 3,018 Mgha in 1961 to about 3,094 Mgha in 2018, with the main contribution coming from forest land, followed by cropland, grazing land and fishing grounds. In terms of per capita BC, there is a signifi-cant decrease in the BC of forest land (about -71%), fishing grounds (about -62%) and grazing land of (about -60%), while the BC of cropland (about +60%) and, in accordance with methodological assumptions, the BC associated with built-up land (about +167%, equal to the relative EF) have in-creased.EF).

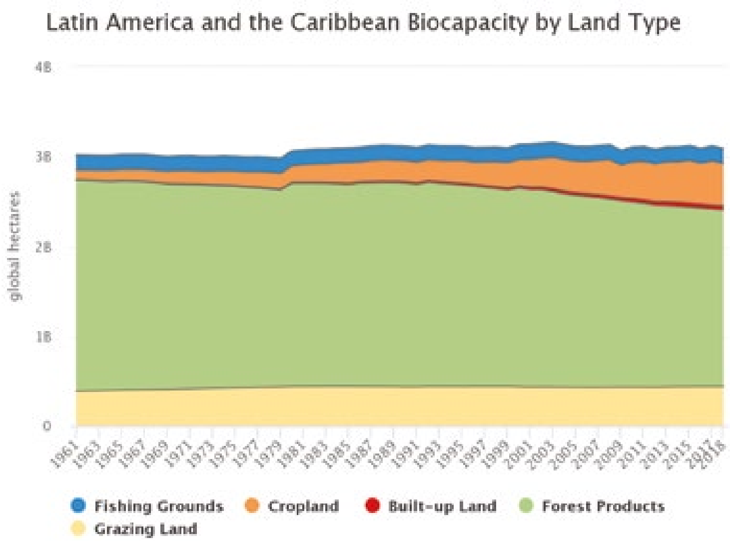

Figura 15. Latin America and the Caribbean - Trend over the years of BC (total and per capita) by component.

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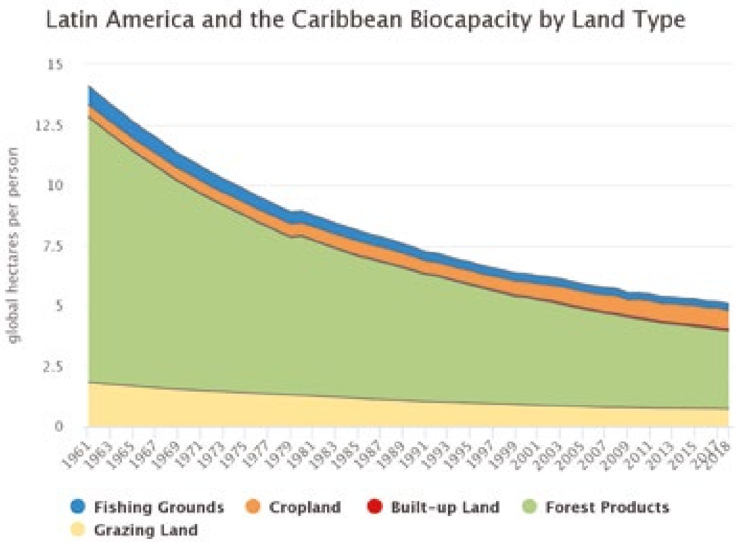
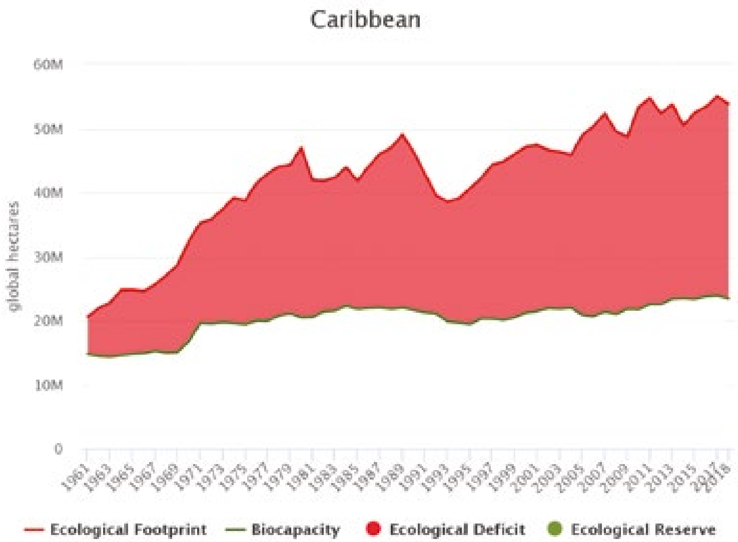


Figura 15. Latin America and the Caribbean - Trend over the years of BC (total and per capita) by component.

To complete the picture, the situation in terms of average values is obviously not reflected in the individual countries or even in the geographical sub-regions of the area. In fact, while South Amer-ica is currently in line with the above descriptions, i.e., in a situation of "ecological surplus", albeit diminishing over time, the other regions (Caribbean and Central America) show a rather different picture (Figure 16).



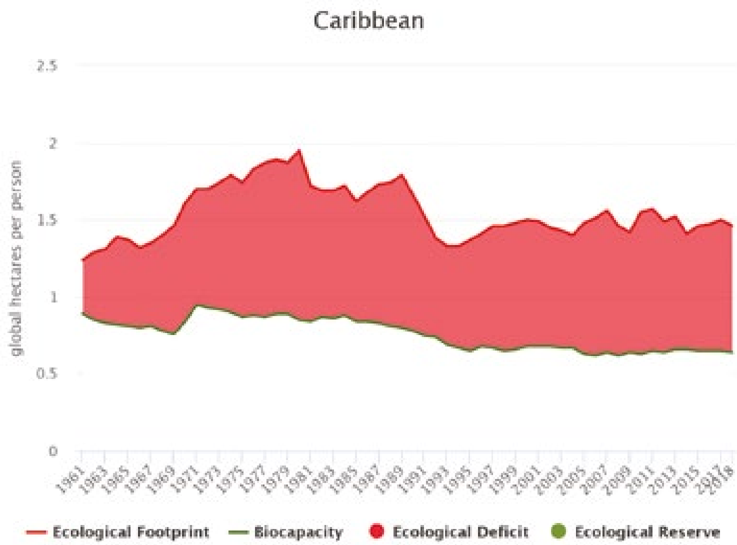


Figura 16. Latin America and the Caribbean – Total EF and BC trends over the years by region.

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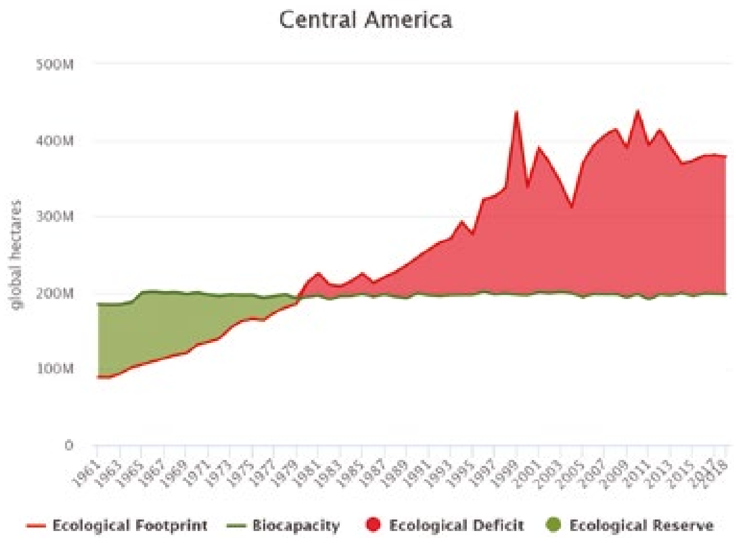


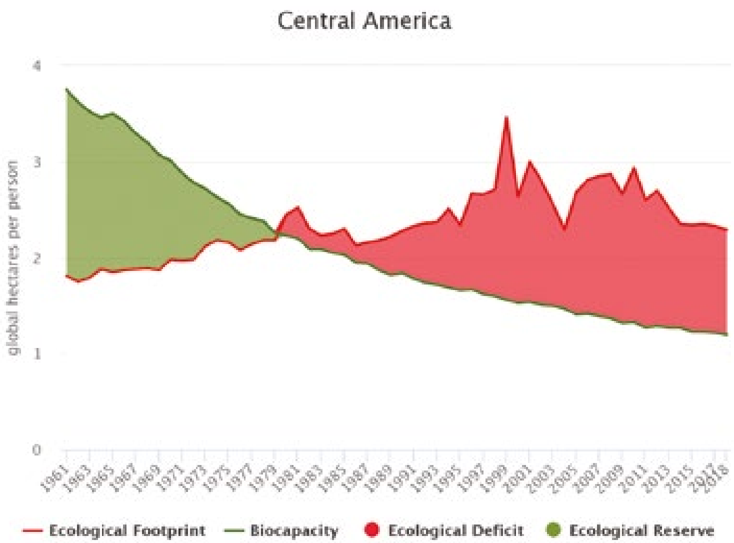
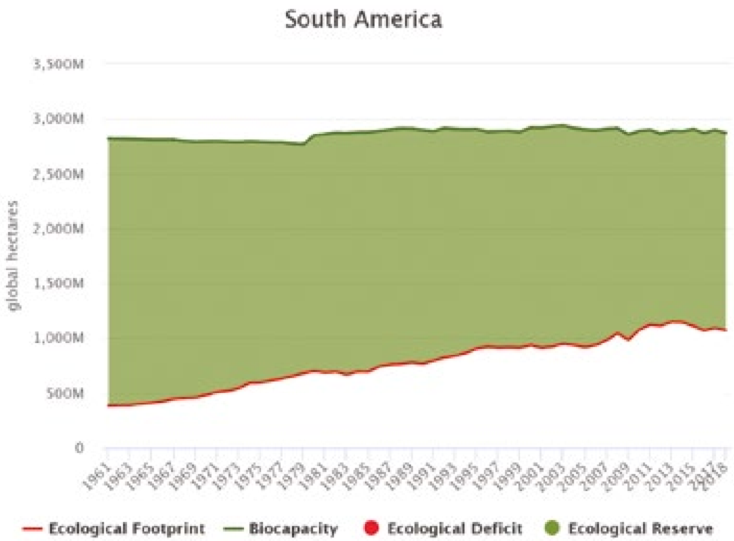


Figura 16. Latin America and the Caribbean – Total EF and BC trends over the years by region.



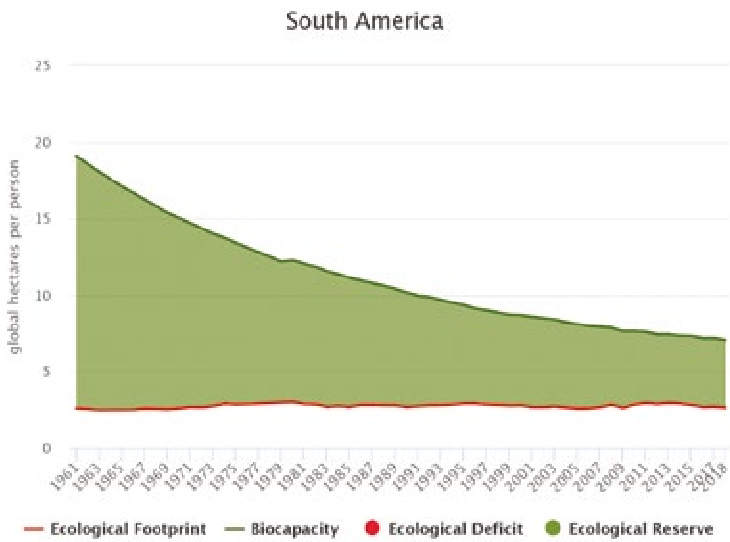


Figura 16. Latin America and the Caribbean – Total EF and BC trends over the years by region.

3.4 COMPARISON WITH THE GLOBAL AND EUROPEAN CONTEXT

Besides differing among themselves, the partner countries under consideration differ quite signifi-cantly from the more developed Western countries (taking Europe as a reference), as well as from the average worldwide situation, as we can see in Figure 17.

In particular, if we examine the most up-to-date data (relative to 2018), the average per capita EF in Africa (at about 1.35 gha) is about half that of Asia (at about 2.45 gha) and Latin America and the Caribbean (at about 2.47 gha), which are both very close to the world average (about 2.77 gha). All EFs, on the other hand, are significantly below the average per capita EF in Europe of about 4.76 gha, considered the Western "standard".

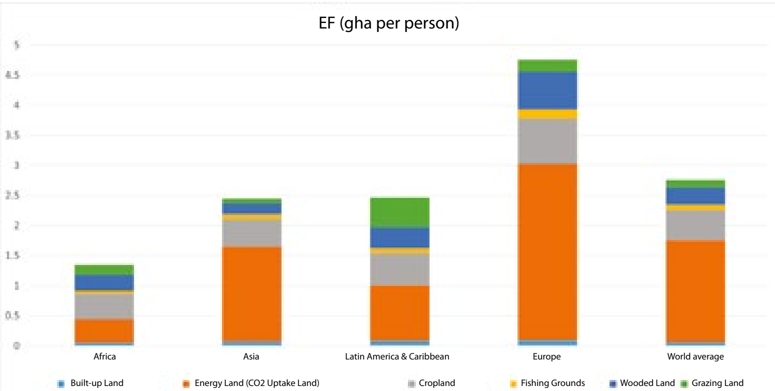


Figura 17. Per capita EF compared with Europe and the world (2018)

When looking at the details of the contributions made by the different EF components, it appears that, basically, the EF associated with energy land (i.e., the land needed to absorb GHG emissions) makes the difference between the areas of interest and between them and the average world sit-uation. In fact, the EF associated with energy land is about 0.39 gha for Africa, about 1.58 gha for Asia, 0.92 gha for Latin America and the Caribbean, while the world average is about 1.69 gha. In-stead, the sum of the other 5 components of the EF (as well as, indicatively, the 5 values of the in-dividual components), is comparable in the different cases, being about 0.96 gha for Africa, about 0.87 gha for Asia, 1.55 for Latin America and the Caribbean, and about 1.07 gha as the world aver-age.

However, compared with the Western "standard" (the average situation of Europe having been taken as a reference), and although the energy land EF plays the key role, several components of the EF featuring appreciable deviations can be observed in the areas of interest, as shown in Table 3.

Table 3. Comparison of per capita EF by component with the Western "standard".

REGION	Built-up land	Energy land (CO_2 up-take)	Cro-pland	Fishing grounds	Forest land	Grazing land
Africa	0,05	0,39	0,42	0,05	0,27	0,17
Asia	0,07	1,58	0,46	0,08	0,18	0,08
Latin America and the Caribbe-an	0,08	0,92	0,54	0,08	0,35	0,5
Europe	0,09	2,94	0,75	0,15	0,63	0,2

4 APPLICATION OF THE EF AND OTHER FOOTPRINTS IN PARTNER COUNTRIES

Except for the annual assessments carried out by the Global Footprint Network, with the National Footprint Accounts, as highlighted in Section 3 above, there appear to be fairly limited case stud-ies and specific applications of the EF carried out in the regions and partner countries of interest, in a more detailed manner than the national level and with regard to international development cooperation activities.

Studies relating to the ecological footprint of cities are unquestionably very interesting, given that cities are home to an ever-increasing majority of the population and activities of a country, there-fore representing the key areas for addressing the challenges posed by sustainability in the future. Such studies include the EF assessment for the city of Campo Grande, in the state of Mato Grosso do Sul (the first city in Brazil to go along this path), as well as the study carried out for the city of Curitiba and the EF assessment for the city and state of São Paulo, also in Brazil, carried out by the Global Footprint Network in collaboration with central and local governments and other local stakeholders. These studies have adopted an input-output model (consistently with the "top-down" approach), which involves the assessment of the EF as the allocation of nationwide data to the sub-national level, on the basis of economic information and consumption patterns allowing the identification of economic and, consequently, resource flows in the various sectors. Moreover, in the case of São Paulo, the results of the assessment also distinctly show how 5 different con-sumption categories – food, housing, mobility, products, services, and government – exert a specif-ic "pressure" on the planet's 6 ecological resources (cropland, grazing land, forest land, fishing grounds, built-up land, energy land and CO2 uptake land).

Although it is not specific to the EF, another relevant study called the "Cities Footprint" project has been carried out in other Latin American countries, , whose first phase entailed measuring the CF and WF of the cities of La Paz (Bolivia), Lima (Peru) and Quito (Ecuador). In terms of footprint assessment at the urban level, a third important study was carried out by ICLEI-South Asia, which calculated the CF and energy footprint of 54 cities in South Asia and, in particular, in India, Bang-ladesh, Bhutan, Nepal, and Sri Lanka. Equally relevant are the EF, or, more generally, the sustainability assessment studies applied to development cooperation organisations and, in particular, to their specific activities. They include a study carried out by

Almeida et al., in 2011, relative to the EF of the mobility and transportation activities of several organisations, highlighting their significant impact, which, moreover, appears to be increasing due to the increase of travel and transport modes (air travel). Or the 2014 study, also by Almeida et al., not relevant to the EF but to the CF of organisations involved in North-South development cooperation, highlighting how most of the footprint of a small sample of Belgian and German organisations is associated with indirect emissions.

Other interesting studies include one by Nicholson et al., in 2003, on the application of EF as an environmental assessment tool for a project, showing how EF can be used in the design phase to evaluate possible construction options, within a framework of sustainable production and con-sumption, based on data relative to energy consumption, material resources and waste produced during construction and then in the operational phase.
For a more detailed understanding of the EF and its applications, there is a large amount of scien-tific literature, which has investigated various aspects of EF assessment in the regions and partner countries over the years, as well as other environmental footprints, such as the WF by the Water Footprint Network for partner countries, at the country level and for specific sectors.

Table 4 below provides a general list (which is certainly not complete and exhaustive) of the most interesting documents (including those mentioned above) for further investigation.

4

Table 4. Summary of some significant references regarding the application of the EF and other environmental footprints		
Type of reference	Short description	Link
AFRICA		
WF study	WF Assessment Profile – Ghana	https://waterfootprint.org/media/downloads/Ghana_Water_Footprint_Profile_1.pdf
WF study	WF Assessment Profile – Kenya	https://waterfootprint.org/media/downloads/Kenya_Water_Footprint_Profile1_1.pdf
WF study	WF Assessment Profile - Mali	https://waterfootprint.org/media/downloads/Mali_Water_Footprint_Profile_1.pdf
WF study	WF Assessment Profile – Mozambique	https://waterfootprint.org/media/downloads/Mozambique_Water_Footprint_Profile_1.pdf
WF study	WF Assessment Profile – Rwanda	https://waterfootprint.org/media/downloads/Rwanda_Water_Footprint_Profile_1.pdf
WF study	WF Assessment Profile – Benin	https://waterfootprint.org/media/downloads/Benin_Water_Footprint_Profile_1.pdf
WF study	WF Assessment Profile - Ethiopia	https://waterfootprint.org/media/downloads/Ethiopia_Water_Footprint_Profile_1.pdf
WF study	WF Assessment – Morocco	https://waterfootprint.org/media/downloads/Report_21_WFP_Morocco_and_Netherlands_1.pdf
WF study	WF Tunisia with economic approach	https://waterfootprint.org/media/downloads/Report61-WaterFootprintTunisia_1.pdf
Scientific paper	Analysis of the changing footprint of the built environment in Sub-Saharan Africa	https://doi.org/10.1016/j.landusepol.2022.106291

Type of reference	Short description	Link
Scientific paper	Study of EF convergence in different African countries	https://doi.org/10.1016/j.jenvman.2022.116061
Scientific paper	Analysis of EF in African cities	https://www.ijern.com/images/February-2013/22.pdf
ASIA		
CF study	CF (and energy footprint) of 54 South Asian cities.	https://e-lib.iclei.org/wp-content/uploads/2015/04/Energy-and-Carbon-Emissions-Profiles-for-54-South-Asian-Cities.pdf
Scientific paper	Trend analysis of average annual BC rate and EF of South Asian countries.	https://www.researchgate.net/publication/351638124_A_Comparative_Study_on_South_Asian_Countries'_Biocapacity_and_Ecological_Footprint_A_Message_Forward_1428_LINGUISTIC_ANTVERPIENSIA
WF study	Comparison of the grey WF for organic and conventional cotton crops	https://waterfootprint.org/media/downloads/Grey_WF_Phase_II_Final_Report_Formatted_06.08.2013.pdf
WF study	Study on sustainable water resource use in the cotton supply chain in India	https://waterfootprint.org/media/downloads/Assessm_water_footprint_cotton_India.pdf
WF study	Study on the reduction of WF cotton cultivation in India	https://waterfootprint.org/media/downloads/A_guide_to_reduce_water_footprint_of_cotton_cultivation.pdf
WF study	Assessment of WF of washing-dyeing-finishing plants in China and Bangladesh	https://waterfootprint.org/media/downloads/WS2_Executive_Summary_for_CA_by_WFN.pdf
WF study	WF and food consumption in China	https://waterfootprint.org/media/downloads/Report30-China_1.pdf

Type of reference	Short description	Link
WF study	WF of cotton, wheat and rice crops in Central Asia	https://waterfootprint.org/media/downloads/Report41-WaterFootprintCentralAsia_1.pdf
WF study	Assessment of WF reduction measures in cotton growing in India	https://waterfootprint.org/media/downloads/Report68-WaterFootprintReduction-Cotton-India.pdf
LATIN AMERICA AND CARIBBEAN		
EF Case Study	EF study of the city of Campo Grande	https://www.wwf.org.br/?31506/Publication-presents-the-study-of-Campo-Grandes-Ecological-Footprint
EF Case Study	EF study of the city of Curitiba	https://www.footprintnetwork.org/content/images/uploads/Curitiba_report_PT.pdf
EF Case Study	EF study of the city and state of São Paulo	https://www.footprintnetwork.org/content/uploads/2017/05/2012saopauloecologicalfootprint.pdf
Project on CF	"Cities Footprint," CF of the cities of La Paz, Lima and Quito.	http://www.huelladeciudades.com/citiesfootprint/index.html
WF study	WF Latin America and Caribbean Assessment	https://waterfootprint.org/media/downloads/Report66-WaterFootprintAssessment-LatinAmericaCaribbean_1.pdf
Date	Ecological footprint assessment of Mexico's per capita consumption of forest land	National Footprint and Biocapacity Accounts (NFA) - knoema.com
Scientific paper	Study of EF convergence in Latin America.	https://doi.org/10.1007/s11356-021-14745-1
Scientific paper	Analysis of environmental degradation associated with the ecological footprint in Latin America	https://doi.org/10.1016/j.jclepro.2021.128585

Type of reference	Short description	Link
Scientific paper	Study of the effect of public-private partnerships in energy and financial development on Brazil's EF	https://link.springer.com/article/10.1007/s11356-021-15791-5
GENERAL / DEVELOPMENT COOPERATION		
EF Study	EF mobility and transportation in development cooperation organisations	https://www.biw.kuleuven.be/lbh/lbnl/forecoman/klimos/papers/wp5ecofootprint-11march11.pdf
CF study	CF of cooperation organisations	https://onlinelibrary.wiley.com/doi/abs/10.1002/sd.1553
Scientific paper	Application of EF as a tool for the environmental assessment of projects	http://www.homepages.ucl.ac.uk/~uces-sjb/S3%20Reading/nicholson%20et%20al%202003.pdf

5 STRATEGIC ACTIONS/ SOLUTIONS FOR REDUCING IMPACTS

Preserving the existing biocapacity to reduce the risk that increasing domestic demand may lead to less and less availability of resources to meet demand is, unquestionably, the first fundamental step that needs to be taken, given that the EF impact is constantly – and more or less rapidly – in-creasing. Similarly, action focused on the domestic demand for resources and its sustainability is of paramount importance.

Therefore, strategies aimed at the efficient use of resources, that can both improve ecosystem re-silience and contribute to reducing GHG emissions while enhancing climate change adaptation, need to be implemented. Such strategies require concerted national and local efforts, across the board, including policy guidance and legislation and improved governance, as well as actions aimed at promoting local innovation and involvement and changing the habits of various stake-holders.

General measures aimed at ensuring the access to natural resources by future generations and adequate security for all may include ([32], [33]):

- improving strategic planning and evaluation processes;
- promoting integrated approaches to resource planning and management at all levels, to reconcile and balance development and conservation while preserving vital ecosystem services;
- preserving and protecting ecosystems that provide key ecosystem services for achieving food, water and energy security;
- establishing financial mechanisms for natural capital conservation;
- strengthening and significantly investing in government processes responsible for sustainable resource allocation and management;
- encouraging investment in the recovery and rehabilitation of the ecological and natural resource base of our economies;
- promoting reforms for equitable access to and sustainable use of natural resources;
- expanding protected area networks and integration of terrestrial and marine landscapes, through effective participation of local communities for improved resilience.

The main global critical issues in the areas of interest, based on the available data and summa-rised in the preceding paragraphs, can be identified as:

- overexploitation of forest resources, i.e., more or less obvious deforestation;
- overcultivation, on often ecologically fragile soils;
- variably, yet steadily, increasing GHG emissions;

and can be more or less directly associated with three main drivers, namely:

- population growth;
- increasing urbanisation;
- growing demand for energy.

To give an idea of the significance of these critical issues, and based on the most updated data, the EFs associated with forest land, cropland, and energy land, which are featuring large-scale variations over the years, are those that make the largest contributions to the total EF. In particu-lar, they collectively account for 78.5% of per capita EF in Africa and 90.7% in Asia, as of 2017.

Various strategic actions and solutions, summarised below, can be implemented by different ac-tors at different levels of action for impact reduction, in terms of these specific components [33].

In detail, specific measures for forest conservation, avoiding deforestation and forest degradation, may include:

- investing in sound and sustainable forest management practices aimed at securing products (food, timber, building materials, etc.) and services (watershed preservation, soil stabilization and erosion prevention, and carbon sequestration) that forest land provides;
- promoting the use of sound environmental and social management standards (e.g. FSC [34] and PEFC [35]);
- combating illegal timber trade;
- reducing emissions from deforestation and forest degradation, by implementing national (and subnational) activities that can reduce human pressure on forest land with associated GHG emissions, including specific framework programmes (such as the UNFCC's REDD+ [36]).

5

Measures can also be implemented to improve food security, without overexploiting the land and without compromising the ecological services on which food supplies depend, such as:

- sustainable intensification and improvement of crops, as opposed to expanding agriculture into new areas;
- investment in the rehabilitation of degraded, abandoned or unproductive land, with related measures to reduce impacts such as erosion and soil loss;
- transformation of current agricultural systems by closing nutrient cycles, increasing resource efficiency and eliminating unsustainable practices that harm the environment and cause biodiversity loss;
- promotion of best management practices and knowledge transfer to reduce impacts and expand knowledge useful for maintaining and restoring healthy ecosystems;
- investment in supporting smallholder farmers to maximize their contribution to food and water security, environmental protection, and climate adaptation, also by promoting sustainable production through compliance with certification standards/schemes;
- increasing the efficiency of food systems by reducing post-production losses, including investments in storage, processing and improving access to markets;
- promotion of wastewater treatment and reuse for agricultural purposes.

Furthermore, low-carbon development can be achieved by implementing actions affecting all the main drivers responsible for increasing the EF, taking decisions centred on the well-being of the population, promoting the development of sustainable cities and urban lifestyles, and placing clean/renewable energy at the centre of energy supply strategies. Strategic measures in this re-gard may include:

- promoting family support policies, child health care services, education, as well as policies for encouraging and increasing opportunities and incomes for women and youth and promoting entrepreneurship;
- generating economies of scale by bundling services and infrastructure at the urban planning stage;
- limiting urban sprawl, particularly in areas that are vulnerable to rising sea levels, flooding or landslides, through appropriate urban planning regulations;
- promoting sustainable construction, in terms of both building materials and energy efficiency of buildings;
- investing in public transport services, to reduce pollution and congestion;
- encouraging urban agriculture and sustainable wastewater management, to support peri-urban agriculture, thereby increasing urban food security and reducing costs and wastage of water and nutrients, and generally promoting good practices for resource efficiency and the circular economy at the urban level;
- long-term national and regional planning, according to a vision based on energy efficiency and renewable energy, encouraging investment in

clean energy production and distribution;

- adopting and implementing laws, regulations, policies and standards for renewable and sustainable energy, fostering cross-sector integration and public participation in decision-making;
- setting national targets to end energy poverty and vulnerability by promoting access to safe, clean and affordable energy services;
- steadily increasing energy efficiency on the production/supply side and encouraging an energy-saving culture on the demand side;
- focusing on the environmental and social externalities of energy production, encouraging the increased contribution of clean renewable energy sources;
- investing in sustainable biomass supply and utilization through multipurpose agroforestry;
- adopting and adapting advanced technologies and promoting technology cooperation.

Other considerations concern the educational function of EF, which has proved to be a useful tool for enhancing consumer awareness about the impacts of their lifestyles and, in this sense, could support development programmes promoting and encouraging healthy lifestyles. Rule-based life-styles for healthy eating, in fact, coincide with functional choices for a sustainable diet, for both humans and the environment. Nutritional education programs that promote virtuous diets and dishes, which look at the health of the planet and human beings, are therefore just as important as the other strategic actions previously mentioned (in this regard, it is worth mentioning the nu-tritional guidelines adopted by various countries [37] are increasingly based on a holistic ap-proach, that also takes into account sustainability or examples aimed at adapting the Double Pyr-amid [12] to different food cultures, as a means for promoting greater awareness about healthy and sustainable diets in different geographical contexts).

6 CONCLUSIONS

The current global context is characterised by obvious environmental criticalities that are largely the consequence of human overexploitation of resources, within the current and prevailing model of economic development based on a "take-make-dispose" approach, which inevitably causes re-source depletion, waste generation and pollution.

Measuring these impacts is of paramount importance within this general framework, in order to build knowledge and subsequently define specific actions and interventions. At this respect, the various environmental "footprints" are very effective indicators.

The focus of this technical annex is specifically on one of these environmental footprints, the Eco-logical Footprint (EF), with a summary of the current "state of the art" for the geographical areas of interest of the partner countries.
The general outcome is a context that shows a significant and growing impact of the EF, albeit at variable speeds, in which actions focused on domestic demand for resources and its sustainability, together with the preservation of existing biocapacity, are unavoidable and of fundamental im-portance to mitigate the risk of ever-decreasing resources to meet this demand.

These actions should strategically aim at achieving the efficient use of resources by improving the resilience of ecosystems, contributing to the reduction of GHG emissions and enhancing climate change adaptation, and require concerted efforts at national and local level in all sectors, ranging from policy guidance and legislation to improved governance. Actions for achieving local innova-tion, involvement and changing the habits of the different stakeholders are equally important, giv-en that cooperation projects in partner countries are to all intents and purposes an effective driv-ing force, being able to maximise the effect of the limited available funding by operating within the key points of intervention.

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8 ANNEX A – SUPPORTING CHECKLIST FOR PROJECT EVALUATION I

The following table is a *checklist* that should assist the evaluator of a project in considering all the elements that are necessary to assess the ecological footprint of that project.

Question	Answer (YES-NO-N/A)	NOTES
General aspects related to the impact of the project		
Is the project area appropriately identified and quantified in terms of extent?		
Are current land uses in and around the project area identified and appropriately described?		
Are any conflicts between "project" land use and current land uses identified and appropriately described?		
Are the soil conditions in the project area appropriately described?		
Is temporary occupation/use of land for project implementation planned? Has the area of land temporarily required been quantified? Is a plan for the restoration of such land provided/ described?		
Is the adoption of "best available techniques" with respect to the spatial context adequately detailed and demonstrated?		

Question	Answer (YES-NO-N/A)	NOTES
Are the relevant primary and direct effects of the project on land uses, eco-logical features, and land conditions appropriately described and, if relevant, quantified?		
Are the relevant primary and direct effects of the project on flora, fauna, and habitat appropriately described and, if relevant, quantified?		
Are the relevant primary and direct effects of the project on the water environment appropriately described and, if relevant, quantified?		
Are the relevant primary and direct effects of the project in terms of depletion of non-renewable natural resources appropriately described and, if relevant, quantified?		
Are the relevant primary and direct effects of the project on air quality and climatic conditions appropriately described and, if relevant, quantified?		
Are secondary effects resulting from the primary and direct effects on any of the above adequately described and, if relevant, quantified?		

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Question	Answer (YES-NO-N/A)	NOTES
Actions and solutions for impact containment		
Has optimisation/reduction of raw material use been considered as part of the project?		
Has appropriate consideration been given to the use of recycled materials/secondary raw materials?		
Has consideration been given to reducing/eliminating the use of hazardous or particularly environmentally harmful materials?		
Has appropriate consideration been given to using materials/products that are certified (e.g., FSC, PEFC) or have environmental declarations?		
Has appropriate consideration been given to the possibility of local sourcing of materials (e.g., distances < 100-150 km)?		
Generally speaking, do the plans provide for the use of "green procurement" as part of project activities?		
Has the "design-for-disassembly" strategy been considered, i.e., the provision for the possibility of reuse of materials used within specific parts/components of the project at the time of its completion?		
Have strategies for maintenance and life extension of project structures/materials been considered?		
Has optimisation/reduction of resource use (energy and non-energy) been considered as part of the project?		

Question	Answer (YES-NO-N/A)	NOTES
Has appropriate consideration been given to the use of renewable (energy and non-energy) resources?		
Has appropriate consideration been given to the possibility of the project being built near existing transportation infrastructure?		
Has consideration been given to the implementation of agricultural soil conservation measures, including the reduction of further soil consumption and the risk of desertification, in the project area?		
Is reforestation and the increase of green areas planned?		
Has the implementation of redevelopment of contaminated soils in the project area been considered?		
Has the implementation of conservation measures for wetlands and water bodies in the project area been considered?		
Has consideration been given to using strategies to keep the biodiversity of the site intact and allow it to regenerate?		
Has the implementation of natural habitat conservation measures in the project area been considered?		
Has intelligent use or reuse of waste been encouraged within project actions by promoting circular economy principles?		

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