0. FOREWORD

0. FOREWORD

0.1. PREFACES

0.1.1. FIRST INTRODUCTION; SUMMER 1999

Let me begin by explaining to the reader the origin of this work. In fact, I would proceed in reverse order. I have spent the last three summers here in Cleveland, Ohio, at Case Western Reserve University, CWRU. This summer 1999 will be my last summer to finish my Doctoral Thesis or Ph. D. dissertation.

Again I have found new motivation in order to do this effort. I carried with me from Barcelona the latest book of Lester R. Brown -The Worldwatch Institute-, Beyond Malthus (will be referenced after). And I have started my summer here reading with it. There are two reasons why I find the book interesting. First, the main topic is population which essentially is the underlying subject of this work. The reader should not forget that the world will have 6 billions people in the next few months. The other reason is related to the fact that many publications from The Worldwatch Institute have served as an inspiration for me since the change of my academic orientation toward global human/earth issues and sustainable development.

The following is taken from this book, which may give the reader a clearer picture of the personal sense that I find in my work:

"*Tragically, the world is dividing into two parts: one where population growth is slowing as fertility falls, and one where population growth is slowing as mortality rises*"

"*Without clearly defined strategies by governments in countries with rapid population growth to quickly lower birth rates and a commitment by the international community to support them, one third of humanity could slide into a demographic dark hole*".

But life has many different and contradictory aspects.

After one week in Cleveland I found out that Pere Duran Farell has died (11-07-99). I first met him when he was the President of the Board of Trustees of the Universitat Politècnica de Catalunya, UPC. He put his trust in me after I explained the plan to organize a conference on Technology, Sustainable Development and Imbalances (Terrassa conference, December 1995). In my opinion, the conference would not be possible without his blessing. I am also indebted for his support on the creation of UNESCO Chair at UPC on Technology, Sustainable Development, Imbalances and Global Change, which I serve as the coordinating professor since May 1996. To me, it is essentially because of him that put me right at where I am now. Thus, I dedicated this work to him in memorial.

("El Pais"; 12-07-99)

0.1.2. SECOND INTRODUCTION: FAMINE AGAIN, NOW IN SUDAN; SUMMER 1998

It was at this Terrassa conference where I first met Professor Mihajlo D. Mesarovic from CWRU. After I spent two summers (1996 and 1997) with him in Cleveland working in GENIe (Global-problematique Education Network Initiative), it seems clear to us that the results of my work should be, finally, my Ph D. So we took the decision and try to do this.

I cannot make anything without "sense" in "my life" or, at least, without trying to find this sense. I recognize that I was tired in 1998 summer. But again a foreign factor had impressed me very much and gave me new motivation: the first New York Times that I bought upon my arrival, in which you can see the following:

"All the News That's Fit to Print"

The New York

VOL. CXLVII . . . . No. 51,228 Copyright © 1998 The New York Times FRIDAY, JULY 24, 1998

Alessandro Abbenzio/Agence France-Presse

A starving Sudanese child was given nourishment last week at a feeding center in Ajiep, in the southern Sudan. Famine is worsening in the region, and more than a million people are said to face food shortages.

Fueled by Drought and War, Starvation Returns to Sudan

Guilty Plea in Sale Of a Tainted Juice

Senate Puts Nations Th

Measure Doome

By

WASHINGTON, July 23

tion to require the United S ernment to punish foreign that permit or endorse rel secution was put off inde day by a Senate committe Republicans were deepl over the issue.

The measure, which p conservatives like the Ch alition against business int the Chamber of Commer major farm organizations, ly opposed by the Adminis

The Senate Foreign Committee removed the bi docket today because at le panel's 10 Republicans p join the 8 Democrats in reject the legislation.

It is not likely that any s ure will be enacted this ye

The bill was brought do fissure in the Republican tween conservative Chris party's foot soldiers, wh party's main focus should rality, and business leaders vide the Republicans' fina and want the party to conc issues like trade, taxes and ty.

In May the House appro under which countries tha in religious persecution w an automatic suspension o from the United States, re

0.1.3. THIRD INTRODUCTION: FROM RWANDA TO SUB-SAHARAN AFRICA, ONE UNFORTUNATE REALITY THAT CAN INTENSIFY AND PROPAGATE DRAMATICALLY; SUMMERS 1996 AND 1997

"*The war in Rwanda, which has resulted in 1.8 million refugees living outside Rwanda's borders in 1995 and close to one million people being slaughtered, is a case point. The most densely populated country in Africa, Rwanda had the world's highest fertility rate*." Mike Mesarovic, as usual, gives me many interesting articles from all kinds of sources. One of the first articles that he passed to me in summer 1998 was: "John M. Swomley (July/August 1998) The Population Wars; The Humanist, p. 24-26". The quotation is from this article.

This allows me to present, finally, the "initial history" of this work, that started in summer 1996 and 1997 when I stayed at CWRU with the financial and institutional help of the Comissionat d'Universitats i Recerca de la Generalitat de Catalunya and the UPC.

In my first summer in Cleveland, June and July 1996, Mike Mesarovic and his team worked with SUN machines that contained two decision support tools namely (its first version was created by Mesarovic and Pestel in order to develop World Integrated Model. The result was summarized in an important report to the Club of Rome which will be referenced after) ARISTO and CROSSROAD, which allows them to work in future scenarios: GLObal forESIGHT.

After I have understood and learned how to use decision support systems (although my first exposure of the systems was at Terrassa conference), Professor Mesarovic suggested me to work with him on some issue that were of my interest. One of his graduate students (I can only remember her first name: Julie) was about to start her Master thesis on Carrying Capacity. It was a familiar concept to me since I used to introduce this biological/ecological concept, as presented in the reports of The Worldwatch Institute, during my first public sessions on sustainable development.

Furthermore, Mike Mesarovic gave us (Julie and me) one report from FAO/IIASA/UN, explicitly cited and referenced after, with a deeper analysis of Carrying Capacity in Developing Countries.

One friend of mine, Joaquim Gascon –medic; a member of the organizing team of the Terrassa Conference– impressed me when he and his wife, Anna Merlos, went to Rwanda to work in a Hospital for four years, sometime in the 80s.

Nobody can forget the civil war of 1992. The hospital in which my friends worked was destroyed! I had a lot of discussions with them about their experiences and about the causes and effects of the war.

Thus it is clear why I chose this country to be my first object of study. As I wrote these lines I could not forget either that just when I was on my way to Barcelona in Summer 1996, Rwanda faced her second large dramatic flight. I think that the results of my work could explain more than thousand of words why it has happened. So, I only tried and try with this study to understand a little more about what has happened in Rwanda and what can happen in the Sub Saharan Africa in general.

Rwandese refugees fleeing (1994)

0. 2.ACKNOWLEDGMENT

0.2.1. PERSONAL

Despite of the hesitation on how to include this section in my dissertation, I have decided to do it in an exhaustive manner. I feel very fortunate to have so many people that have helped me in doing and finishing this project and I try to thank all of them here. I would like to thank personally:

- Jaume Pagès, Antoni Giró, Ferran Laguarta, Ramon Capdevila, Lluís Jofre, Pere Botella, Pedro Serrano, Josep Ma. Mata, Josep Ma. Casas

- Mike Mesarovic, Gori, N. Sreenath, Shoboa, Ali Vali, Mayora, Gundo Susiarjo, Windy, Marta, Mery, Lluís Miret, Julie, Techa Kittiroj Kittiphan, Deanna Thomas

- Rosa Pujol, Beatriz Escribano, Lourdes Altes, Marisa Ysunza

- Xavier Alvarez, Pepe Antequera, Miquel Barcelo, Josep Burcet, Enric Carrera, Josep Casanovas, Miquel Coll, Joaquim Gascon, Guillermo Lusa, Juan Martínez, Manuel Medina, Climent Nadeu, Oriol Pibernat, Marc Pintor, Jordi Roca, David Segarra, Ildefons Valls

- Ana Andres, Jordi, Albert, Oscar, Sonia, José Antonio Rodríguez, Josep Miquel Vidal, Esperanza Ros, Pepita Cabana

- Jordi Rotger, Dolors Puig, Luis Martinez, Carolina Yela, Alfred Gil, Dolors Oriols, Andreu Rodríguez, Pepa Alberola, Gustavo Flores, Didac Martínez, Lluisa, Roser, Sumpta Sabater, Miquel Ralló, Teresa Tort, Roger (+)

- Mamà (+), Pare, Mariona, Jaume, Enric, Isabel, Roser, Salvador

- And you.

0.2.2. INSTITUTIONAL

Also I am indebted to several institutions that made this effort possible. I would like to express my sincere gratitude to the following institutions:

- Comissionat d'Universitats i Recerca de la Generalitat de Catalunya and Universitat Politècnica de Catalunya, UPC, which help me, institutionally and financially, to stay and work in CWRU

- CWRU, Case Western Reserve University, Cleveland, OHIO, USA, and especially to its Global Issues Group, under the leadership of Professor Mihajlo D. Mesarovic, in the Electrical Engineering and Computer Science (EESC) Department

- UPC, Universitat Politècnica de Catalunya, and especially to the Doctoral Program "Natural Resources and Environment", under the leadership of Professors Josep Ma. Mata and Josep Ma. Casas.

0.3. STRUCTURE

0.3.1. BIBLIOGRAPHY

I have listed the bibliography in one appendix B and organized it into eight different topics, starting from: B.1. Africa and Sub-Saharan Africa.

And then in the text we follow the subsequent notation: [B.3.10.], that means the book, or the paper, referenced in the Bibliography Appendix B, is the number 10 book of topic B.3.

0.3.2. FORMATS

We use some kind of formats that can help the reader to follow the dissertation.

"When we explicitly reproduce some cite we use this italic format normally inside quote".

When we want to emphasize the importance of some paragraph we normally use this bold format.

Sometimes we put, with the same goal before, the whole paragraph under this kind of border.

When we present one variable, for the first time, we also use **bold** format, or sometimes color.

0.3.3. ABBREVIATIONS

CWRU, Case Western Reserve University

FAO, Food and Agricultural Organization

GENIe, Global-problematique Education Network Initiative

GLOBESIGHT, GLOBal forESIGHT

IIASA, International Institute for Applied Systems Analysis

IFPRI, International Food Policy Research Institute

ISEE, International Society of Ecological Economics

NIE, National Institute for Environment

PAI, Population Action International

SEI, Stockholm Environment Institute

UN, The United Nations

UNDP, The United Nations Development Program

UNEP, The United Nations Environment Program

UNESCO, The United Nations Education, Scientific and Cultural Organization

UNU, The United Nations University

UPC, Universitat Politècnica de Catalunya

WB, The World Bank

WI, The Worldwatch Institute

WRI, The World Resources Institute

0.4. SUMMARY

0.4.1. ORGANIZATION

In the context of the global human/earth issues (population, poverty, imbalances, environment problematic, global warming, water scarcity, economical globalization, etc.) with the others the Carrying Capacity issue is emerging. It is a "driver" which is not always simply related with sustainable development concepts. It is therefore enormously important to give adequate answers to the majority of the global dilemmas.

The definition of carrying capacity is not easy because it is controversial. So the first chapter of this study is to adopt a clearer position in reference to the meaning, the borders, the key aspects, etc., of our approach to this issue. Basically, our approach is, first, from the sustainable development point of view and, second, a local approach in a global view. Finally and concretely, we indicate what aspects, in which place, how do we study carrying capacity? The answer to these questions will be: the agricultural (land and water) reality in a very specific region of East Sub Saharan Africa.

So the next step of the work is to specify and delimit our chosen region and, obviously, to study it in detail. Chapter 2, and some parts of Chapter 8, are the results of this.

The kind of methodological approach to global human/earth issues is, clearly, the most characteristic point of our work. We follow a scientific approach developed by Dr. Mihajlo Mesarovic over forty years ago in the mathematical systems analysis field and "finished" in multilevel integrated assessment with reasoning support tools for policy analysis. We study in depth and analyze this methodology in Chapter 3.

From a first or high level point of view of a hierarchy of models in our methodology, we study the population and, for the moment in this level, the carrying capacity reality, which is a dynamic system in reality, of our case study region. We have created the corresponding model and then, we have used a reference study from FAO/IIASA/UN [B.3.7] that, according to our bibliography searches and the role that it is continuing to play in the international studies of this issue in developing countries, is a "key reference". We find all of this in chapters 5 (population) and 6 (carrying capacity). In fact one of the goals of this work as a

whole is to involve, extend, and indeed test the results of the mentioned report using our methodology.

Always from the hierarchical point of view we affront, finally, the second level representation of our issue. It is the most creative part of our study. We decide, after a deep analysis of the background, that we can succeed in developing a new agricultural model involving land and water aspects.

Because water is another controversial driving factor of the global human/earth issues, we focus on it in chapter 7. We add some personal special approach according to our methodology and "philosophy".

Chapter 8 is the highlight and plays, at the same time, an integrated role of the whole study and, in particular, the second level approach from the point of view of the hierarchy of the models. It allows us to make many final conclusions in several directions. About the methodology itself: extremely powerful with the interrelated combination of the different models levels approach. About the key report cited: only needs to be revised in its high input/output forecasting. The success and new possibilities in order to study the carrying capacity issue, for future policy "vision" analysis, that we now have from the point of view of agricultural reality. Finally, a dramatic foresight and call to the international decision- makers about the situation in our Case Study Region (essentially, the more stressful sub-region of East Sub-Saharan Africa).

0.4.2. OBJECTIVES AND CONTRIBUTIONS

Assessment of carrying capacity is essential in the search for the condition of sustainable development. While sustainability has a global dimension focus, for carrying capacity assessment has to be on geographic areas within which the needs of population have to be satisfied consistent with the physiologically determined time constraints. Specifically, food had to be secured for the population on location and in time where the need exists. Large geographic areas cannot be sustained by food imported from distant locations on the globe. In short, some degree of food self-sufficiency is a prerequisite for sustainability. The research reported here started by identifying eastern Sub-Sahara Africa as the most vulnerable geographic region in the sense of carrying capacity.

The objective of the research was to approach the question of carrying capacity in a practical integrated manner ("problematique"); i.e., in the context of real constraints imposed by environmental life support resources, rather than to "reduce" the problem to the considerations of the theoretical extreme capacity that have no chance of being achieved in reality.

On the first level, a model is developed focusing on the most dominant relationship between population evolution and carrying capacity as a dynamic, time varying system. Broad based data available in international sources are used. Results of FAO research, which is recognized as being the most authoritative, is used to parameterize the model for all countries in the region as well as for the region itself. The concept of an index of carrying capacity potential is developed to assess the results of the simulation using three levels of technology inputs of agricultural production, identified by the FAO.

A second level model is developed in which actual physical constraints -land, yields, water and irrigation- are explicitly taken into account. Assessment of carrying capacity supported by actual data is then conducted using the same carrying capacity potential index as the first level. Consistency of the results on the two levels has been demonstrated. This conclusion -not to be expected a priori- has justified the application of the multilevel, from the hierarchical of the models point of view, approach. As such it presents a contribution to the methodology beyond the carrying capacity problem per se.

So, in summary, the main contributions of the thesis are threefold:

a) Contribution to the complex systems analysis methodology based on the multilevel modeling hierarchy approach, that uses the notions of a dominant relationship rather than more detailed approximation, in order to construct models on different levels of the modeling hierarchy. Consistency of the results on two levels—not expected a priori—open the ways for application of the approach to other problem domains (global warming, water scarcity, etc.).

b) Development of an agricultural (land and water) model to study carrying capacity for any country, region, on the globe. The developed models and the reasoning approach in scenario analysis can be applied to other agricultural carrying capacity problems such as, i.e., for Afghanistan, Bangladesh, etc.

c) Concrete results about targets and policies for the region in the East Sub-Saharan Africa in order to improve their food self-security.