Towards an analysis of the ecological economics of West African forests

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Abstract

This paper presents a model of the Ecological Economy as instrument of management lands. The model relates the human capital with natural capital and pursuing the environmental sustainability in primary emphasis in the economic system. The protection of biodiversity must be part of a long-term development strategy. A profit becomes sustainable when its increase or its stability is not negatively affecting the natural capital over time. The identification of the equilibrium point in a set of lands permits the pinpoint of a baskets of goods and services that it maintains the biodiversity level in a target area. The basket identified is the key tool to address the management policy in the target areas. These policies will promote economic sustainable growth with more income for the families of the local communities in the park area for a selected target of lands. Thus, the decision process in the land management will be the result of a scientific identification process.

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Introduction

A new interdisciplinary approach concerns the relationship between economic systems and the biological and physical world with a new approach for theory of ecosystem services (Baggethun, E. et al 2009). The realization of profit is achieved with the right combination of production factors. The inputs to the production process are the resources of a much larger system. Both ecology and economics are concerned with interactions between organisms and their environment, from individuals within resource-scarce conditions through to populations. Interactions occur along social and kinship networks and within communities, along supply chains, and within markets, economies, and ecosystems (Heckbert, S. et all 2010).

By convention we could share resources in two sets: the Human Made Capital and Natural Capital. The economy is just a sub-system of the larger human-environment system (Guana, D. et all 2011) (Vemuri, A. W. et al 2005). If we assume that natural capital is not unlimited, then we place the environmental sustainability in primary emphasis in the economic system. This allows to have an approach of ecological economy pursuing a balance between economic development and environmental sustainability, the search for a balance between economic development and environmental sustainability (the *equilibrium*) must be sought with the involvement of all stakeholders. The protection of biodiversity is not only a scientific issue but is a global issue that requires a holistic approach. The protection of biodiversity must be part of a long-term development strategy. For a sustainable development it is necessary to consider the biodiversity as the key parameter to match the more efficient combination of resources. The biodiversity preservation is extremely interconnected with the equilibrium between humans and nature, that can be reached through a sustainable development approach based on scientific evidence. Ecological economics is interested in the interactions between human behavior and the environment as a social-ecological system. The environment and the economy are interconnected at many levels, and neither can be understood without considering the social context (Spash, C. 2009)

This paper focus on a suite of forested areas in West Africa which represent the diversity of regional natural environments (for instance, see Figure 1). For most of these areas, there is already available a detailed dataset concerning biodiversity attributes, but no data concerning the economic grounds for building an efficient strategic planning for environmentally-friendly economic development. Therefore, the present paper would present a new ecological economy model that provide a theoretical baseline for filling this information gap.

The strategic planning of the environmental conservation in the selected areas should be made by keeping in mind the balance between human activities and the intervention of environmental restoration (Figure 2). To give a tangible meaning to the concept of sustainability it is necessary to analyze the effects of the human activities impact on the environment. It is important to reach an equilibrium point between the preservation of the biodiversity levels and the humanity's footprint on the ecological system from which the resources are taken. Understanding how ecosystems function and how they are affected by human activity—for example, what determines human uses and human intervention into ecosystems, and how is this affected, among other things, by the ecosystem's characteristics and regulatory paradigms (Bockstael, N. et al 1994)

Without this equilibrium the loss of money is inevitable. The balance between human activities and environment must be taken at both spatial and temporal scale.

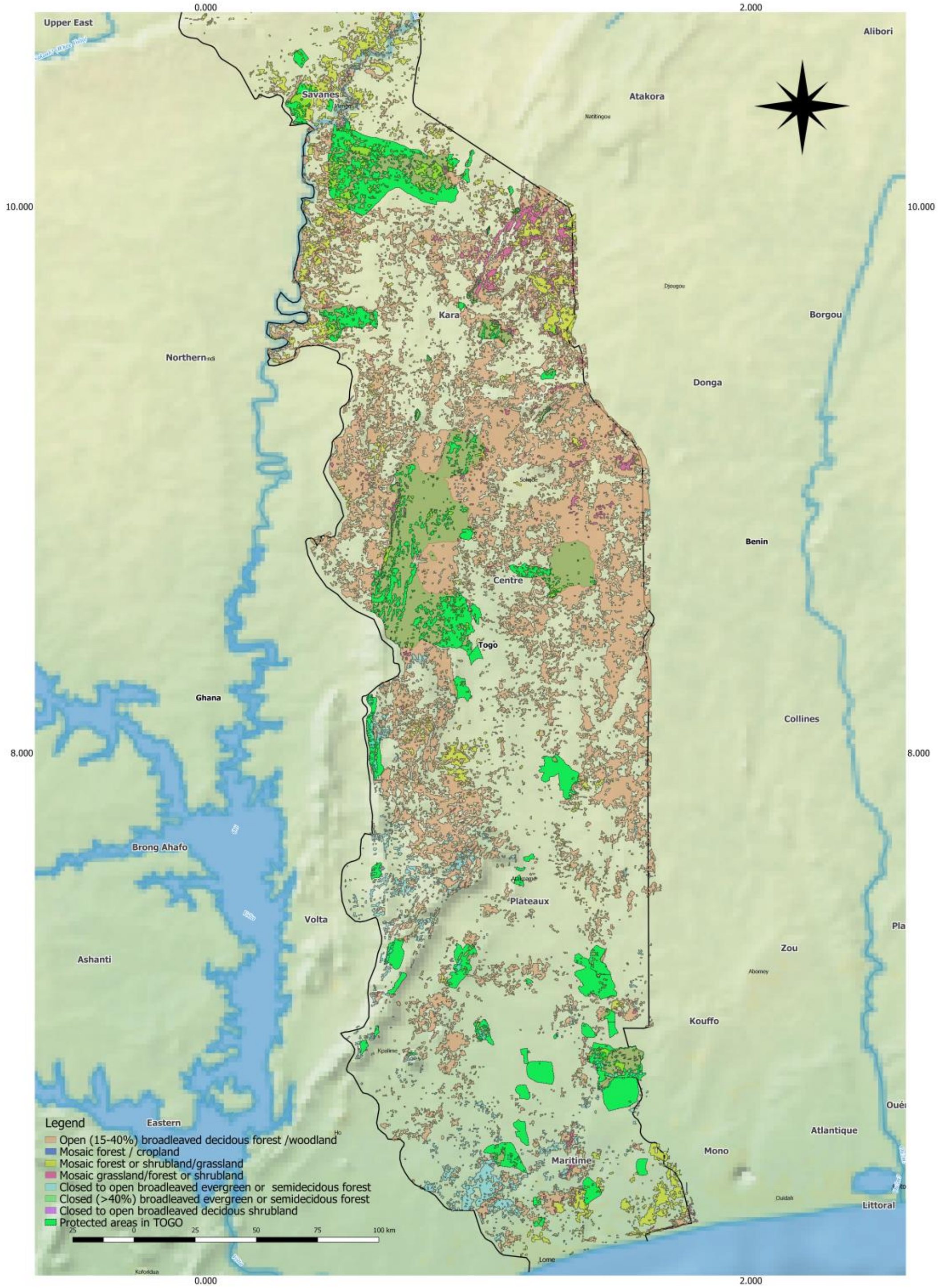

Figure 1. Example of the current extension of forest zones in a West African country (Togo)

The environmental depletion costs now need to be taken into account in a more complex land management system. There is a sharp conflict between an international policy of unregulated trade and national policy of internationalization of external environmental costs. A country that internalizes environmental costs into its prices

will be at disadvantage, at least in the short term, in unregulated trade with a country that does not internalize environmental costs. Therefore, national protection of a basic policy of internalization of environmental costs constitutes a clear justification for tariffs on import from a country which does not internalize its environmental costs (Daly, H., Goodland, R., 1994). This is not in term of protectionism but in term of accountability and management of environmental costs. Human society can be seen as a metabolic organism appropriating resources from the environment, transforming them for purposes useful for humans, and finally discarding them as waste (Røpke, I., 2009).
In order to integrate the concept of sustainability in economics we want to put the emphasis on profits distribution over time (Costanza, R., Daly, H. E., Bartholomew, J. A., 1990). Such distribution allows to relate the maintenance of a certain level of natural capital with the economic growth. A profit becomes sustainable when its increase or its stability is not negatively affecting the natural capital over time (Costanza, R., Daly, H.E., 1992). It is necessary a change of vision from high short-term profits despite environmental impoverishment to lower profits but stable in the long term where the economic value of the natural resource does not decline over the time.

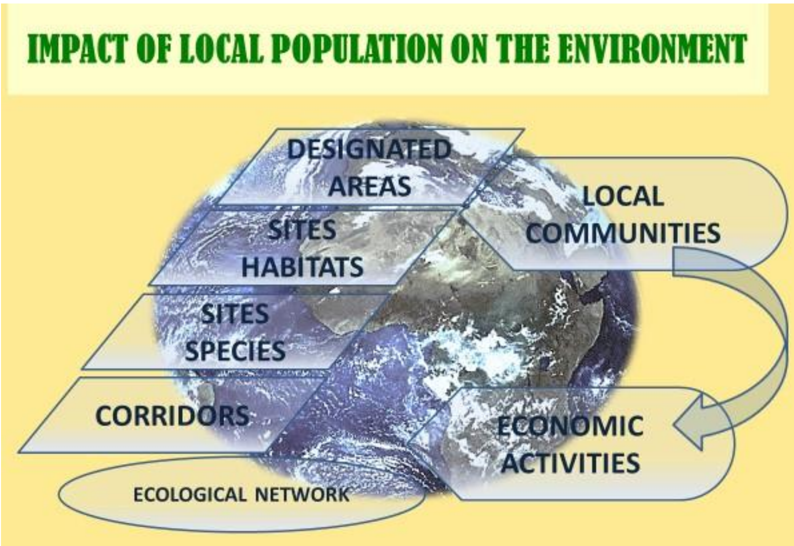

Figure 2. Theoretical synthesis of the study of the impact of local communities on the general environment

An ecological economy view addressed to study the human impact on the ecosystem with an extension in the overlapping areas that include neoclassical environmental economics and ecological impact studies (Costanza, R. 1989). Environmental aspects may be included directly in co-evolutionary studies on the changing configurations of practices, modes of provision and global supply chains (Southerton, D. et al 2004) The other aim of the theoretical model presented in this paper is to define an *equilibrium* in the spatial dimension (Figure 3). Considering the land as a fundamental component as a basic unit of a more complex mechanism. This dimensional approach of the model puts the unit of the land in relation to the necessity of exploitation of the human population. The levels of biodiversity are part of the well-being of certain communities. Where the *Resilience in Social-Ecological Systems* is interlinked with systems of people and ecosystems (Walker, B. H., et al 2009). The cost of the environmental deterioration is related with the sustainability of natural capital (Rennings, K., Wiggering H.,1996). The biodiversity will be placed in relation to investments and wealth levels of the local communities. Spatial sustainability
and sustainable trade need to be approached from a dynamic and non-biased perspective, paying due attention to insights from neoclassical economics, ecology, and social-political sciences. Spatial or regional sustainability should focus on 'bioregions' rather than political regions (Van den Bergh, J. C.J.M., Verbruggen, H., 1999).

The model should satisfy the following characteristics:

- Each unit of land has a different investment absorption capacity.
- The equilibrium could be reach in a set number of lands.
- Some lands may be designed to support the extra weight of anthropic pressure in favor of the others lands who could remain virgins.

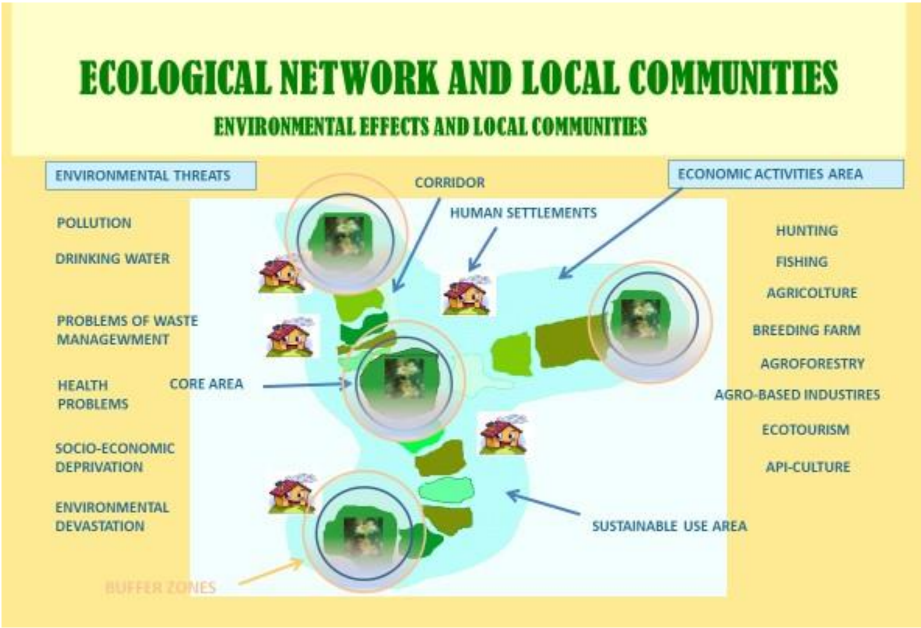

Figure 3. Example of ecological networks and economic activities to be implemented in a designated target area for sustainable development

Terminology

In this paper, I use the following terms:

Richness: this term is used to define the economic value produced by the combination of human made capital and natural capital.

Natural Capital: It is an economic evaluation of nature without considering all aspect correlated with human activities of investments and work in a suite of lands.

Human Made Capital: It is an economic evaluation of Capital Investment and Human Labor to produce income in a suite of lands.

Land Factor: the model refers to the land as the main drive to relate the economic value of Natural Capital and Human Made Capital. The land unit of reference is the acre.

Evenness: diversity index used to measure the biodiversity value of a given parcel of territory.

Model Objectives

General objectives

The ultimate scope of this model would be to direct the actions in the next decades, in function of the ecosystemic characteristics and of the potential economic value of the land. Our model will integrate the Willingness to pay (WTP) to the true and estimated value of land and biodiversity.

More in general, our approach would be of great relevance if there is a need or intention to extrapolate the model to other scenarios in tropical Africa or elsewhere.

Specific objectives

In detail, the model aims at:

- Give an economic evaluation of the land factor;

- Finding the level of correlation between economic activities and evenness;

- To identify the causes of anthropogenic origin that have caused an alteration in the biodiversity levels;

- Planning a rational use of natural resources per unit of territory on both spatial and temporal scale;

- To identify a basket of goods and services of equilibrium to maximize the sustainability of the biodiversity and the economic sustainability for the local communities;

- To identify the strategic economic projects in order to increase the income of the local communities;

- To highlight segments of the market where it is possible and necessary to implement actions addressed to trigger processes of economic improvement according to the specific needs of local populations and according to the needs of environmental conservation.

Model Description

The basic assumption is that any biodiversity levels for a given study area is deeply interconnected with socio anthropological factors. For example there is some correlation between the biodiversity levels and the income levels of local communities in given areas. It is arguable to establish a linear relationship between the status of the environment and the levels of wealth/poverty of the local population. This is the core of the ecological sustainability theory. As every linear relationship, also the above-mentioned one will allow to predict the needed equilibrium point between land exploitation and biodiversity maintenance for any area where the theoretical evenness is known as well as the potential and realized income of the local populations.

"T" is a first variable of interest for our model (Figure 4). This variable describes 'the Land'. It is designated that the unit of T is one acre. As being a true dimension, T needs to be characterized by using a full dimensional unit. This dimensional unit is hence the acre. T is the valuation of the non-human side of the richness, in other words the natural capital. The keys elements that directly impact on the T value are:

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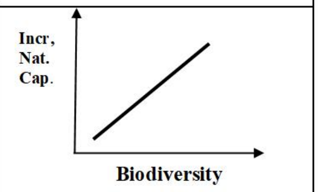
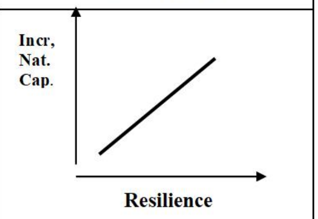
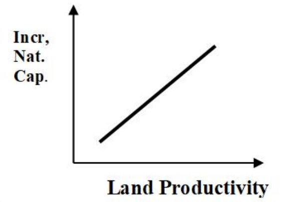
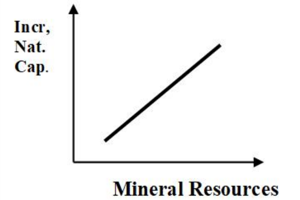
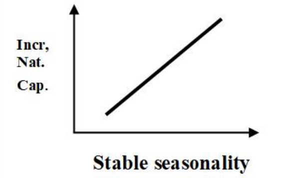
T COMPONENTs	INCREASE OF NATURAL CAPITAL	T VALUE	TREND
BIODIVERSITY	+	⇧	
RESILIENCE	+	⇧	
LAND PROCUCTIVITY	+	⇧	
MINERAL RESOURCES	+	⇧	
STABLE SEASONALITY	+	⇧	

Figure 4. Description of 'T' component with all the constituting elements and their relationship with the increasing natural capital

T value changes accordingly to changes of its elements. The biodiversity levels directly impact on the value of T. A decrease of biodiversity level contributes to a reduction of T. Other factors that directly affects to the T value are resilience, land productivity, mineral resources and seasonal stability. All of these factors are positively related to T value (Figure 4). A necessary prerequisite of our model is that all of these factors weight identically for determining the T value.

The other model component is "C", i.e. the Human Capital factor.

The "C" component (Figure 5) consists of Fixed Investment that is the Infrastructure investment like streets, aqueducts, electricity; more in general investment of public administration. The other factor of "C" is the investment in the production as all investments, all those investment that are intended for the income production, we can define variable investment. The last factor is the Income produced by human labor that will be measured with the Gross Domestic Product (GDP) for each unit of "T", we use the concept of value added to be able measure it.

C= Human Capital Factor or Labor

FC= Fix Capital

VC=Variable Capital or Capital Production

Y= Income produced for each unit of T

So the relation between these components will be:

$$\mathbf{C=FC+VC+Y}$$

where Y is the sum of a basket composed by the goods and services *produced* in the Unit of "T":

$$\mathrm{Y} = \sum_{i=1}^{n} \mathrm{p}_i \mathrm{q}_i$$

where p_i is the price of good or service and q_i is the quantity of goods and service produced in the unit of "T". This represents a basket of goods and services produced at determinate levels of prices in a time unit of reference.

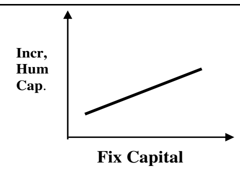
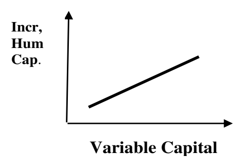
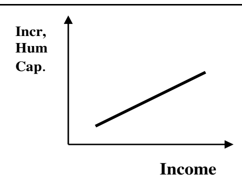
C COMPONENTs	INCREASE OF NON NATURAL CAPITAL	C VALUE	TREND
FIX CAPITAL	+	⇧	
VARIABLE CAPITAL	+	⇧	
INCOME	+	⇧	

Figure 5. Description of 'C' component with all the constituting elements and their relationship with the increasing natural capital

The basket of goods and services is chosen between the most representative and significant factors that have a real tangible economic impact. For commuters worker that earn their income outside the unit "T" it will be used as reference the level of wages.

The need is to define 3 kinds of basket (Table 1); a basket of good and service (i) produced, (ii) purchased (ii) and desired (iii).

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	MATRIX INTERVIEWEE				
	BASKET OF GOOD AND SERVICES PRODUCED				
	x1	x2	x3	x4	x5
SELLING PRICE	PxQ	PxQ	PxQ	PxQ	PxQ
SALARY	PxQ	PxQ	PxQ	PxQ	PxQ
Total Income produced for the T Unit	PxQ	PxQ	PxQ	PxQ	PxQ

	MATRIX INTERVIEWEE				
	BASKET OF GOOD AND SERVICES PURCHASED				
	x1	x2	x3	x4	x5
GOODS	PxQ	PxQ	PxQ	PxQ	PxQ
SERVICE	PxQ	PxQ	PxQ	PxQ	PxQ
Total purchases for the T Unit	PxQ	PxQ	PxQ	PxQ	PxQ

	MATRIX INTERVIEWEE				
	BASKET OF GOOD AND SERVICES DESIRED				
	x1	x2	x3	x4	x5
GOODS	PxQ	PxQ	PxQ	PxQ	PxQ
SERVICES	PxQ	PxQ	PxQ	PxQ	PxQ
Total goods and services deired for theT Unit	PxQ	PxQ	PxQ	PxQ	PxQ

Table 1. Basket of goods and services produced

The sum of all baskets will be the total basket of the area "T".

The selection of the composition of the basket will be crucial and has to respect:

	SUM OF MATRIX INTERVIEWEES					TOTAL
	BASKET OF GOOD AND SERVICES PRODUCED INTHE "T" UNIT					
	x_1	x_2	x_3	x_4	x_5	
MATRIX INTERVIEWEE 1	PxQ	PxQ	PxQ	PxQ	PxQ	$\sum_{i=1}^{n} p_i q_i$
MATRIX INTERVIEWEE 2	PxQ	PxQ	PxQ	PxQ	PxQ	$\sum_{i=1}^{n} p_i q_i$
MATRIX INTERVIEWEE 3	PxQ	PxQ	PxQ	PxQ	PxQ	$\sum_{i=1}^{n} p_i q_i$
TOTAL	$\sum_{k=1}^{n} p_k q_k$	$\sum_{k=1}^{n} p_k q_k$	$\sum_{k=1}^{n} p_k q_k$	$\sum_{k=1}^{n} p_k q_k$	$\sum_{k=1}^{n} p_k q_k$	$\sum_{i,k}^{n} \boldsymbol{p_{i,k} q_{i,k}}$*

**Income produced for each unit of "T" in the reference time*

Table 2. Total of the produced income for each unit of T

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- the representativeness of the real effect in the local economy;

- the representativeness of the basket will be defined based on the real economic sustainability for the producer of that income;

- the impact basket production on the environment.

The sum of the all baskets represents the Real Income produced in the area.

For each interviewee we can also define a basket of goods and services desired in the unit of "T".

A selected unit of T is extremely interconnected with other T unit of the Park Area. The interconnection of the economic effects flows through a lot of channels in any direction.

But for the model is important the environmental sustainability and the economic sustainability for the families living in the Park Area. For this reason, the macroeconomic system integrates different units of "T" in the Park Area to search Eco systemic economic equilibrium.

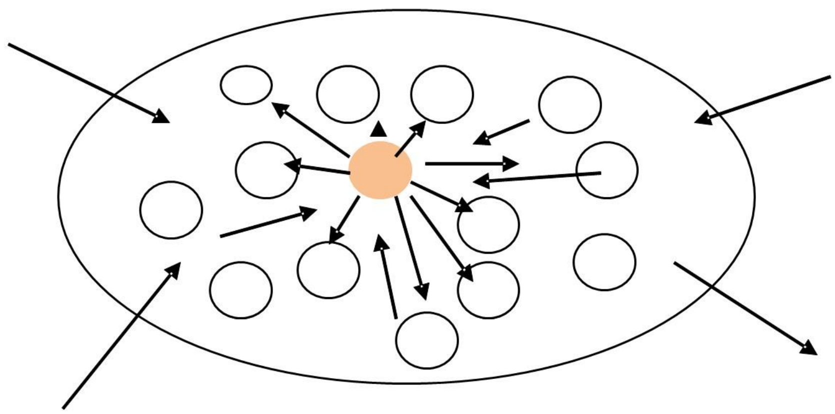


Figure 6. Different units of "T" are part of a macro system highly interconnected

The analysis on the economic basket permits to select the economic activities that do not affect the environmental balance of the area and that permits the radicalization of the population on the territory.

Figure 6 shows a selected Unit of "T" which belongs to the wide system The Park Area. The economic flows are extremely interconnected between the different units of "T". To give feasibility and sustainability for a determinate production is important to follow the product value chain.

Figure 7. Example of a value chain for a given goods

Following the production value chain (Figure 7) for each of the selected basket items is an important result of our survey because it would permit to analyze the path price of each item in any step of the value chain.

The incidence of each step of the value chain will be (Table 3):

	PRICE MATRIX VALUE CHAIN					INCIDENCE FOR EACH STEP RING
	X_1	X_2	X_3	X_4	X_5	
Delta step ring 1-0	$\Delta_1 px_1$	$\Delta_1 px_2$	$\Delta_1 px_3$	$\Delta_1 px_4$	$\Delta_1 px_5$	%
Delta step ring 3-2	$\Delta_2 px_1$	$\Delta_2 px_2$	$\Delta_2 px_3$	$\Delta_2 px_4$	$\Delta_2 px_5$	%
Delta step ring 4-3	$\Delta_3 px_1$	$\Delta_3 px_2$	$\Delta_3 px_3$	$\Delta_3 px_4$	$\Delta_3 px_5$	%
Final price of good for each quantity	$\sum_{k=1}^{n} \Delta_k px_1$	$\sum_{k=1}^{n} \Delta_k px_2$	$\sum_{k=1}^{n} \Delta_k px_3$	$\sum_{k=1}^{n} \Delta_k px_4$	$\sum_{k=1}^{n} \Delta_k px_5$	100%

Table 3. Variation of the price along the various rings of the value chain for the basket of goods and services produced in the "T" Unit

Table 4 shows the distribution of the value added for each step of the value chain. It allows monitoring of the effects of inflation and speculation in each step ring. The planning of economic development intervention could be based on this analysis.

The aim of the value chain study is to define the optimal basket of the equilibrium. A sustainable basket of equilibrium for families' livelihoods and for environment.

The ecological-economic optimality model predicts that T value and C value are negatively correlated (Figure 8).

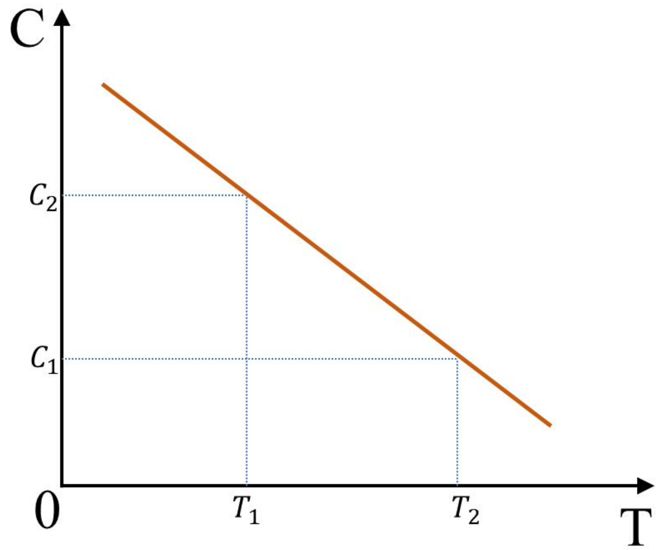


Figure 8. Ecological-economic optimality model

Although the above-mentioned relationship suggests a linear trend, it should be mentioned that this is a virtual pattern. Indeed, this negative relationship is to be considered as an intermediate pattern between two extremes, that are showed in figure 9. Where a big amount of C is related with a low amount of T, (C_2,T_1).

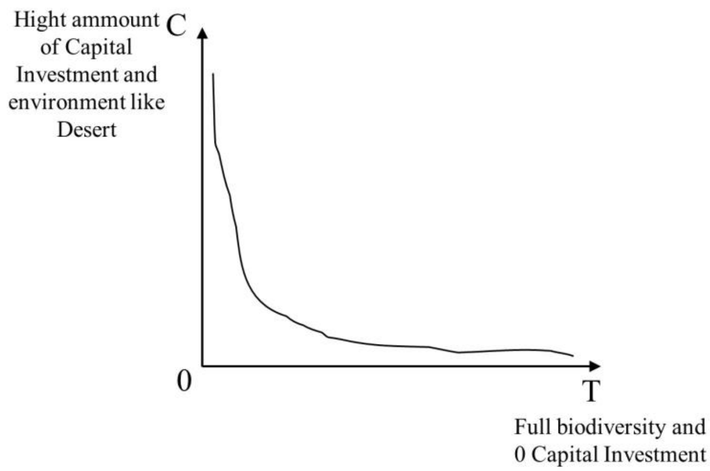


Figure 9. Relationships between full biodiversity and capital investment and high amount of capital investment

The aim of the present work is hence of getting the data for producing a shift in the model, from condition (αi) to condition (αii).

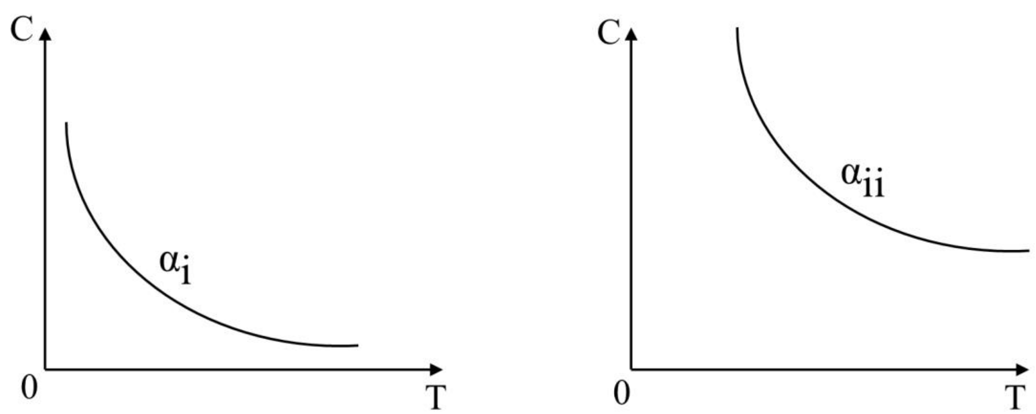


Figure 10. Relationships between T and C in different conditions

The position of the curve depends on the environment, the curves showing two different kinds of habitats. By convention we will call α_i and α_{ii} **Habitat curves**. The displacement of the habitat curve from position *αi* and *αii* represents an improvement because permits a higher combination of C and T.

Each ecosystem zone has a specific value of T and C. In the graph below are reported different types of ecosystem zones that have different allocation of T and C.

« **Habitat Curve** » α_i=f(C,T)

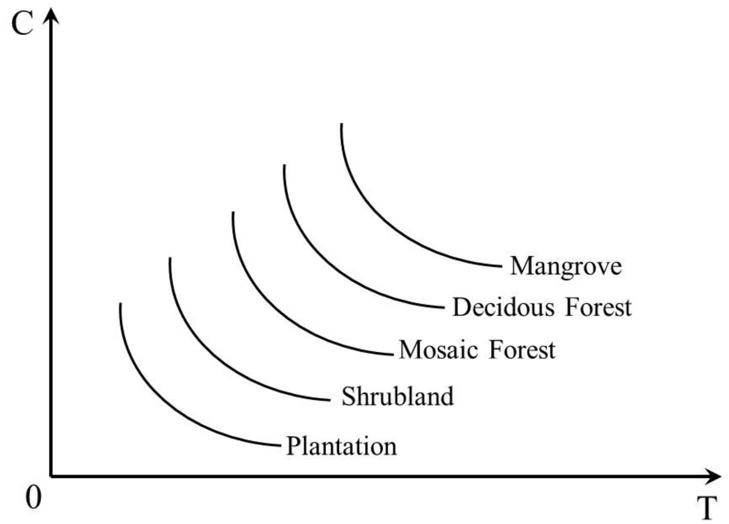


Figure 11. Habitat curves for the various environmental types in West Africa

The data analysis may be done, for instance, by Monte Carlo simulations (with Ecosim Software, for instance).

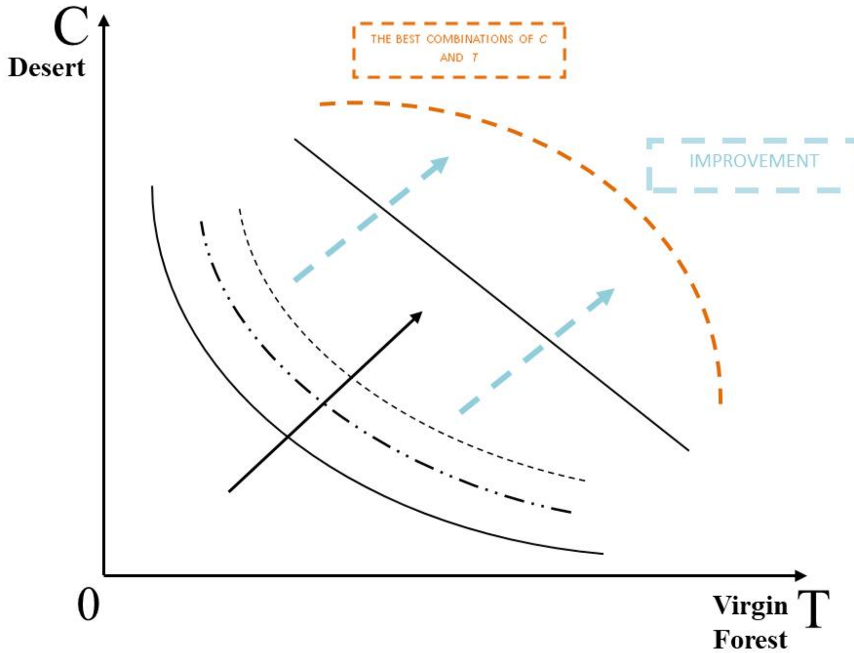


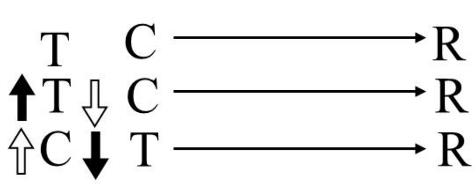
Figure 12. Relationships between T and C of different habitats

The relationship between the two variables C and T are inversely correlated (Figure 12). Every increase of one variable, for given values of the variable, has a negative effect on the other variable.

For example if we consider a big investment of C for a given plot of land (our unit of T) the value of T decreases. High levels of the T value correspond with a virgin land and very low levels of C, where the investments and the anthropic pressure remain nearly zero. Huge quantities of C correspond with a very low level of T, example the Niger Delta with 90% forest cut, mmillions of oil barrels extracted, eexponential growth of wealth for some elitist classes and loss of wealth for other classes

Large industrial investment has negative effects on the components of the T Value as the Biodiversity. Furthermore, high levels of investments have a big impact on the production of wealth, although high levels of investments have a negative impact of the value of T.

The richness of a selected lands is defined by the sum of the T value and C value for each land:



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In order to determine what are the net effects on the levels of wealth due to changes in one of the two variables and its effects on the other variable is necessary to establish a mathematical relationship to quantify the wealth.

The two variables jointly contribute to the production of wealth. Not only as a simple sum of the C component and T component, but also with the jointly combination of the C and T. So we can define the capacity of selected quantities of Lands to produce wealth as the sum of the **C value**, **T value** and the **Expected Income Production** resulting from the join combination of both components.

If we define **R** the **Richness** of *n* Lands after the standardization the mathematical relation will be:

$$R = \sum_{i=1}^{n} \sqrt{(T_i + C_i)^2 + (T_i \times C_i)^2}$$

The overlapping of the Richness Curve with the Habitat curve (combinations of C and T) is reported in Figure 13. The amount of “C” that maximize the richness for a given quantities of “T”, it is represented by the match of the curves.

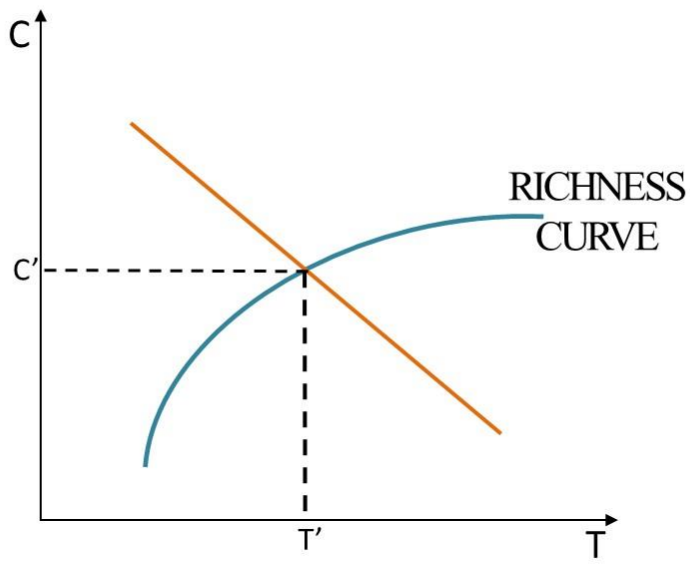

Figure 13. Overlap of the Richness Curve with the Habitat curve (combinations of C and T)

The equilibrium point is related for an amount of lands (from 1 to n lands). The research of equilibrium point is a dynamic of land use planning. The equilibrium could be reached in a system of lands where some lands could be scarified in favor of other lands with high levels of “T”. Some lands could produce a huge amount of R, despite the overexploitation of their environment. It could be possible to sacrifice the environment in favor of richness production. The sacrifice is planned in an environmental protection system. Then if the overexploited lands belong to a wide system with other virgin lands, it could be possible to reach and equilibrium between T and

C. The above equilibrium between environment and local development is sustainable in the long term, because the production of Richness and the T value don't decline over the time. The slope of the curve is the optimum point:

$$MSR = \frac{\Delta C}{\Delta T}$$

The optimum point shows the quantity of C that maximizes the level of Richness for each unit of T. The Marginal Substitution Rate (MSR) shows for any further increment of "C" would cause a decreasing of "T" at the marginal level C', under T'. The decreasing of "T" has negative effects on Richness curve. The equilibrium point is made up by a specific combination of "C" and "T" that maximize the Richness for a suite of Lands.

The income component (Y) of "C" is composed by a basket of goods and services produced on the lands. The basket composition depends on the levels of wealth that ensure sustainability for the lands communities. The production of the goods and services basket is able to maintain a specific level of "T".

We have to assume that the families of the "T" unit have a basket of goods and services produced that represents the income for their livelihood. The family also has a basket of goods and services purchased to meet the own needs. The income level imposes a limit to satisfy all family's needs. The basket of "*desired*" goods and services is the basket not satisfied.

We can assume that each basket would match with an utility level of the Utility Basket = (X_1, X_2) where X_1 and X_2 are the goods and services that compose the basket. We can define 3 different baskets corresponding with 3 different utilities levels:

- Utility basket of goods and services produced = (X_1, X_2)
- Utility basket of goods and services purchased = (Y_1, Y_2)
- Utility basket of goods and services desired = (Z_1, Z_2)

The basket can be represented graphically as a curve of indifference. Along the indifference curve, the utility remains constant for different combinations of goods and services. If we order the utility (X_1, X2) < (Y_1, Y2) < (Z_1, Z2) we will have a graphic representation as reported in the figure 14.

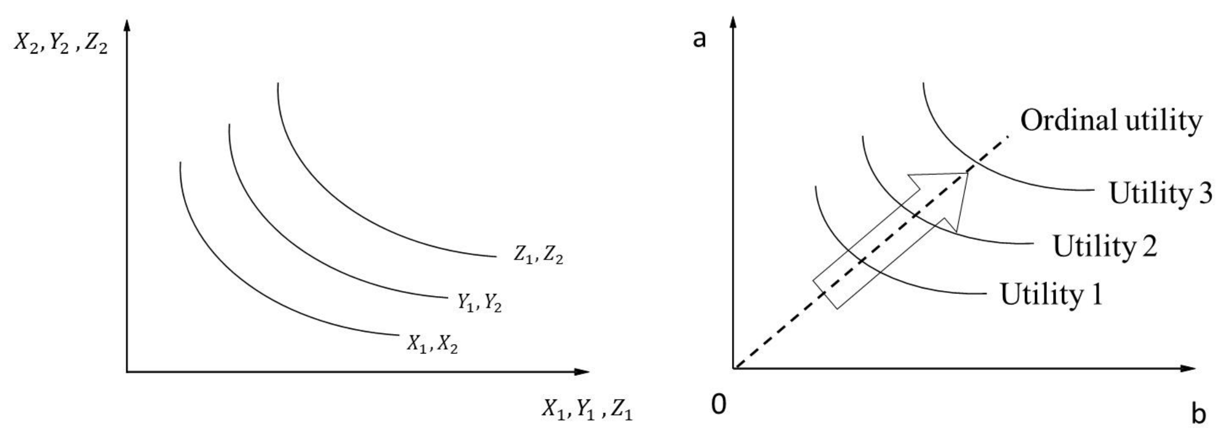

Figure 14. The basket can be represented graphically as a curve of indifference.

The present research aims to foresee activities to define the basket that carries in equilibrium the mathematical model and that assures a sustainable economic development over the time.

The identification of the equilibrium basket will be the key tool to address the management policy in the target areas, that will be focused to the improvement of the utility levels. These policies will promote economic sustainable growth with more income for the families of the local communities in the park area for a given target of T Factor previously planned by the competent Authorities. Thus, the decision process will be the result of a scientific identification process.

This model allows:

- To identify for each target's land the T Factor, that it means to have an economic value of the Natural Capital,
- To identify the habitat curve for each target's land, that it means to photograph the present combination of C Factor and T Factor,
- To identify the actual Richness curve, that it means to have the present equilibrium point from the habitat curve and curve of richness,
- To identify the corresponding utility basket connected with the point where Richness curve crosses the habitat curve, that it means to evaluate the utility of the basket and that permits to plan policies addressed to improve the management of the target areas in term of policies addressed to increase local income levels, policy addressed to plan investment in infrastructures, policy addressed to maintain the habitat suitability.
- To identify a planning combination of C and T for a set of lands, that it means to reach an optimum point for a set of lands with a creation of a macro system where the intended use for each land is planned.

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