September 1, 1999

Doctoral Thesis

CARRYING CAPACITY IN EAST SUB-SAHARAN AFRICA: A multilevel integrated assessment and a sustainable development approach

Student: Josep Xercavins i Valls, Professor at

UPC (Universitat Politècnica de Catalunya)

Director: Dr. Mihajlo D. Mesarovic; Cady Staley Professor at

CWRU (Case Western Reserve University)

Tutor: Dr. Josep Ma. Casas; Professor at

UPC (Universitat Politècnica de Catalunya)

CONTENTS

CONTENTS

- 0. FOREWORD; p 1
- 1. CARRYING CAPACITY, POPULATION AND SUSTAINABLE DEVELOPMENT: LOCAL APPROACH IN A GLOBAL VIEW; p 15
- 2. THE CASE STUDY REGION; p 37
- 3. GOALS; p 73
- 4. METHODOLOGY: TOWARDS INTEGRATED ASSESSMENTS WITH REASONING SUPPORT TOOLS; p 78
- 5. POPULATION ON CASE STUDY REGION; p 107
- 6. CARRYING CAPACITY FIRST LEVEL MODEL; p 130
- 7. WATER SCARCITY; p 155
- 8. CARRYING CAPACITY SECOND LEVEL MODEL; p 197
- A.1. COUNTRY TO COUNTRY GENERAL INFORMATION APPENDIX; p 268
- A.2. FAOSTAT AND FAODOC APPENDIX; p 293
- A.3. MODEL APPENDIX; p 315
- B. BIBLIOGRAPHY APPENDIX; p 330

CONTENTS

CONTENTS

0. FOREWORD

0.1. PREFACES

- 0.1.1. FIRST INTRODUCTION; SUMMER 1999
- 0.1.2. SECOND INTRODUCTION: FAMINE AGAIN, NOW IN SUDAN; SUMMER 1998
- 0.1.3. THIRD INTRODUCTION: FROM RWANDA TO SUB-SAHARAN AFRICA, ONE UNFORTUNATE REALITY THAT CAN INTENSIFY AND PROPAGATE DRAMATICALLY; SUMMERS 1996 AND 1997
- 0. 2. ACKNOWLEDGMENT
- 0.2.1. PERSONAL
- 0.2.2. INSTITUTIONAL
- 0.3. STRUCTURAL NOTES
- 0.3.1. BIBLIOGRAPHY
- **0.3.2. FORMATS**
- 0.3.3. ABBREVIATIONS
- **0.4. SUMMARY**
- 0.4.1. ORGANIZATION
- 0.4.2. OBJECTIVES AND CONTRIBUTIONS

1. CARRYING CAPACITY, POPULATION AND SUSTAINABLE DEVELOPMENT: LOCAL APPROACH IN A GLOBAL VIEW

- 1.1. HUMAN CARRYING CAPACITY CONCEPT
- 1.2. MORE ABOUT THE CARRYING CAPACITY CONCEPT: A FIRST GENERAL FOOD/LAND APPROACH
- 1.3. POPULATION GROWTH AND CARRYING CAPACITY
- 1.4. MORE ABOUT THE CARRYING CAPACITY CONCEPT: FROM THE ECOLOGICAL TO THE SOCIAL APPROACH
- 1.5. SUSTAINABLE DEVELOPMENT
- 1.5.1. ABOUT THE CONCEPT
- 1.5.2. HUMAN SUSTAINABLE DEVELOPMENT AND OTHER MORE RECENT CONSIDERATIONS ABOUT THE SUSTAINABILITY CONCEPT
- 1.6. LOCAL APPROACH TO AFRICA (FOR EXAMPLE) IN A GLOBAL VIEW

CONTENTS	II
CONTENTS	

2. THE CASE STUDY REGION

- 2.1. AFRICA, THE SECOND LARGEST CONTINENT OF THE WORLD 2.2. GENERAL VIEW TO THE PAST AND THE TRENDS IN AFRICA AND, SPECIFICALLY, SUB-SAHARAN AFRICA AGRICULTURE 2.3. THE PAST AND THE TRENDS IN AFRICA AND, SPECIFICALLY, SUB-SAHARAN AFRICA AGRICULTURE: CHALLENGES AND POTENTIALS
- 2.3.1. CONTROVERSY OVER SOURCES OF POTENTIAL FOOD PRODUCTION GROWTH
- 2.3.2. POTENTIAL FOR EXPANDING CROPLAND
- 2.3.3. POTENTIAL FOR INCREASING IRRIGATION
- 2.3.4. POTENTIAL FOR INCREASING YIELDS
- 2.3.4.1. TRENDS IN YIELDS
- 2.4. THE CASE STUDY REGION
- 2.5. THE CASE STUDY REGION, UNDER THE LIGHT OF SOME OF THE PRINCIPAL INTERNATIONAL INDICATORS
- 2.6. THE CASE STUDY REGION COUNTRY TO COUNTRY

3. GOALS

- 3.1. THE GOALS OF THIS DOCTORAL THESIS
- 4. METHODOLOGY: TOWARDS INTEGRATED ASSESSMENTS WITH REASONING SUPPORT TOOLS
- 4.1. CHARACTERISTICS OF GLOBAL EARTH/HUMAN ISSUES AND SYSTEMS: UNCERTAINTY AND THE GOAL-SEEKING (OR DECISION-MAKING) PARADIGM
- 4.2. CHARACTERISTICS OF GLOBAL EARTH/HUMAN ISSUES AND SYSTEMS: COMPLEXITY AND MULTILEVEL HIERARCHY MODELING
- 4.3. CHARACTERISTICS OF GLOBAL EARTH/HUMAN ISSUES AND SYSTEMS: MULTIDISCIPLINARY AND MULTILEVEL VERSUS INTEGRATED MODELING
- 4.3.1. DECONSTRUCTION OF A SYSTEM AND HIERARCHICAL REPRESENTATION
- 4.4. INTEGRATED ASSESSMENT AS A PROCESS
- 4.5. GLOBESIGHT: A REASONING SUPPORT TOOL

4.6. THE MODELS BASE IN GLOBESIGHT

4.6.1. ABOUT THE MORE GENERAL EQUATIONS IN OUR GLOBESIGHT MODELS

4.7. SCENARIO ANALYSIS

5. POPULATION ON CASE STUDY REGION

- 5.1.POPULATION ISSUE
- 5.2.POPULATION FIRST LEVEL MODEL
- 5.3.THE DEMOGRAPHIC TRANSITION
- 5.4.POPULATION SECOND LEVEL MODEL
- 5.5.FORESCATING POPULATION IN OUR CASE STUDY REGION: USING FIRST AND SECOND LEVEL MODEL
- 5.6.REMARKS

6. CARRYING CAPACITY FIRST LEVEL MODEL

- 6.1. CARRYING CAPACITY FIRST LEVEL MODEL
- 6.2. FAO/IIASA/UN ASSESMENT TO POTENTIAL POPULATION SUPPORTING CAPACITIES OF LANDS IN THE DEVELOPING WORLD
- 6.2.1. FAO/IIASA/UN CONCEPTS
- 6.2.2. FAO/IIASA/UN METHODOLOGY
- 6.2.2. THE FAO/IIASA/UN ASSESSMENT RESULTS FOR THE CASE STUDY REGION
- 6.3. THREE FIRST REFERENCE SCENARIOS
- 6.3.1. FIRST REMARKS AND CONCLUSIONS
- 6.4. ONE EXAMPLE OF A DESIRABLE AND COULD BE FEASIBLE HIGH LEVEL OF INPUTS SCENARIO FOR THE CASE STUDY REGION 6.5. WHAT HAPPENED IN RWANDA-BURUNDI?

7. WATER SCARCITY

7.1. AROUND CONCEPTS AND DIMENSIONS

- 7.1.1. DEFINITIONS OF KEY WATER TERMS AND CONCEPTS
- 7.1.2. THE EARTH'S WATER
- 7.1.3. THE EARTH'S WATER AND POPULATION
- 7.1.4. WATER AVAILABILITY IMBALANCES
- 7.1.5. HUMAN USES OF WATER

CONTENTS	V

- 7.2. POPULATION AND WATER STRESS AND SCARCITY
- 7.2.1. WATER-SCARCE COUNTRIES
- 7.3. A COMPLEMENTARY POINT OF VIEW AROUND THE STRESS AND SCARCITY INDEX'S
- 7.4. THE CASE STUDY REGION AND THE FIRST AND SECOND WATER SCARCITY INDEX'S
- 7.5. SOME TRENDS IN WATER RENEWABLE AND WITHDRAWAL AVAILABILITY AND USE
- 7.5.1. WATER USE IN AGRICULTURE
- 7.5.2. WATER USE FOR DOMESTIC PURPOSES
- 7.6. ANOTHER DIFFERENT POINT OF VIEW ABOUT THE CONCEPT OF WATER STRESS AND SCARCITY, STRONGLY RELATED WITH THE SUSTAINABLE DEVELOPMENT IDEAS AND/OR THE CAPABILITY POINT OF VIEW
- 7.7. THE CAPABILITY AND SUSTAINABLE INDEX'S OF WATER SCARCITY OF OUR CASE STUDY REGION; A POSSIBLE MORE OPTIMISTIC FUTURE PERSPECTIVE
- 7.7.1. A DYNAMICAL APPROACH TO THE IMPROVE WATER WITHDRAWAL IN THE COUNTRIES OF OUR CASE STUDY REGION 7.7.2. OUR WATER FIRST LEVEL MODEL

8. CARRYING CAPACITY SECOND LEVEL MODEL

- 8.1. TOWARDS CARRYING CAPACITY SECOND LEVEL MODEL
- 8.1.1. SOME SCIENTIFIC BASIS AND SOME SUBSEQUENTLY HYPHOTESIS FOR AN AGRICULTURAL MODEL
- 8.1.2. AN AGRICULTURAL MODEL
- 8.2. CONCEPTS AND DATA IN AND FROM FAOSTAT
- 8.2.1. OBSERVING, THINKING AND CONCLUDING FROM SOME DATA
- 8.3. MAIN DATA SUMMARY COUNTRY BY COUNTRY
- 8.3.1. ETHIOPIA
- 8.3.2. SOMALIA
- 8.3.3. KENYA
- 8.3.4. UGANDA
- 8.3.5. RWANDA
- 8.3.6. BURUNDI
- 8.4. THE "WORST-CASE, WoT" SCENARIO
- 8.4.1. REMARKS AND CONCLUSIONS
- 8.5. THE BaUo SCENARIO
- 8.5.1. REMARKS AND CONCLUSIONS

CONTENTS	V
CONTENTS	V

8.6. THE LAND POTENTIAL, LaP, SCENARIO

- 8.6.1. TRENDS AND POTENTIALITIES
- 8.6.2. THE CONSTRAINTS IN EXPANDING AGRICULTURAL LAND
- 8.6.3. THE LaP SCENARIO
- 8.6.4. REMARKS AND CONCLUSIONS
- 8.7. THE WATER OPTIMISTIC POTENTIAL, WaP, SCENARIO
- 8.7.1. POTENTIAL EXPANDING IRRIGATION: CONSTRAINT OR CHALLENGE?
- 8.7.2. THE WaP SCENARIO
- 8.8. COUNTRY TO COUNTRY UNDER THE LIGHT OF THE RESULTS OF ALL THE SCENARIOS
- 8.8.1. REMARKS AND CONCLUSIONS
- 8.9. FINAL REMARKS AND CONCLUSIONS AROUND THE WHOLE STUDY

A.1. COUNTRY TO COUNTRY GENERAL INFORMATION APPENDIX

- A.1.1. ETHIOPIA
- A.1.2. SOMALIA
- A.1.3. KENYA
- A.1.4. UGANDA
- A.1.5. RWANDA
- A.1.6. BURUNDI

A.2. FAOSTAT AND FAODOC APPENDIX

- A.2.1. FAOSTAT AGRICULTURE DATA
- A.2.2. FAOSTAT DATABASE: PRODUCTION AND EXPLANATORY NOTES
- A.2.3. FAOSTAT DATABASE: FAO INDICES OF AGRICULTURAL PRODUCTION NOTES
- A.2.4. FAOSTAT DATABASE: COMMODITY BALANCES NOTES
- A.2.5. FAOSTAT: FOOD SUPPLY NOTES
- A.2.6. FAOSTAT: LAND USE NOTES
- A.2.7. FAOSTAT DATABASE EXAMPLES RESULTS. ETHIOPIA FOOD CONSUMPTION 1990
- A.2.8. FAOSTAT DATABASE EXAMPLES RESULTS. TOWARDS KENYA BaUo.

CONTENTS	VI
----------	----

A.2.9. FAODOC. TABLES FROM REFERENCES [B.2.2.], [B.2.7.] AND [B.2.9.]

A.3. MODEL APPENDIX

- A.3.1. MODEL SOURCE CODE
- A.3.2. DIMENSIONS AND VARIABLES OF THE MODEL

B. BIBLIOGRAPHY APPENDIX

- **B.1. AFRICA AND SUB-SAHARAN AFRICA**
- **B.2. AGRICULTURE AND FOOD**
- B.3. CARRYING CAPACITY, POPULATION AND SUSTAINABLE DEVELOPMENT
- **B.4. GENERAL REFERENCES**
- B.5. INTERNATIONAL DATA AND DOCUMENT REFERENCES FROM THE INTERNET
- **B.6. INTERNATIONAL DATA REFERENCES**
- **B.7. MODELS**
- **B.8. WATER; SPECIALLY WATER IN AFRICA**

CONTENTS