8. CARRYING CAPACITY SECOND LEVEL MODEL

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

8. CARRYING CAPACITY SECOND LEVEL MODEL

8.1. TOWARDS CARRYING CAPACITY SECOND LEVEL MODEL

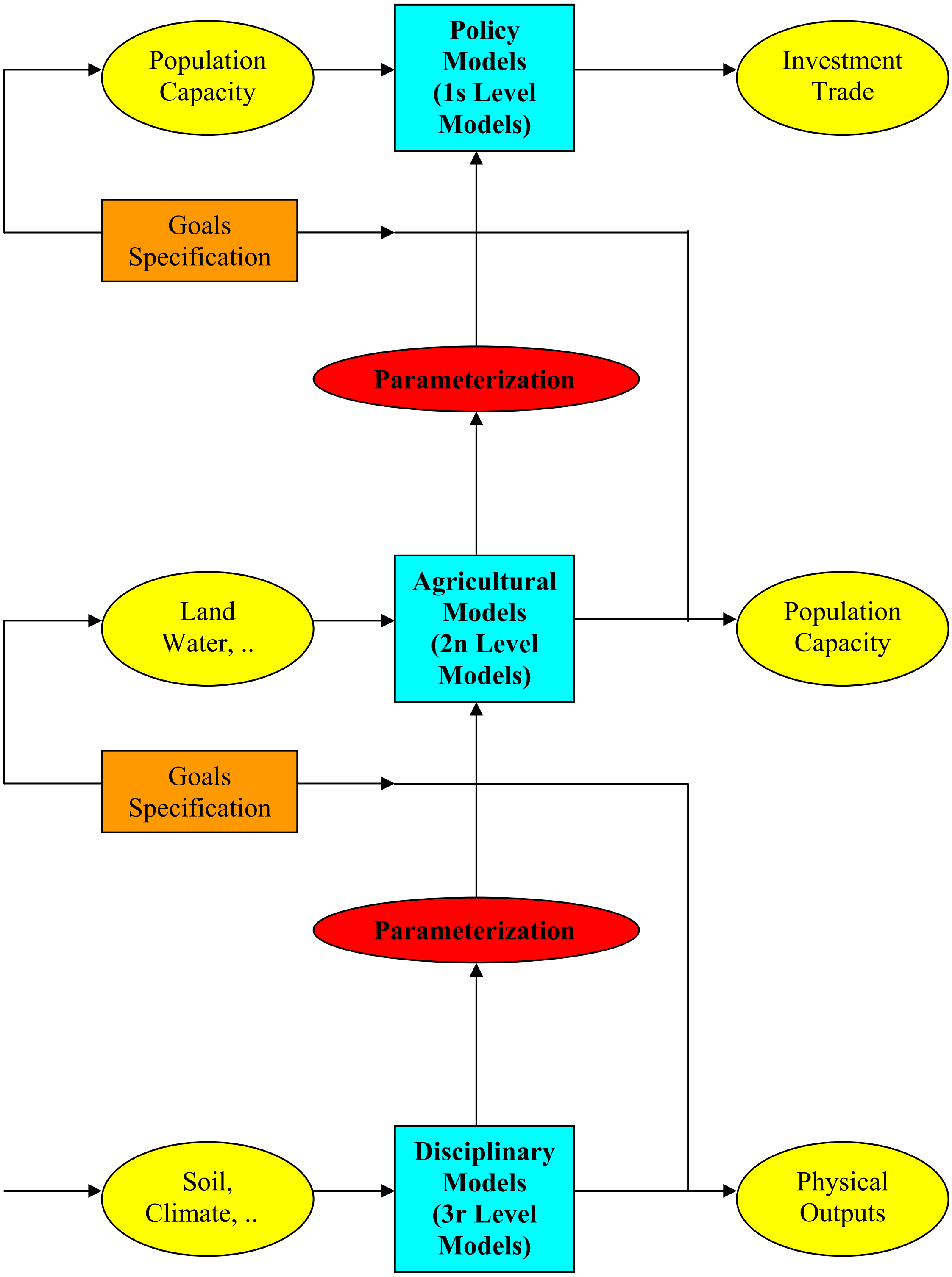
We will talk about the Carrying Capacity Second Level Model according to the methodological ideas that were described at length in chapter 4. In summary the hierarchical of the models can be illustrated as seen in Figure 8.1., which in essence is the same as the diagram for global warming issue, used as example in chapter 4, only in this case the issue is carrying capacity.

The Carrying Capacity First Level Model was presented in chapter 5. It needs the knowledge of data from a third and second level analysis in the FAO/IIASA/UN study, which detailed information, however, is not provided in the report. Still the first level analysis allowed us to have a first general high level view of the problematique (possible future scenarios in population and population capacity, in self supporting sense, of our case study region). But it has not given us any reference to what kind of concrete policies have to be carried out at lower levels, for example, at the agricultural land and water level.

Those are exactly the aspects that we want to investigate building and using a second level model. Specifically an agricultural approach to our problematique with the development of some concrete policies on land and water use related with the own capacity of the case study region to provide for itself the food that is needed for supporting its population growth. For example, we would like to check, with the scientific knowledge that we now (actually) have, how much land and water we need in order to determine whether the scenarios that we have studied in chapter 5 are feasible.

In order to build and use this second level model, we need to be clear on some basic concepts in the lowest or third level approach to our problematique, which is more related to the controversial NPP (Net Primary Production) discussions around the soil, climatic, and biochemical energy transformations. The only way to build an efficient usable and understandable second level model is to have the appropriate basis for making the hyphotesis.

Figure 8.1.:
Multilevel Architecture for Integrated Policy Assessment in Carrying Capacity



And why we concentrate on the second level and not directly on the third level?. Because as is repeatable explained in this study, we would like to concentrate on policy analysis. We would like to approach the real policies (land used, water used,…) that are necessary in order to self-support the people in these countries.

8.1.1. SOME SCIENTIFIC BASIS AND SOME SUBSEQUENTLY HYPHOTESIS FOR AN AGRICULTURAL MODEL

The food that human eat is the way to obtain the energy necessary for living. This energy is basically expressed and converted in and for human body in calories.

The protein and other nutritional needs of human can always be expressed in terms of calories. In fact the modern knowledge of this particular point tell us that the real important idea is the energy (the calories), and that indeed the proteins can be obtained for human body itself if it has enough number of calories ([B.2.22.], [B.2.23.], [B.2.18]). But anyway, the proteins contents that we usually receive from livestock food, at the beginning is also computable through the calories from, for example, the grain food (the calories) that the animals need for living. Furthermore we know without any doubt ([B.2.17.], [B.2.18.]) that this kind of energy transformation (all the steps in the atrophic chain) is very inefficient. So if we only take into account the direct calorie production from land then, from the potential (the maximum that is feasible) point of view, we are not doing any, any we insist, mistake. On contrary, we will be closer to the potential capacity of this land.

So we have the first and concrete hyphotesis of our study: we only model the direct land food capability production, because we are interested in the potential capacity of this land.

From one specific soil (with some specific geological, chemical and biological characteristics) **that receives some solar energy radiation in function of its geographical coordinates**, and that is placed in some specific climate area (with some specific **rainfed**, temperature, etc.), we will have some NPP, Net Primary Production. Controversially, we can think that this NPP is, more or less, computable but, also, more or less, constant ([B.2.17.], [B.2.18.], [B.2.19.]). **The point of our interest here is that, finally, the agricultural land production (always, we again insist, from the potential and/or the limit point of view) is initially determined by, in essence, some constant energy inputs (geo-bio-chemical, solar, climate) for each particular regional land. Obviously, they will produce some constant primary energy, calories, outputs, at the subsequent link of the atrophic chain.**

This energy outputs can and will be improved with the help of other factors that, finally, are related with exogenous energy inputs (irrigation,

fertilization, mechanization, etc.). But in fact again, if we really take into account the real energy balance of the energy yield increase when we use fertilization, mechanization, etc. [B.2.18.], we can again arrive to the conclusion that our last assumption is correct.

The existence of this regional potentially constant but limited primary energy, calories, output, is another basis (we will see where and how later) of the model that we propose and finally use.

Strongly and not simple related with the last discussions there will be the kind of crops that we use as an interface of these energy transformations. In fact, really, **the crops are the most adequate vegetable species that maximize the energy transformation** that was allowed for endogenous and some exogenous inputs.

Each crop has a physical constant that allows us to compute the number of Kcal that will be obtained, through it, from each Kg of the crop produced ([B.5.3.], [B.3.7.]).

In other words we should note the following practical important dissertation: when we say that, for example, the sorghum is better than maize, we ought to be sure that the combination between the productivity yield of the land to this crop (Kg/He) and the calorie productivity yield of this crop (Kcal/Kg) is, really, the maximum energy production that we can obtain from this regional land. Sometimes there are inaccurate assertions because they only take into account one of this productivity's. Usually the first, that initially is some potential primary constant that normally we do not know, but that finally is the variable depending of the exogenous energy inputs to the harvest (fertilization, mechanization, etc.).

Following these ideas we want to cite here, from many authoritative sources ([B.2.1.] – [B.2.13.]), that cereal grain is one of the most common and representative crops that we know on earth. And specifically, that if we know the sufficient information of the area of study we can model the food production of this area from an equivalent cereal grain production (taken into account both productivity's, the yield of the land and the yield of the cereal grain). This again is based on the facts mentioned before but that we shall see clearly later.

8.1.2. A GENERAL AGRICULTURAL MODEL

What should be a general agricultural model? After the discussion in the previous section we can say that the answer is probably: does not exist! It only exists depending on the amount and the type of variables that we want to take into account.

Thus following the discussion that just started in previous section, we can write, easily from the conceptual approach, the following possible general, but from a concrete point of view, key agricultural food production relationship:

Calorie production (Kcal) = lost coefficient *
*** agricultural land rainfed (He) ***
*** cropping intensity ***
*** yield land (Kg/He) ***
*** yield crop (Kcal/Kg)**

Clearly, the loss coefficient represents the many and different "loss" that we will experience "from the field to the people" in the long process "from harvest to eating". It includes the lost itself, but also the amounts for seed, stocks, etc.. But, finally, in the way that we will build the model we won't speak again about it. We have internalized the coefficient working directly with calories supply (it is assumed that it represents, more or less, the 25% of production). So, for us, it will be equal to 1 everywhere from now on.

The cropping intensity

Kcrintnir

is a key factor that includes a lot of information related, mainly, with the exogenous energy inputs (mechanization, fertilization, etc.). This kind of exogenous energy inputs will be those that allows us, in practice, to have or not different number of harvests in one year. Some linear variation in time can be assumed for it in order to represent the improvements in these technological aspects.

The other factors in the equation were previously cited and explained indirectly.

It is also clear that this relation should be added for all the different crops that we use. But if we can find the way to model this addition with some common representative crop we can leave the addition outside our procedure.

In other aspects the agricultural and yield land variables in the equation are dynamical dependent on time and will follow identical growth rate equations that were used in GLOBESIGHT in all the models before this.

We are talking about irrigation as an exogenous input. The water, the irrigation, is one of the most influent factors in improving the land yields and the cropping intensity. And because the water is in fact a local resource that if we can use it in a sustainable way we ought to use (remember the discussions of chapter 7) for agricultural purposes, we must take into account exactly the same equation as before but for irrigated land. And absolutely all the considerations that we have made for the equation before will be correct for this and should be extend to this.

Thus, depending only on the available data and on the existence of the representative crop that allows us to model the aggregation for all the crops in only one summation so that we will achieve our goal.

There is only another important but conceptually different last step. According to the FAO, 2350 Kcal/(capita day) is the standard quantity of calories that one human being needs for a good quality of life from the food point of view. We know this number and idea as a daily standard. So using the similar final nomenclature that we used in chapter 5 we can compute now, in this second level approach, the capacity of the lands to self-support its population, the population capacity, in this evident way

$$\text{Population Capacity} = \text{Calorie production (Kcal)} \,/\, [(2350\ \text{Kcal/(capita day)}) * 365\ \text{day/year}]$$

About this point/assumption we also know, again from FAO, that, for example, the daily consumption for Ethiopia is around 1750 Kcal/(capita day). **It means that, on average in the last years, and taken also into account, explicitly, food import and food aid, it is considered that, on average again, the people in**

Ethiopia, currently, are living, more or less, with this amount of calories. We have decided not to use these daily country "levels" for two main reasons. First because we think that if we have defined one universal standard for "welfare", we need to achieve it everywhere. Second because these country levels are also so controversial and, in fact, subject to discussion (see, for example, section A.2.7. in appendix A.2.).

In the next Figure 8.2 we can see, detailed, the model itself. Some aspects of it will be commented in subsequent sections of this chapter. All the necessary information about all the models used in this work are also available in the appendix A.3.

Figure 8.2.:
Carrying Capacity Second Level Model

```
/***********************************
 *
 *  CARRYING CAPACITY 2n LEVEL MODEL
 *
 *  AGRICULTURAL LAND AND WATER MODEL
 *
 *  from population 1st level model
 *
 ***********************************/


 if (year > firstYear)
{
                /*  Compute agricultural land */

        for (r=0; r<reg; r++) {
                agland[r] = sagland[r]*(1.+raglandm[r]*ragland[r]/100.);
        }

                /*  Compute population density related with agricultural hectares          */

        for (r=0; r<reg; r++) {
                popdsaghe[r]=(agland[r]/1000.)/pops[r];
        }

                /*          Compute agricultural irrigated land */

        for (r=0; r<reg; r++) {
                aglandir[r]=saglandir[r]*(1.+raglandirm[r]*raglandir[r]/100.);
        }
}
```

```
                /*  Compute water used in irrigation (water in cubic Kilometers)*/

        for (r=0; r<reg; r++) {
                irwtus [r] = kcrintir[r]*kirwthc[r]*aglandir[r];
        }
                /*          Compute agricultural non-irrigated land */

        for (r=0; r<reg; r++) {
                aglandnir[r]=agland[r]-aglandir[r];
         }
                /* Compute yield production non-irrigated (Kg/He)    */

 if (year > firstYear)
{
        for (r=0; r<reg; r++) {
                yldpnir[r] = syldpnir[r]*(1.+ryldpnirm[r]*ryldpnir[r]/100.);
        }
}
                /* Compute yield production irrigated           */

 if (year > firstYear)
{
        for (r=0; r<reg; r++) {
                yldpir[r] = syldpir[r]*(1.+ryldpirm[r]*ryldpir[r]/100.);
        }
}
                /*  Compute daily kilocalorie supply per capita and day */

        for (r=0; r<reg; r++) {
                dailys[r]= klostag[r]*(aglandir[r]*kcrintir[r]*yldpir[r]*calyld[r]+
                        +aglandnir[r]*kcrintnir[r]*yldpnir[r]*calyld[r])/(pops[r]*365.*1000.);
        }
                /*  Compute daily Index */

        for (r=0; r<reg; r++) {
                indailys[r]=dailys[r]/dailyfao[r];
        }
                /*  Compute population capacity in agreement to grain production total equivalent and
                FAO Daily */

        for (r=0; r<reg; r++) {
                popcpag[r] = klostag[r]*(aglandir[r]*kcrintir[r]*yldpir[r]*calyld[r]+
                          +aglandnir[r]*kcrintnir[r]*yldpnir[r]*calyld[r])/(dailyfao[r]*365.*1000.);
        }

                /*  Compute index carrying capacity 2n level */

        for (r=0; r<reg; r++) {
                incrcp[r]=popcpag[r]/pops[r];

                if (incrcp[r] > 1)
                        {
                                incrcp[r]=1;
                        }
        }
```

```
		/*  Compute population capacity in agreement to grain non irrigated production total
		equivalent and FAO Daily */

for (r=0; r<reg; r++) {
		popcpagnir[r] =
		= klostag[r]*(aglandnir[r]*kcrintnir[r]*yldpnir[r]*calyld[r])/(dailyfao[r]*365.*1000.);
}
		/*  Compute index carrying capacity non irrigated 2n level */

for (r=0; r<reg; r++) {
		incrcpnir[r]=popcpagnir[r]/pops[r];

		if (incrcpnir[r] > 1)
			{
				incrcpnir[r]=1;
			}
}
		/*  Compute population capacity in agreement to grain irrigated production total
		equivalent and FAO Daily */

for (r=0; r<reg; r++) {
		popcpagir[r] =
		= klostag[r]*(aglandir[r]*kcrintir[r]*yldpir[r]*calyld[r])/(dailyfao[r]*365.*1000.);
}
		/*  Compute index carrying capacity irrigated 2n level */

for (r=0; r<reg; r++) {
		incrcpir[r]=popcpagir[r]/pops[r];

		if (incrcpir[r] > 1)
			{
				incrcpir[r]=1;
			}
}
		/*  Compute Variables Aggregate */

		agland_agg = 0.;
		aglandir_agg = 0.;
		aglandnir_agg = 0.;
		irwtus_agg = 0.;
		popcpag_agg = 0.;
		popcpagnir_agg = 0.;
		popcpagir_agg = 0.;

		for (r=1; r<7; r++) {

			agland_agg = agland_agg + agland[r];
			aglandir_agg = aglandir_agg +aglandir [r];
			aglandnir_agg = aglandnir_agg + aglandnir [r];
			irwtus_agg = irwtus_agg + irwtus [r];
			popcpag_agg = popcpag_agg + popcpag[r];
			popcpagnir_agg = popcpagnir_agg + popcpagnir[r];
			popcpagir_agg = popcpagir_agg + popcpagir[r];
		}
```

```
                irwtus_agg = kcrintir[9] * kirwthc [9] * aglandir_agg;
                popdsaghe_agg = (agland_agg/1000.)/pops_agg;
                incrcp_agg = popcpag_agg/pops_agg;
                incrcpnir_agg = popcpagnir_agg/pops_agg;
                incrcpir_agg = popcpagir_agg/pops_agg;

                if (incrcp_agg > 1)
                        {
                                incrcp_agg =1;
                        }

                if (incrcpnir_agg > 1)
                        {
                                incrcpnir_agg =1;
                        }

                if (incrcpir_agg > 1)
                        {
                                incrcpir_agg =1;
                        }

/********************
*
*  BACKUP VARIABLES
*
*********************/

        for (r=0; r<reg; r++) {

                /* Backup agricultural model variables */

                sagland[r]=agland[r];
                saglandir[r]=aglandir[r];
                syldpir[r]=yldpir[r];
                syldpnir[r]=yldpnir[r];
        }
```

8.2. CONCEPTS AND DATA IN AND FROM FAOSTAT

FAO has done an enormous effort in order to have and to give to the public an actualized database about agricultural aspects of the world. We can use this tool in several ways, but principally through an iterative database accessible from Internet in the WEB site cited in the bibliography [B.5.4.].

In the appendix A.2. we have combined the main conceptual information and the main kind of search and results, as examples, what we have done and found there for own study on this level.

The reader can see this appendix and/or the database on Internet. Particularly, the reader also can build the following specific data table of our case study region from this international source (Figure 8.3).

All the data start from the year 1990 (the year from which we always start running our models in order to test the necessary coherency with the recent past trends). But we have searched and looked for data from the 80's to the 90's. And it is important to note explicitly, first of all, that in our case study region this period is like a constant period; practically we do not have any appreciable variation on the many of main (not on the all but) data of our interest and subject. We will come back to this point after.

If you do this, you can see that for Ethiopia, for the reason of the Eritrea's independence, the continuity of data is a little more difficult to obtain.

The data are for the most important crops in all these countries; and in spite of the non addition of the lands from other less important crops, the number that we have for total harvested land is close to the real harvested land.

These data play basically two roles in our study. The first, in the following sub section, is to make our model as accurate as possible. The second, in the following section of this chapter, is to have the initial data necessary to run the model and, in general, the data necessary for drawing the main scenarios of our study.

8.2.1. OBSERVING, THINKING AND CONCLUDING FROM SOME DATA

Figure 8.3. (Appendix A.2.)

	AREA HAV. (He)	YIELD P. (Kg/He)	Kcal (ML)	C. YIELD Kcal/Kg	Kcal/He
ETHIOPIA					
Cereals	6737000	1361	26259370	2864	3897784
Pulses	1247000	893	3310443	2973	2654726
Roots	552900	3682	1644491	808	2974301
"aggregate"	8536900	1443	31214304	2534	3656398
SOMALIA					
Cereals	732500	793	2427317	4179	3313743
Pulses	43000	326	47530	3391	1105349
Roots	4830	10414	43645	868	9036232
Fruits	28200	10699	102294	339	3627447
"aggregate"	808530	1171	2620786	2768	3241421
KENYA					
Cereals	1833666	1488	7692926	2819	4195380
Pulses	690000	305	617756	2935	895298
Roots	176282	8577	1348258	892	7648302
Fruits	143563	6115	444603	506	3096919
"aggregate"	2843511	1874	10103543	1896	3553193
RWANDA					
Cereals	241000	1270	879307	2873	3648577
Pulses	288000	715	684872	3326	2378028
Roots	249500	6425	1472638	919	5902357
Fruits	400900	6992	1246090	445	3108231
"aggregate"	1179400	4170	4282907	871	3631429
BURUNDI					
Cereals	217500	1349	656970	2239	3020552
Pulses	312900	1178	1098147	2979	3509578
Roots	206720	6837	1116485	790	5400953
Fruits	307300	5314	368066	225	1197742
"aggregate"	1044420	3551	3239668	874	3101882
UGANDA					
Cereals	1055000	1498	2755410	1744	2611763
Pulses	636915	787	1391064	2775	2184065
Roots	856835	6229	3650150	684	4260038
Fruits	1513250	5584	2985754	353	1973074
"Aggregate"	4062000	3907	10782378	680	2654451
REGION AG.	18474761	2332	62243586	1444	3369115

It is obvious (see the red numbers in the table) that in our regional area, with more or less the same endogenous primary energy inputs and with, for sure, more or less the same actual exogenous energy inputs we have, finally, an amount of Kcal/He that is practically, in reality, an "initial regional physical constant" (more than the same order of magnitude).

It is also obvious (see the blue numbers) that the cereals are the representative crop also in our region, as mentioned before.

Thus, according to these results and to the considerations in sections 8.1.1. and 8.1.2. we can complete our agricultural model, using one equivalent cereal grain of about 2800Kcal/Kg of constant calorie yield (is the most general mean value of this number in Sub Saharan Africa -see references from [B.2.1.] to [B.2.13.]- and in our concrete region) with an actual (1990) yield productivity of the land of about 1300Kg/He. The latter is also a very representative number in our region and, in general, in Sub Saharan Africa. The dynamical evolution in time of this latter number/variable allows us to simulate the policies and subsequently the improvement in the productivity of lands.

The product of these numbers is 3640000Kcal/He.

Taken into account that the calories of the table of the Figure 8.3., are the calories corresponding to the food consumption, we can ratify the assumption made before that, for us, the "loss" have been endogenaized. But we can not forget the main idea that, finally, with our key equation of section 8.2.1. we really model the capacity to produce calories.

8.3. MAIN DATA SUMMARY COUNTRY BY COUNTRY

The following notes are common to all the following countries data table. Basically they are telling us that obviously not only from FAOSTAT, but also from other international sources (The World Bank, The World Resources Institute, etc.), we can obtain some consistent data about all the aspects that are taken into account in our study.

These common notes are:

(1) Wherever it is not indicated, the data are our consistency conclusions from three basic sources. World Resources 1996-97, from The World Resources Institute; the reference [B.6.8.]. World Development Indicators 1997, from The World Bank; the reference [B.6.5.]. And, basically, the following reference (3). The majority of them are data between 1990 and 1995 and we use them as initial data in 1990.

(2) World Population Projections 1994-95, from The World Bank and The Johns Hopkins University Press; our reference [B.3.1.].

(3) FAOSTAT summer 1998; our reference [B.5.4.].

(4) Potential population supporting capacities of lands in the developing world; Higgins & others; FAO, IIASA, UN, 1982. Our reference [B.3.7.].

8.3.1. ETHIOPIA

	ETHIOPIA (1)		(reference) COMMENTS
POPULATION			(2)
POP	48501000		
RPOP	3,26		
LAND AREAS			(3)
AREA	$110430*10^3$ha		
LAND AREA	$100000*10^3$ha		
AGRICULTURAL AREA	$31650*10^3$ha		
ARABLE LAND	$11000*10^3$ha		
PERMANENT CROPLAND	$650*10^3$ha		
TOTAL CROPLAND	$11650*10^3$ha		
PASTURE	$20000*10^3$ha		
FOREST	$13300*10^3$ha		
OTHERS	$55050*10^3$ha		
NON ARABLE&PER	$88350*10^3$ha		
TOTAL "FOODSELF" LAND			(3)
LAND UNDER CEREAL	$6737*10^3$ha		
CEREAL YIELD	1361Kg/ha		
LAND UNDER PULSES&OTHERS	$1247*10^3$ha		
PULSES YIELD	893Kg/ha		
LAND UNDER ROOTS&TUBERS	$553*10^3$ha		
ROOTS YIELD	3682Kg/ha		
LAND UNDER FRUIT			
FRUIT YIELD			
WATER AND LAND			
IRRIGATED AGRICULTURAL AREA	$190*10^3$ha		
WATER RESOURCES			
ANNUAL INTERNAL RENEWABLE WATER	110 Km^3		
ANNUAL WITHDRAWALS	2,21 Km^3		
" IN AGRICULTURE	1,90 Km^3	86%	
IRRIGATION WATER/HA IRRIGATE	$10*10^3 m^3$/ha		
" IN INDUSTRY		3%	
" IN DOMESTIC		11%	
CARRYING CAPACITY FAO/IIASA/UN			(4)
CRCP (LOW)	0,17		
CRCP (INTERMEDIATE)	0,59		
CRCP (HIGH)	2,56		

8.3.2. SOMALIA

	SOMALIA (1)		(reference) COMMENTS
POPULATION			(2)
POP	7805000		
RPOP	2,84		
LAND AREAS			(3)
AREA	$63766*10^3$ha		
LAND AREA	$62734*10^3$ha		
AGRICULTURAL AREA	$44042*10^3$ha		
ARABLE LAND	$1022*10^3$ha		
PERMANENT CROPLAND	$20*10^3$ha		
TOTAL CROPLAND	$1042*10^3$ha		
PASTURE	$43000*10^3$ha		
FOREST	$15945*10^3$ha		
OTHERS	$2747*10^3$ha		
NON ARABLE&PER	$61694*10^3$ha		
TOTAL "FOODSELF" LAND			(3)
LAND UNDER CEREAL	$732*10^3$ha		
CEREAL YIELD	793Kg/ha		
LAND UNDER PULSES&OTHERS	$43*10^3$ha		
PULSES YIELD	326Kg/ha		
LAND UNDER ROOTS&TUBERS	$4,8*10^3$ha		
ROOTS YIELD	10414Kg/ha		
LAND UNDER FRUIT	$28,2*10^3$ha		
FRUIT YIELD	10699Kg/ha		
WATER AND LAND			
IRRIGATED AGRICULTURAL AREA	$180*10^3$ha		
WATER RESOURCES			
ANNUAL INTERNAL RENEWABLE WATER	6,00 Km^3		
ANNUAL WITHDRAWALS	0,81 Km^3		
" IN AGRICULTURE	0,79 Km^3	97%	
IRRIGATION WATER/HA IRRIGATE	$4,4*10^3m^3$/ha		
" IN INDUSTRY		0%	
" IN DOMESTIC		3%	
CARRYING CAPACITY FAO/IIASA/UN			(4)
CRCP (LOW)	0,03		
CRCP (INTERMEDIATE)	0,05		
CRCP (HIGH)	0,12		

8.3.3. KENYA

	KENYA (1)		(reference) COMMENTS
POPULATION			(2)
POP	24160000		
RPOP	2,77		
LAND AREAS			(3)
AREA	$58037*10^3$ha		
LAND AREA	$56914*10^3$ha		
AGRICULTURAL AREA	$25800*10^3$ha		
ARABLE LAND	$4000*10^3$ha		
PERMANENT CROPLAND	$500*10^3$ha		
TOTAL CROPLAND	$4500*10^3$ha		
PASTURE	$21300*10^3$ha		
FOREST	$16815*10^3$ha		
OTHERS	$14299*10^3$ha		
NON ARABLE&PER	$52414*10^3$ha		
TOTAL "FOODSELF" LAND			(3)
LAND UNDER CEREAL	$1834*10^3$ha		
CEREAL YIELD	1488Kg/ha		
LAND UNDER PULSES&OTHERS	$690*10^3$ha		
PULSES YIELD	305Kg/ha		
LAND UNDER ROOTS&TUBERS	$176*10^3$ha		
ROOTS YIELD	8577Kg/ha		
LAND UNDER FRUIT	$144*10^3$ha		
FRUIT YIELD	6115Kg/ha		
WATER AND LAND			
IRRIGATED AGRICULTURAL AREA	$60*10^3$ha		
WATER RESOURCES			
ANNUAL INTERNAL RENEWABLE WATER	20,20 Km^3		
ANNUAL WITHDRAWALS	2,05 Km^3		
" IN AGRICULTURE	1,56 Km^3	76%	
IRRIGATION WATER/HA IRRIGATED	$26*10^3m^3$/ha		
" IN INDUSTRY		4%	
" IN DOMESTIC		20%	
CARRYING CAPACITY FAO/UN			(4)
CRCP (LOW)	0,10		
CRCP (INTERMEDIATE)	0,24		
CRCP (HIGH)	0,93		

8.3.4. UGANDA

	UGANDA (1)		(reference) COMMENTS
POPULATION			(2)
POP	16330000		
RPOP	3,19		
LAND AREAS			(3)
AREA	$24104*10^3$ha		
LAND AREA	$19965*10^3$ha		
AGRICULTURAL AREA	$8510*10^3$ha		
ARABLE LAND	$5000*10^3$ha		
PERMANENT CROPLAND	$1710*10^3$ha		
TOTAL CROPLAND	$6710*10^3$ha		
PASTURE	$1800*10^3$ha		
FOREST	$6366*10^3$ha		
OTHERS	$5089*10^3$ha		
NON ARABLE&PER	$13255*10^3$ha		
TOTAL "FOODSELF" LAND			(3)
LAND UNDER CEREAL	$1055*10^3$ha		
CEREAL YIELD	1498Kg/ha		
LAND UNDER PULSES&OTHERS	$637*10^3$ha		
PULSES YIELD	787Kg/ha		
LAND UNDER ROOTS&TUBERS	$857*10^3$ha		
ROOTS YIELD	6229Kg/ha		
LAND UNDER FRUIT	$1513*10^3$ha		
FRUIT YIELD	5584 Kg/ha		
WATER AND LAND			
IRRIGATED AGRICULTURAL AREA	$9*10^3$ha		
WATER RESOURCES			
ANNUAL INTERNAL RENEWABLE WATER	39 Km^3		
ANNUAL WITHDRAWALS	0,20 Km^3		
" IN AGRICULTURE	0,12 Km^3	60%	
IRRIGATION WATER/HE IRRIGATE	$13*10^3m^3$/ha		
" IN INDUSTRY		8%	
" IN DOMESTIC		32%	
CARRYING CAPACITY FAO/IIASA/UN			(4)
CRCP (LOW)	0,56		
CRCP (INTERMEDIATE)	2,20		
CRCP (HIGH)	7,72		

8.3.5. RWANDA

	RWANDA (1)		(reference) COMMENTS
POPULATION			(2)
POP	6950000		
RPOP	2,29%		
LAND AREAS			(3)
AREA	$2634*10^3$ha		
LAND AREA	$2467*10^3$ha		
AGRICULTURAL AREA	$1849*10^3$ha		
ARABLE LAND	$850*10^3$ha		
PERMANENT CROPLAND	$315*10^3$ha		
TOTAL CROPLAND	$1165*10^3$ha		
PASTURE	$694*10^3$ha		
FOREST	$252*10^3$ha		
OTHERS	$356*10^3$ha		
NON ARABLE&PER	$1302*10^3$ha		
TOTAL "FOODSELF" LAND			(3)
LAND UNDER CEREAL	$241*10^3$ha		
CEREAL YIELD	1270Kg/ha		
LAND UNDER PULSES&OTHERS	$288*10^3$ha		
PULSES YIELD	715Kg/ha		
LAND UNDER ROOTS&TUBERS	$249*10^3$ha		
ROOTS YIELD	6425Kg/ha		
LAND UNDER FRUIT	$401*10^3$ha		
FRUIT YIELD	6992Kg/ha		
WATER AND LAND			
IRRIGATED AGRICULTURAL AREA	$4*10^3$ha		
WATER RESOURCES			
ANNUAL INTERNAL RENEWABLE WATER	6,30 Km^3		
ANNUAL WITHDRAWALS	0,77 Km^3		
" IN AGRICULTURE	0,72 Km^3	94%	
IRRIGATION WATER/HE IRRIGATE	$181*10^3 m^3$/Ha		
" IN INDUSTRY		1%	
" IN DOMESTIC		5%	
CARRYING CAPACITY FAO/UN			(4)
CRCP (LOW)	0,29		
CRCP (INTERMEDIATE)	1,42		
CRCP (HIGH)	3,22		

8.3.6. BURUNDI

	BURUNDI (1)		(reference) COMMENTS
POPULATION			(2)
POP	5492000		
RPOP	2,75		
LAND AREAS			(3)
AREA	$2783*10^3$ha		
LAND AREA	$2568*10^3$ha		
AGRICULTURAL AREA	$2180*10^3$ha		
ARABLE LAND	$810*10^3$ha		
PERMANENT CROPLAND	$340*10^3$ha		
TOTAL CROPLAND	$1150*10^3$ha		
PASTURE	$1030*10^3$ha		
FOREST	$325*10^3$ha		
OTHERS	$63*10^3$ha		
NON ARABLE&PER	$1418*10^3$ha		
TOTAL "FOODSELF" LAND			(3)
LAND UNDER CEREAL	$217,5*10^3$ha		
CEREAL YIELD	1349Kg/ha		
LAND UNDER PULSES&OTHERS	$312,9*10^3$ha		
PULSES YIELD	1178Kg/ha		
LAND UNDER ROOTS&TUBERS	$206,7*10^3$ha		
ROOTS YIELD	6837Kg/ha		
LAND UNDER FRUIT	$307,3*10^3$ha		
FRUIT YIELD	5314Kg/ha		
WATER AND LAND			
IRRIGATED AGRICULTURAL AREA	$14*10^3$ha		
WATER RESOURCES			
ANNUAL INTERNAL RENEWABLE WATER	3,6 Km^3		
ANNUAL WITHDRAWALS	0,1 Km^3		
" IN AGRICULTURE	0,064 Km^3	64%	
IRRIGATION WATER/HE IRRIGATED	$4.6*10^3 m^3$/ha		
" IN INDUSTRY		0%	
" IN DOMESTIC		36%	
CARRYING CAPACITY FAO/IIASA/UN			(4)
CRCP (LOW)	0,33		
CRCP (INTERMEDIATE)	1,78		
CRCP (HIGH)	4,05		

8.4. THE "WORST-CASE, WoT," SCENARIO

As mentioned before according to all the sources, for the countries of our case study region there is a first main clear conclusion: the 70's, the 80's and the 90's means for this countries, as a general and practical "universal" conclusion, no changes in arable land and irrigated land irrigated. This situation, practically, could not be worst.

If we now extend this trend to all the other variables of our model, i.e., yields and cropping intensities, then we can talk about the "worst case, WoT" scenario. At least from the point of view of the yields this is not the trend during the last 30 years (we will come back to this point later). So it is not a realistic scenario. It is one pessimistic scenario, that extends the negative trend in lands and in other African realities to the other agricultural variables.

The scenario has also another important point of interest: to test the consistency of the initial values given for the model with the data available for the countries in the region. It will also allow us to validate this new model, by comparing its results with the results from the first carrying capacity model.

If we want to draw this first scenario we need to face definitely two things. First to specify what are the values, and why are these values, of all the initial data that are necessary to run the model. Second, to define the way to draw the scenario that we would like to create and analyze (in this case the WoT scenario).

Starting with the second point, it is obvious that WoT means that all the rates of growth of all the variables depending on time through a rate equation have to be 0. We can remark this:

WoT Agricultural Scenario: Rates of Growth in Agricultural Model = 0

And continuing with the first point, we can look at the next Figure 8.4. with all the data that, at the same time, need to be commented carefully.

Figure 8.4.: WoT Agricultural Scenario Data Table

VARIABLE LONG NAME	VARIABLE SHORT NAME	DATA VALUE	COMMENTS
Agricultural Land	Agland	Country data from section 8.3.	(1) Arable and permanent cropland
Agricultural Land Rate	Ragland	0	Constant
Agricultural Land Irrigated	Aglandir	Country data from section 8.3	
Agriculture Land Irrigated Rate	Raglandir	0	Constant
Agricultural Land Non Irrigated (or rainfed)	Aglandnir	Compute	
Calorie Yield	Calyld	2800Kcal/Kg	See section 8.2.1.
Yield Land Non Irrigated	Yldpnir	1300Kg/He	See section 8.2.1.
Yield Land Non Irrigated Rate	Ryldpnir	0	Constant
Yield Land Irrigated	Yldpir	2400Kg/He	(2)
Yield Land Irrigated Rate	Ryldpir	0	Constant
Cropping Intensity Non Irrigated Land Coefficient	Kcrintnir	0,55	(3); constant
Cropping Intensity Irrigated Land Coefficient	Kcrintir	0.75	(3); constant

(1) Taken into account the FAO definitions of the lands (agricultural, arable, cropland, etc.) - see appendix A.2.- and, basically then, that all the countries of our case study region have some significant part of its agriculture dedicated to commercial purpose (as a controversial result of the colonial era) –see appendix A.1.-, we conclude that, **only because we are interested in the potential approach**, the best way to model is, really, to use, as a land for agricultural food self supporting countries goals, the total "Arable and Permanent Cropland".

(2) The irrigation is one of the most effective method to increase the yield productivity of the land itself; furthermore it is also the way in which cropping intensity could be more important. All the main sources mentioned in this chapter, in the same way that are consistent with the initial yield productivity land that we have finally decided to use in our model, are also consistent in providing us the **2400Kg/He as the actual (1990) mean value in Sub Saharan Africa for the yield productivity of irrigated land.**

(3) Exactly from the same common references we have this consistency values for the actual mean cropping intensities in Sub Saharan Africa. See again data of appendix A.2..

So now we are absolutely ready to start our analysis with our reasoning support tool: GLOBESIGHT.

As we did in chapter 6, when we presented and studied the scenarios from the FAO/IIASA/UN report, the most, at the same time, understandable and compact way to do the analysis is by using again the normalized carrying capacity index defined exactly as in the chapter mentioned. So, we have

$$\mathbf{incrcp} = \frac{\mathbf{popcp}}{\mathbf{pops}}$$

and, obviously,

$$\text{if} \quad \mathbf{popcpag} \geq \mathbf{pops} \quad \text{then} \quad \mathbf{incrcp} \equiv 1$$

$$\text{and if} \quad \mathbf{popcpag} < \mathbf{pops} \quad \text{then} \quad 0 \leq \mathbf{incrcp} < 1$$

We cannot forget that our scenarios are, first of all, the foresight evolution in time of our issues, by taking into account, mainly, the increasing population as we have studied in chapter 5.

So, now, using our reasoning support tool with the model that we have created and data specified we can have a new vision, from this Carrying Capacity Second Level Model -an agricultural model-, of the problematique of our case study region.

Obviously it should be really interesting to compare this new agricultural second level view with our high level view of this chapter 4.

The results can be seen in the next Figures.

Figure 8.5.

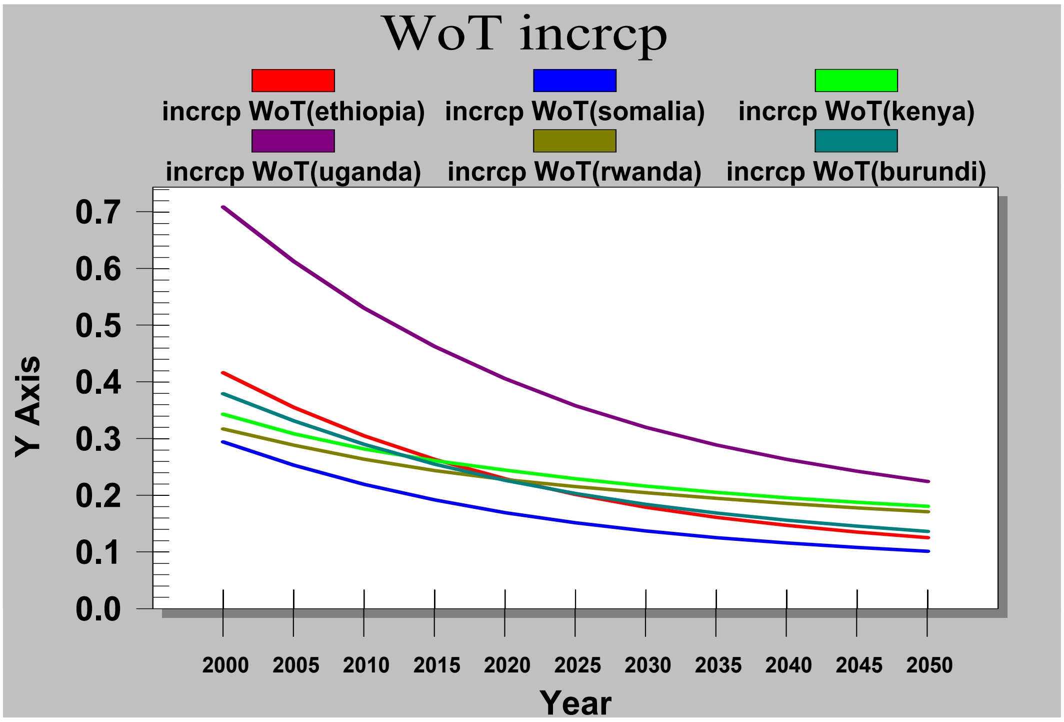


Figure 8.6.

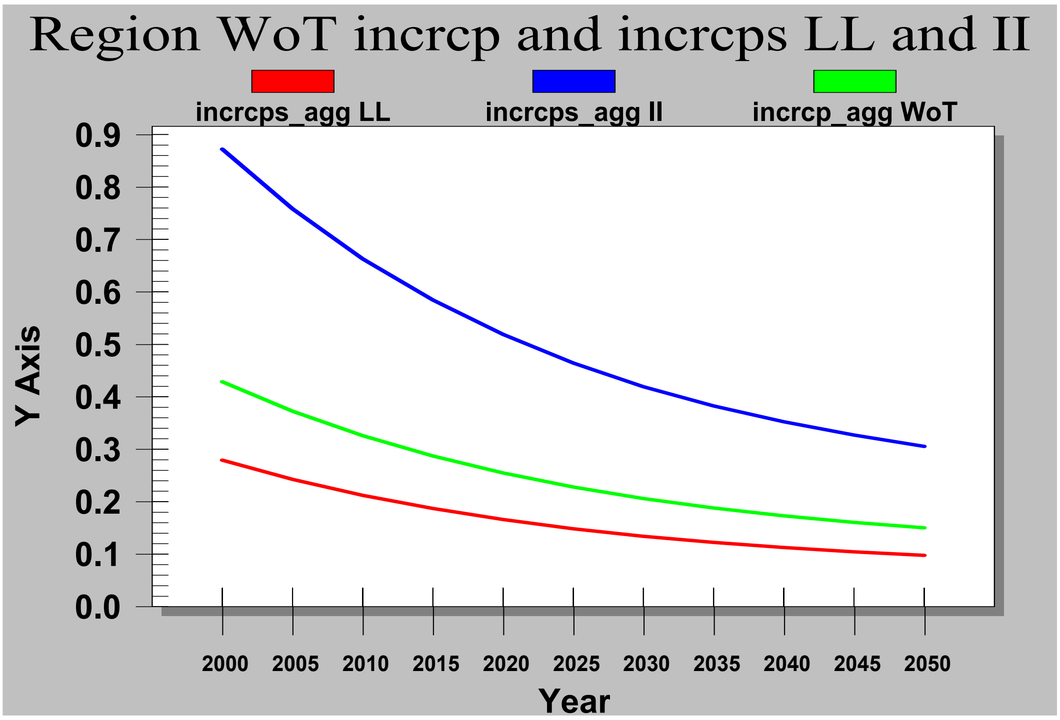


Figure 8.7.

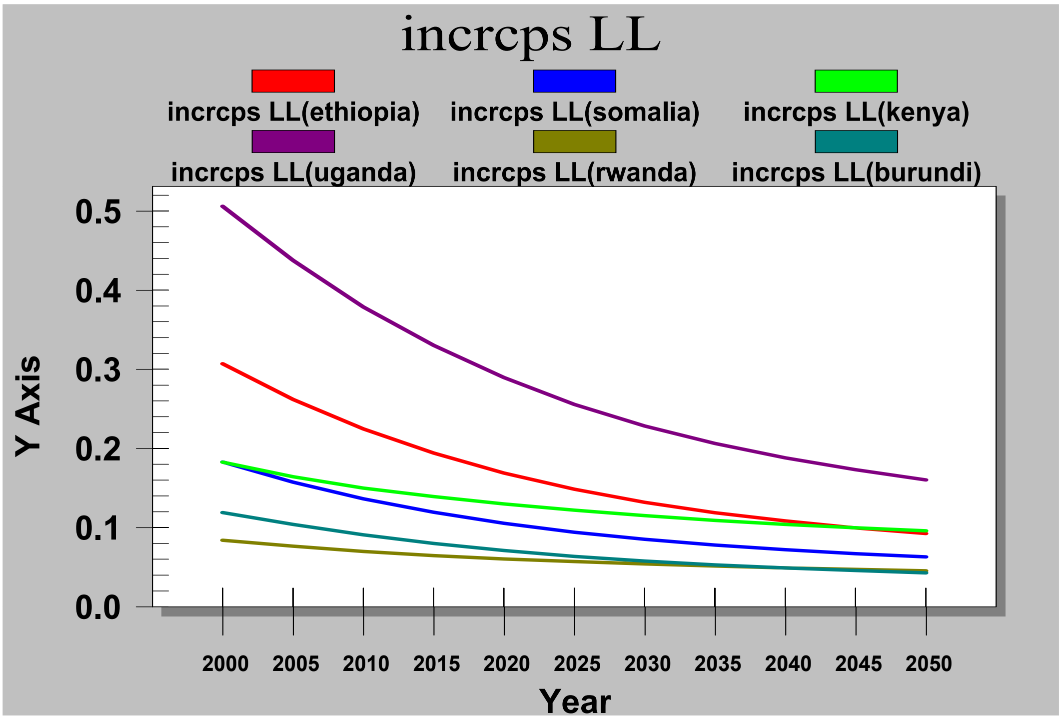
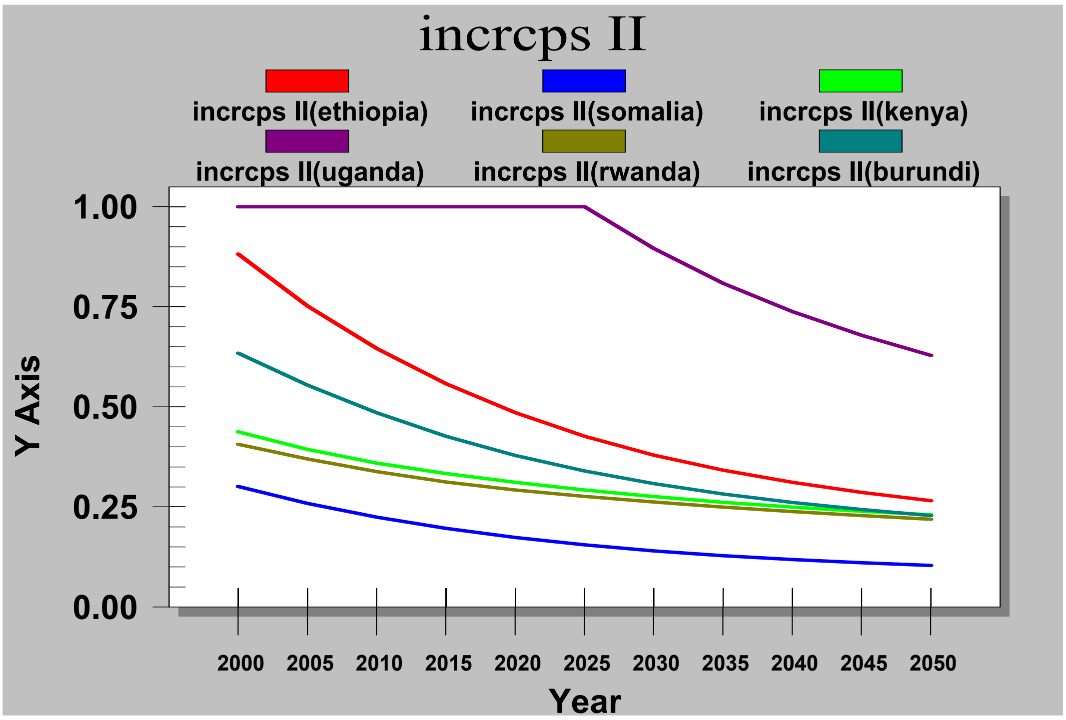


Figure 8.8.



8.4.1. REMARKS AND CONCLUSIONS

If we look at Figure 8.6., and then we compare Figure 8.5. (the main result of our WoT scenario) with Figures 8.7. and 8.8., we can conclude, easily, that **from the point of view of the 1990 level**, and starting from the aggregate region, we were in some intermediate level between the low (LL) and intermediate (II) level of inputs of the FAO/IIASA/UN report. This is also specifically true for the countries, and the most remarkable aspect is that we have the same country order of problematique, from the bottom to the top, in our WoT scenario as in the II scenario from FAO/IIASA/UN.

This last remarkable aspect, together with the facts that the patterns (obvious) and the order of magnitude of the problematique (another important result), that we have from the two models, are so similar, allows us to say that the first and more more important conclusion of this comparison is the validation of the model that we have created. It could not be any luck that the combination of the real data of the countries and the region with some key driver equations and hyphotesis give us a result so similar to the results from the report from FAO/IIASA/UN.

It is a validation, we insist, because the similarity of the results is not only the general order of magnitude but also the exact sequence of this order of magnitude for the countries of the region.

Another important remark/conclusion of this comparison is that we know better now the concrete meaning of low (L) or intermediate (I) level of inputs in the FAO/IIASA/UN Report. What it means is in the sense that the actual, 1990 at least, harvest land, irrigated land, land yields, calorie yields, cropping intensity, etc., in Sub Saharan Africa in general, and in the countries of our case study region in particular, are practically correspond to some intermediate position between these two levels of inputs of the cited report.

Until now this level of inputs of the report only meant for us some theoretical ideas about levels of use, technology, etc. of agricultural world. From now we also know what is the realization of these ideas in concrete or practical physical variables: amount of land used, cropping intensities, yields, etc.

And the third remark/conclusion at this point of our study is the really dreadful initial (1990) potential situation in all the countries of our case study

region. We have now seen explicitly why our case study region were so problematique and the countries, all of them, are placed at the bottom positions of all the international comparisons of the basic aspects of the human development.

About this third conclusion we ought to remark the following: the scenario represents the pessimistic (but indeed possible) evolution of our case study region from the potential currently real situation experienced in our countries in 1990; which is not exactly the goal of the study, but which knowledge and appropriate use of it in the model is basic in order to do our next scenario analysis from a consistent initial reproduction of the reality.

If the reader is interested, in the section A.2.7. of appendix A.2. he or she can find the concrete illustration that shows, first that the model results and the 1990 reality are absolutely consistent, and second that the model is starting from this initial potential (maximum and bigger than the real) 1990 position.

This initial position, that we have named potential, allows us, from the beginning, to speak confidently from the carrying capacity point of view.

So, with this important conclusions we can follow our study with renewable effort and confidence.

But before, we should mention here another significant result that we can extract, at once, from our first scenario, and that will be common for all the next scenarios, except for the last for evident reasons that we will see. The contribution of the irrigation to the self-supporting food capacity of the countries of the region is, except for Somalia (see Figure 8.10, but we will come back later to this specific result), really small (see for example Figure 8.11 for Ethiopia that is fully representative). In fact the objective of the last scenario that we will develop is to check the possibilities and the effective results of the water agricultural policy in our countries.

Figure 8.9.

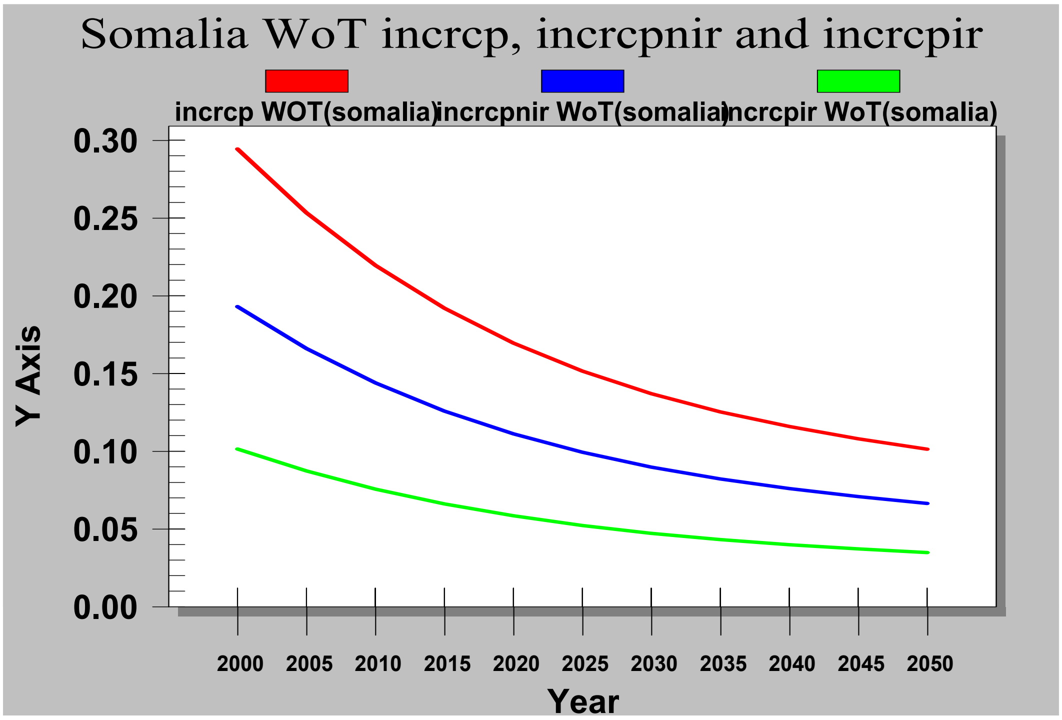
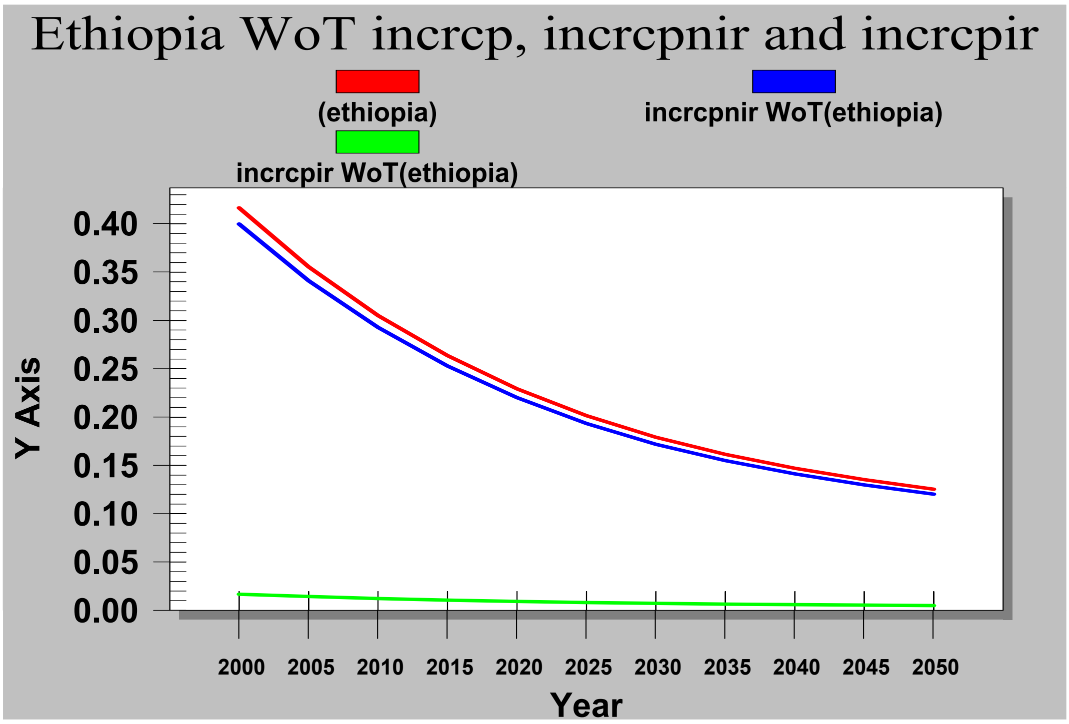


Figure 8.10.



8.5. THE BaUo SCENARIO

Usually, what we mean by Business as Usual scenario is a scenario in which the main historical trends of are extended or projected to the future. In fact we are saying that nothing will change in the future in the sense that the policies are the same as in the past.

In the last section we mentioned something about these trends but now we have to be precise in order to really build this new, sometimes the reference, scenario. In the following Figures we show the historical trends and their projections to the future for arable and permanent cropland, population and PIN for Kenya. The Production Index of Agricultural, PIN, give us (see again appendix A.2.) the % that the total agricultural production of one year represents with respect to production in the period 1989-91, in which we have assumed that total production was, normalized, 100%). We only show the graphs for Kenya, as a representative of the region, because the patterns and the conclusions are exactly the same for all the countries in the region. The source of the data in these Figures is, again, in the appendix A.2. (section A.2.8.).

Figure 8.11.

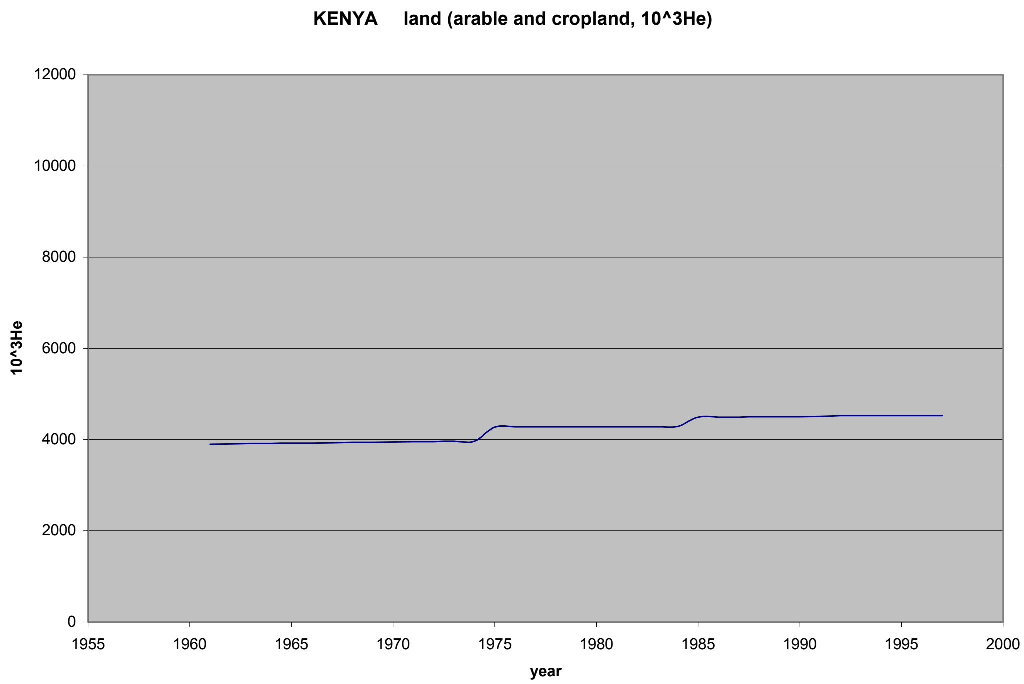


Figure 8.12.

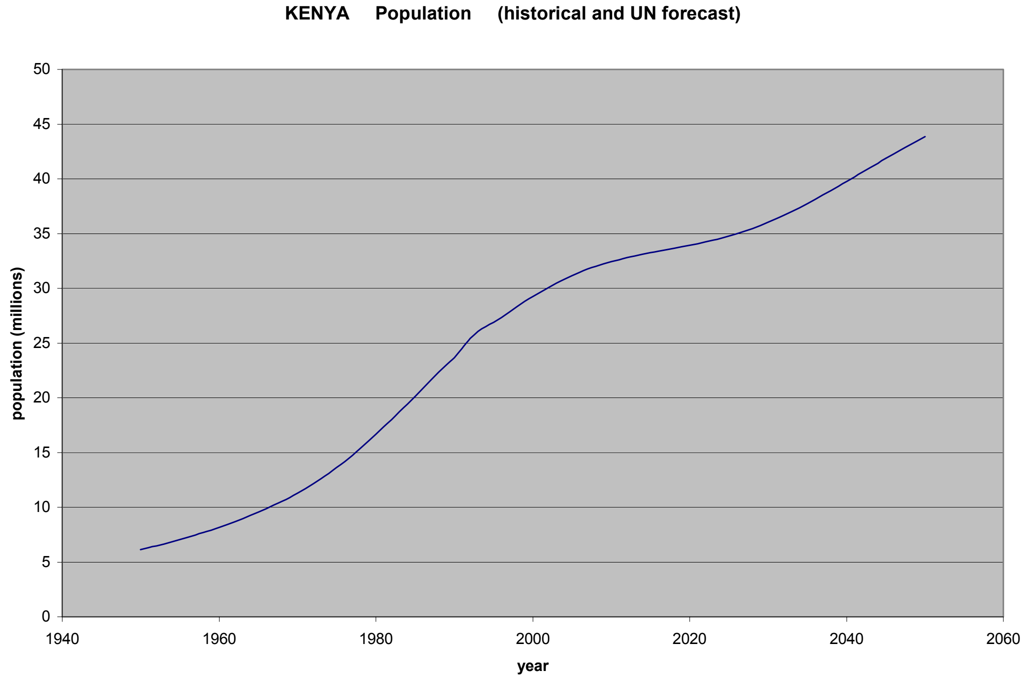


Figure 8.13.

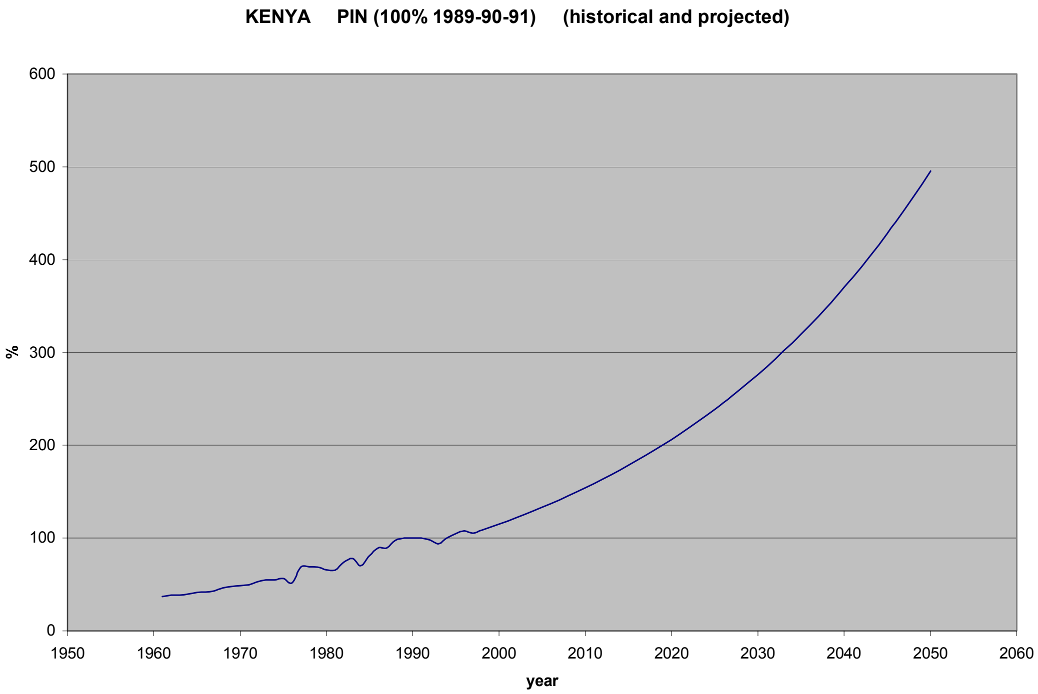


Figure 8.14.

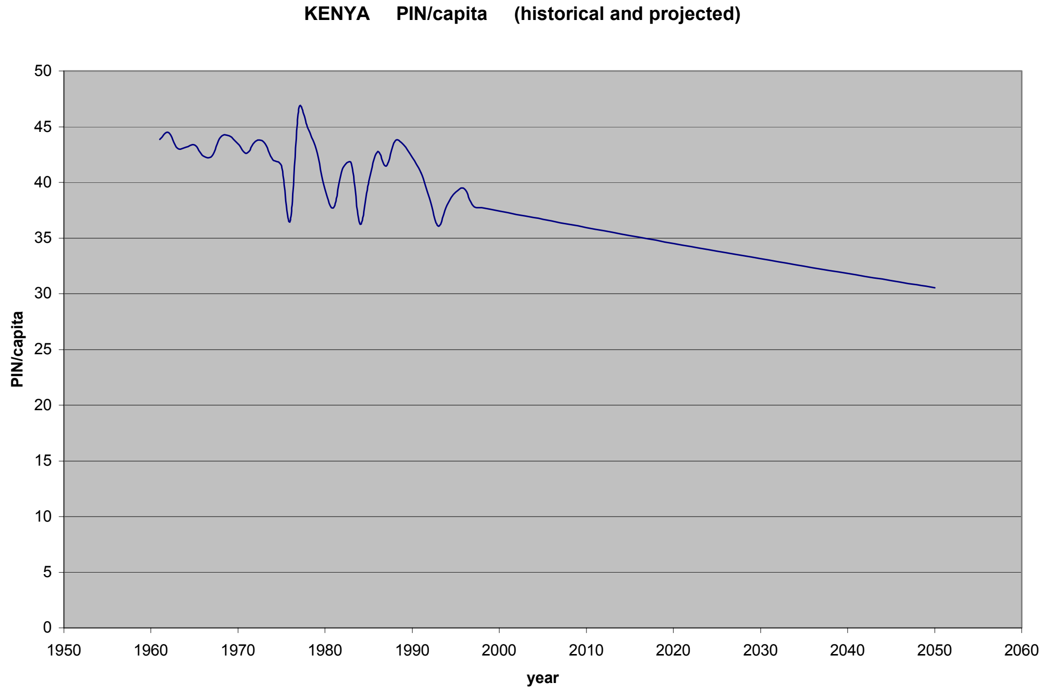
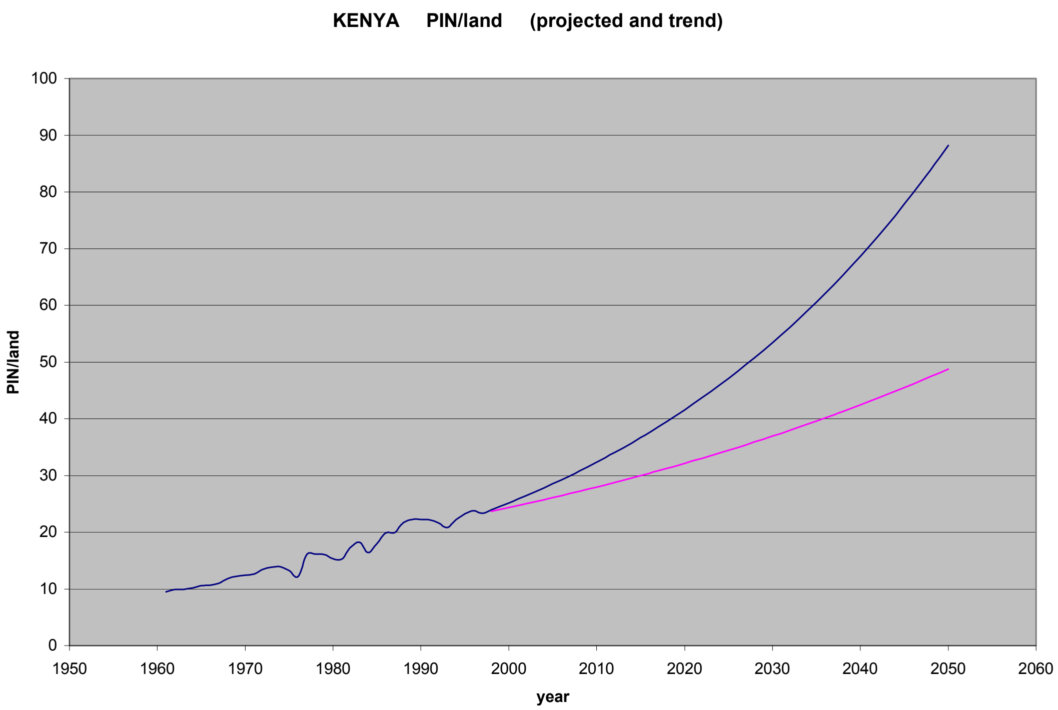


Figure 8.15.



First of all we can see, Figure 8.11., that, as we said in the section before, nothing in the amount of agricultural lands was changed during the last three decades. This is also more clear for the other countries in the region.
But population was and is increasing according to Figure 8.12.. Fortunately the PIN was and is also growing (Figure 8.13.), but (and according to the general discussion that we had in chapter 2) without enough rate of growth in order to compensate the growth of the population; see Figure 8.14..

But more problematic, according to Figure 8.15., is that taken into account the fact that agricultural land is not changing, the increase in total production must be the result of the increase in yields production (that again is in accordance with the general discussion of chapter 2). But the projected increase in yields production is not feasible (we can again come back to chapter 2) because it means to multiply practically by 5 the 1990 level of yield production (1300Kg/He). So twice more than can be feasibly expected.

So, strictly speaking, the BaU scenario is not feasible. We decided to build one scenario with the main recognized yields production trends/potentialities for the future, taking into account the past, that we have from the literature.

These trends/potentialities, see again chapter 2 or references [B.2.2.], [B.2.7.] and [B.2.9.], are also optimistic, because of the difficulties in maintaining the 70's and 80's growing trends in yields (specially if we watch the 90's evolution). Then, we finally decide to talk about the BaUo scenario, in the sense that it is more optimistic than the typical Business as Usual scenario (curiously but, this will not be our case) and, specially, because as always we are interested in the potential -optimistic- approach and, from the point of view of yields production, this is already the potential scenario.

The color line of Figure 8.15. shows these trends and the specific numbers for the rates are in the table of the following Figure 8.16..

With respect to the cropping intensity (at the moment only for non irrigation land because we do not introduce in this scenario any change in water use for irrigation -this is clearly the BaU trend-), which is the other factor that can be assumed, in our actual future approach, that is growing, in a linear tendency, to the half of this potential maximum value (from the same literature sources).

Figure 8.16.: BaUo Agricultural Scenario Data Table

VARIABLE LONG NAME	VARIABLE SHORT NAME	DATA VALUE	COMMENTS
Agricultural Land	Agland	Country data from section 8.3.	(1) Arable and permanent cropland
Agricultural Land Rate	Ragland	0	Constant
Agricultural Land Irrigated	Aglandir	Country data from section 8.3	
Agriculture Land Irrigated Rate	Raglandir	0	Constant
Agricultural Land Non Irrigated (or rainfed)	Aglandnir	Compute	
Calorie Yield	Calyld	2800Kcal/Kg	See section 8.2.1.
Yield Land Non Irrigated	Yldpnir	1300Kg/He	See section 8.2.1.
Yield Land Non Irrigated Rate	Ryldpnir	1,4	Constant
Yield Land Irrigated	Yldpir	2400Kg/He	(2)
Yield Land Irrigated Rate	Ryldpir	1,6	Constant
Cropping Intensity Non Irrigated Land Coefficient	Kcrintnir	0,55	(3); to 0,66 linear
Cropping Intensity Irrigated Land Coefficient	Kcrintir	0.75	(3); constant

The notes for this table are the same as for the table of Figure 8.4.

Putting these assumptions in GLOBESIGHT and running again the model we obtain the following results, that we should look and interpret again carefully. The scenario analysis is just started.

Figure 8.17.

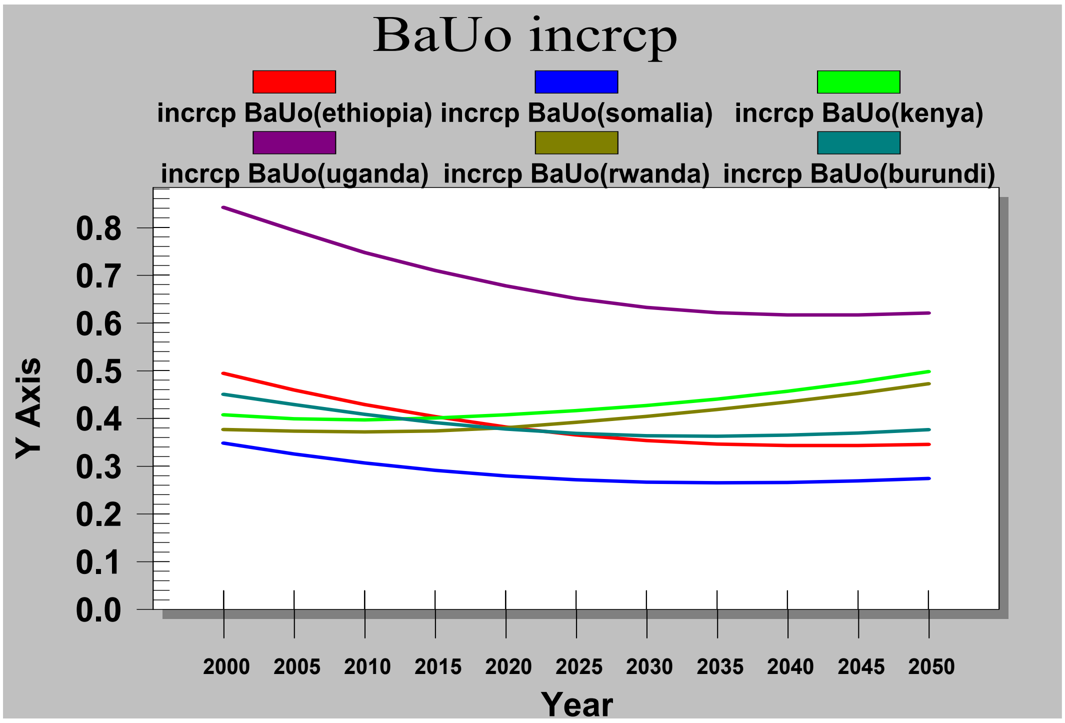
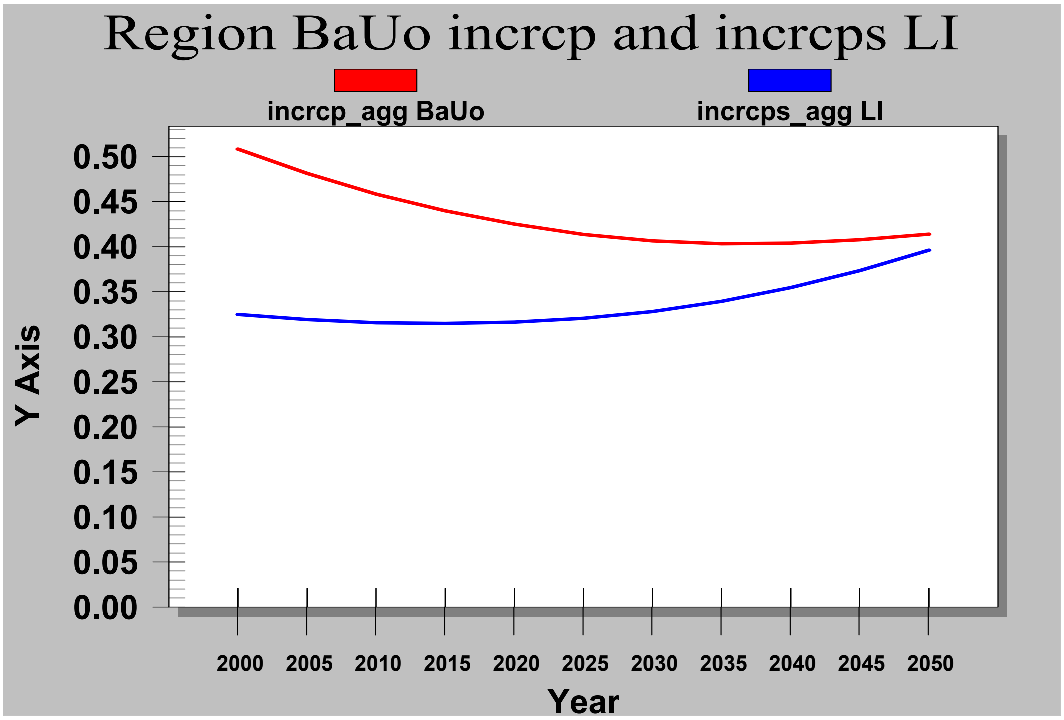


Figure 8.18.



8.5.1. REMARKS AND CONCLUSIONS

The first remark/conclusion from the BaUo scenario results is the confirmation, again, that the situation of all the countries of our case study region, under the light of the more characteristics and "probable" future trends (population, yields production, lands policy, etc.), is really dramatic. And we are saying this stronger than ever, because we have started in the potential or maximum (1990) agricultural food capability position (you should remember the discussion in the section before) and we have applied future, in general optimistic, trends in yields and cropping intensities productions. But the results, Figure 8.18., only shows that if this happens, at maximum, we can conserve the very problematic food self-security situation in 1990, or improve a little bit for Kenya and Rwanda.

The only factor that we could say it is not included in our study is the livestock that is related to the "natural pasture land", "which can never be used as agricultural land (for example, mountainous areas)". Whether or not this amount of land is large, it can never represent, due to its low efficiency, more than 2% of the daily of the people in the country.

Closely related to this first remark/conclusion, it appears absolutely clear that, at least, <u>the actual trend of agricultural land -no change- must be broken if we want to improve the situation</u>. This lead us to the subsequent scenarios.

From Figure 8.19. we can check again the consistency between this results of the second level model and the results of the first level model using FAO/IIASA/UN data. Identical considerations as we have done in section 8.4.1. could be done here.

8.6. THE LAND POTENTIAL, LaP, SCENARIO

8.6.1. TRENDS AND POTENTIALITIES

It is for sure that policies are absolutely necessary in Sub Saharan Africa faced with the actual situation and the very important growth of the population.

The expert and popular opinion (remember again the discussion in chapter 2) is that Africa in general will face a dramatic situation, but that at the same time there are many potentialities that can really improve the situation. We will see this in the present and in the next sections.

Our next step will be to take into account what are the general trends that the international experts expect the region, at least, to follow if, of course, someone take the necessary decisions.

We will first look at this point of our study these general consistent, from all the sources, trends in the big region of Sub Saharan Africa thinking in the effects for the countries of our case study region. We can named this scenario **GoT (General optimistic Trends)** because we want to emphasize here that it is the application of some general trends to our region that experts thought this can also occur in the Sub Saharan Africa region as a whole.

One summary to the main sources of our study of this kind of trends, following the dissertation of chapter 2 and/or again the references [B.2.2.], [B.2.7.] and [B.2.9.] -the reader can see again the tables of section A.2.9. of appendix A.2.-, can be put in the following data table of Figure 8.19., as the characteristic of this new scenario. It implies the need to take into account the main trends to improve the agricultural sector in the region: expanding croplands and expanding irrigation. The trends in increasing yields are included since the BaUo scenario (always, you should remember, in a potential perspective).

The notes for this table, we insist for the last time, are the same as for the table of Figure 8.4..

Figure 8.19.: GoT Agricultural Scenario Data Table

VARIABLE LONG NAME	VARIABLE SHORT NAME	DATA VALUE	COMMENTS
Agricultural Land	Agland	Country data from section 8.3.	(1) Arable and permanent cropland
Agricultural Land Rate	Ragland	0,9	Constant
Agricultural Land Irrigated	Aglandir	Country data from section 8.3	
Agriculture Land Irrigated Rate	Raglandir	1,4	Constant
Agricultural Land Non Irrigated (or rainfed)	Aglandnir	Compute	
Calorie Yield	Calyld	2800Kcal/Kg	See section 8.2.1.
Yield Land Non Irrigated	Yldpnir	1300Kg/He	See section 8.2.1.
Yield Land Non Irrigated Rate	Ryldpnir	1,4	Constant
Yield Land Irrigated	Yldpir	2400Kg/He	(2)
Yield Land Irrigated Rate	Ryldpir	1,6	Constant
Cropping Intensity Non Irrigated Land Coefficient	Kcrintnir	0,55	(3); to 0,66 linear
Cropping Intensity Irrigated Land Coefficient	Kcrintir	0,75	(3); to 0,975 linear

----

But one thing is the trends and another is the potentialities. Sometimes is difficult, but it is not now the situation, to differentiate the two perspectives. So another different step of our study is to try to determine the real potential of these countries as a maximum food self-supporting that they can achieve.

Again and formally identical as before, we will first look at this point of our study the generally consistent, from all the sources, potentialities in the big region of Sub- Saharan Africa thinking in the effects for the countries of our case study region. We can named this scenario **GoP (General optimistic Potentiality's)** because we want to emphasize here that it is the application of some general potentialities to our region that experts thought it can also be achieved in the Sub Saharan Africa region as a whole.

And also again in summary to the main sources of our study of this kind of trends, following the dissertation of chapter 2 and/or again the references [B.2.2.], [B.2.7.] and [B.2.9.] -the reader can see again the tables of section A.2.9. of appendix A.2.-, can be put in the following data table of Figure 8.20., the characteristic of this new scenario. It implies the need to take into account the main potentialities to improve the agricultural in the region: expanding croplands and expanding irrigation. One more time the potentialities in increasing yields are included since the BaUo scenario.

But it is not by chance that we are concentrating in the more stressful part of Africa. If these general potentiality's could be possible in our case study region then it can be shown (but not necessary be reproduced here) that we will not have any theoretical problem in the future in these countries.

But if we go down deeper to the country to country detail, relatively only to two main physical constraints: the amount of land that can be used for agricultural development and the amount of water that can be used for irrigation, then really we can derive the maximum potentiality of the region. And then we can see whether this GoP scenario is or not accessible for one, two or both physical constraints.

In other words, we need to test for each country if the general land and irrigation potentialities (and indeed the trends) of Sub Saharan Africa are "proportionally" achieved in the countries of our region.

Figure 8.20.: GoP Agricultural Scenario Data Table

VARIABLE LONG NAME	VARIABLE SHORT NAME	DATA VALUE	COMMENTS
Agricultural Land	Agland	Country data from section 8.3.	(1) Arable and permanent cropland
Agricultural Land Rate	Ragland	3,2	Constant
Agricultural Land Irrigated	Aglandir	Country data from section 8.3	
Agriculture Land Irrigated Rate	Raglandir	5,2	Constant
Agricultural Land Non Irrigated (or rainfed)	Aglandnir	Compute	
Calorie Yield	Calyld	2800Kcal/Kg	See section 8.2.1.
Yield Land Non Irrigated	Yldpnir	1300Kg/He	See section 8.2.1.
Yield Land Non Irrigated Rate	Ryldpnir	1,4	Constant
Yield Land Irrigated	Yldpir	2400Kg/He	(2)
Yield Land Irrigated Rate	Ryldpir	1,6	Constant
Cropping Intensity Non Irrigated Land Coefficient	Kcrintnir	0,55	(3); to 0,77 linear
Cropping Intensity Irrigated Land Coefficient	Kcrintir	0,75	(3); to 1,25 linear

8.6.2. THE CONSTRAINTS IN EXPANDING AGRICULTURAL LAND

If we search deeper in the literature we can find from our main sources in this issue, and especially in reference [B.1.2.], that for the countries (very stressful countries) of our case study region the maximum potential exploitable agricultural land should be the following

Figure 8.21.

	AGLAND 1990 (ARABLE AND PERMANENT)	AGLAND POTENTIAL	CONSTANT RATE IN A 50 YEARS PERIOD
ETHIOPIA	11650	31650	2
SOMALIA (2)	1042	?	0,9
KENYA	4500	7300	1
UGANDA	6710	10700	0,95
RWANDA	1165	1300	0,2
BURUNDI	1150	1300	0,25
REGION	26217	53880	1,45

(1) We currently have no knowledge on the potential agricultural land of Somalia. In the international sources there are, sometimes, lacks of data for Somalia. But we know that the agricultural conditions of the country are extremely bad and really far from the potential 3.2% growth of rate. We assume the optimistic general trend, 0,9%, as the potential growth rate.

8.6.3. THE LaP SCENARIO

We have finished showing that our stressful case study region, as an aggregate region has more "potentialities than trends" but less potentialities than the Sub-Saharan Africa region as a whole. And this is true because Ethiopia, the largest country of the region, had bigger potentiality (**0,9 -GoT-** < **2** < **3,2 -GoP-**) than the trends, which is not true for all the other countries.

So we decided to build a new scenario that will reproduce all the particular potentialities of the countries of our case study region, according to the table of the Figure before. It is called the Land Potential Scenario, LaP, because it will show us the real maximum potential possibilities specific country to country, from this land agricultural policy point of view.

Again the table database that includes all the characteristics of this new LaP scenario is in the following Figure 8.22.. In the direction to represent the maximum potential of agricultural land, we will also assume the potential cropping intensity for the non irrigated land, in agreement with the references that me cited before.

And we should note that if we represent with this scenario the specific policy to achieve the land potentialities of the countries of our region, it has no sense if we do not take into account any assumption about irrigated land. So, because we really want to see, separately, the effects of the maximum potentialities of the land agricultural policy and the water agricultural policy, at the moment, we only consider in this scenario the general optimistic trends for this second aspect.

This means for the irrigated land the general trend in the growth rate of the table of Figure 8.19. and, with respect to the cropping intensity for irrigated land, which is the other factor related with this aspect, it can be assumed, from the same literature sources, that is growing, in a linear tendency, to the half of this potential maximum value. In the next section we will come back, with more details, to all these points.

Figure 8.22.: LaP Agricultural Scenario Data Table

VARIABLE LONG NAME	VARIABLE SHORT NAME	DATA VALUE	COMMENTS
Agricultural Land	Agland	Country data from section 8.3.	(1) Arable and permanent cropland
Agricultural Land Rate	Ragland	Country data from Figure 8.22.	
Agricultural Land Irrigated	Aglandir	Country data from section 8.3.	
Agriculture Land Irrigated Rate	Raglandir	1,4	Constant
Agricultural Land Non Irrigated (or rainfed)	Aglandnir	Compute	
Calorie Yield	Calyld	2800Kcal/Kg	See section 8.2.1.
Yield Land Non Irrigated	Yldpnir	1300Kg/He	See section 8.2.1.
Yield Land Non Irrigated Rate	Ryldpnir	1,4	Constant
Yield Land Irrigated	Yldpir	2400Kg/He	(2)
Yield Land Irrigated Rate	Ryldpir	1,6	Constant
Cropping Intensity Non Irrigated Land Coefficient	Kcrintnir	0,55	(3); to 0,77 linear
Cropping Intensity Irrigated Land Coefficient	Kcrintir	0,75	(3); to 0,975 linear

Again we are ready to use GLOBESIGHT and to show the results in the subsequent Figures and, in the following sub section, discussing the corresponding remarks/conclusions.

Figure 8.23.

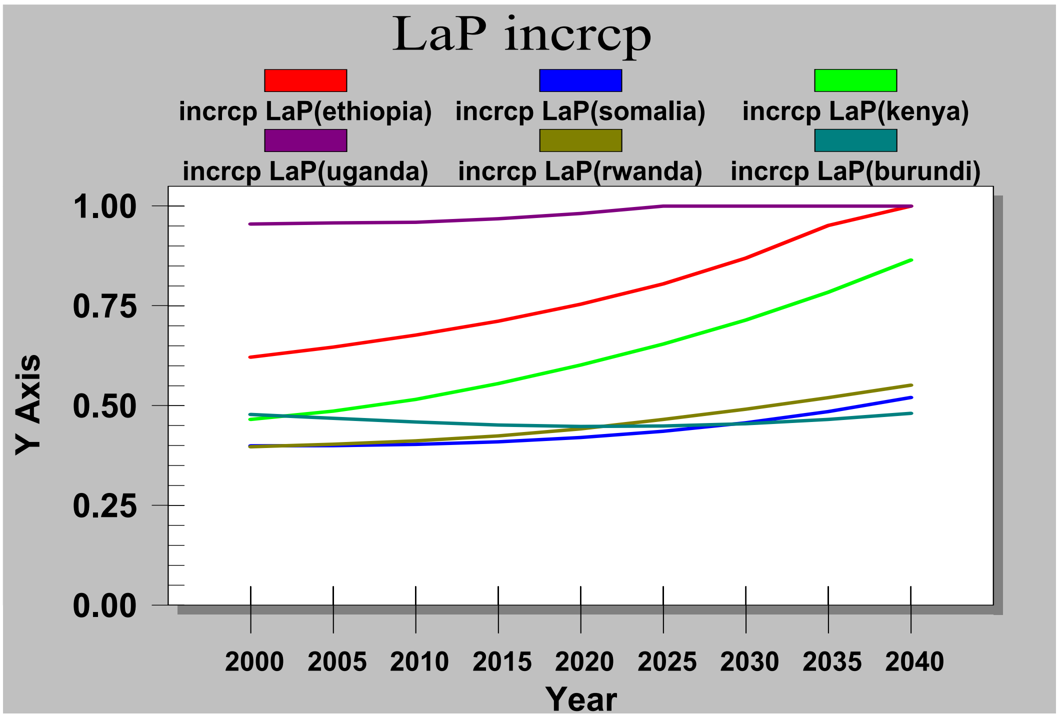


Figure 8.24.

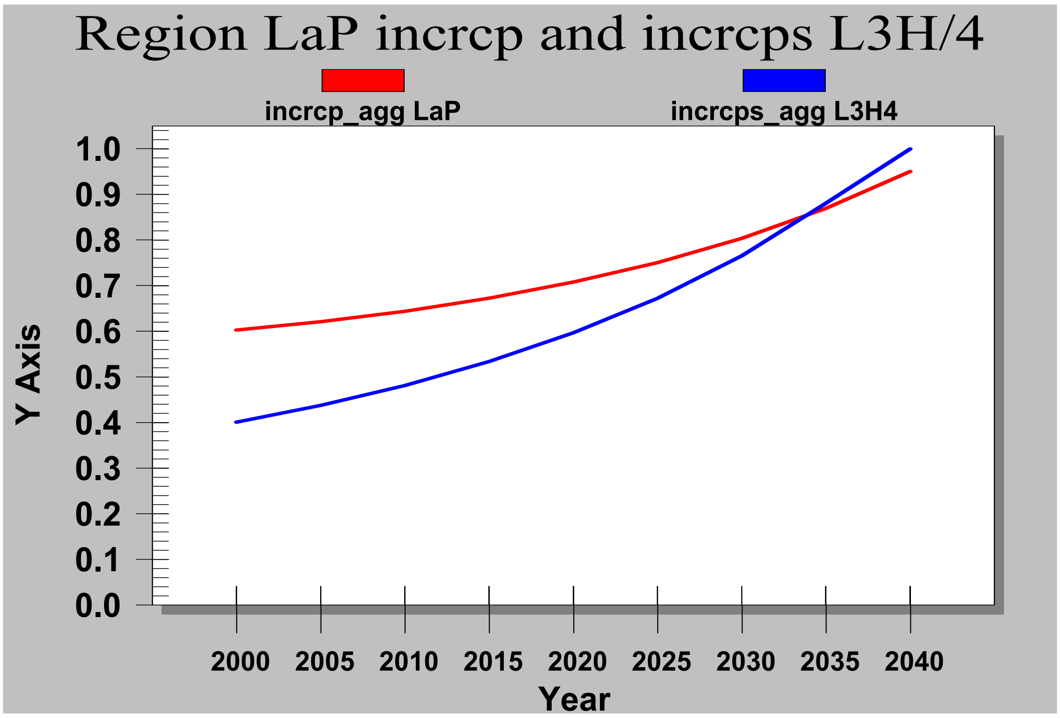
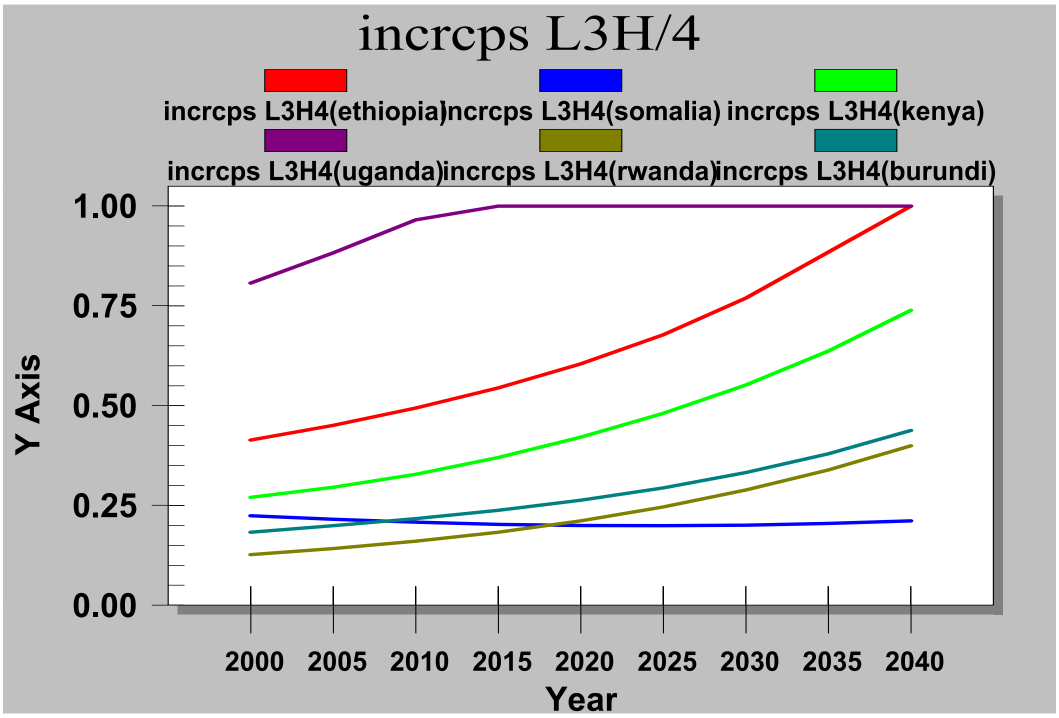


Figure 8.25.


incrcps L3H/4
incrcps L3H4(ethiopia)
incrcps L3H4(somalia)
incrcps L3H4(kenya)
incrcps L3H4(uganda)
incrcps L3H4(rwanda)
incrcps L3H4(burundi)
Y Axis
1.00
0.75
0.50
0.25
0.00
2000
2005
2010
2015
2020
2025
2030
2035
2040
Year

8.6.4. REMARKS AND CONCLUSIONS

Although the situation is clearly dramatic we have identified policies and that could have, finally, some important effect.

At least for Uganda, Ethiopia and Kenya the potential possibilities to use more land for agricultural purposes seems to be a real challenge for their future. We can see in Figure 8.23. one important change in the pattern of the carrying capacity index of these countries that, indeed for some of them, lead us near to food self-support. The necessary effort is, however, unbelievable.

Other countries (Rwanda, Burundi, Somalia), seems to be condemned to suffer the big problem of not achieving food self-security. Specially for Rwanda and Burundi which are using almost the entire potential land that they have. For Somalia, it is simply because of its poverty.

The case study region as a whole follows, obviously, the same "direction" that the larger countries of the region take. See Figure 8.24.

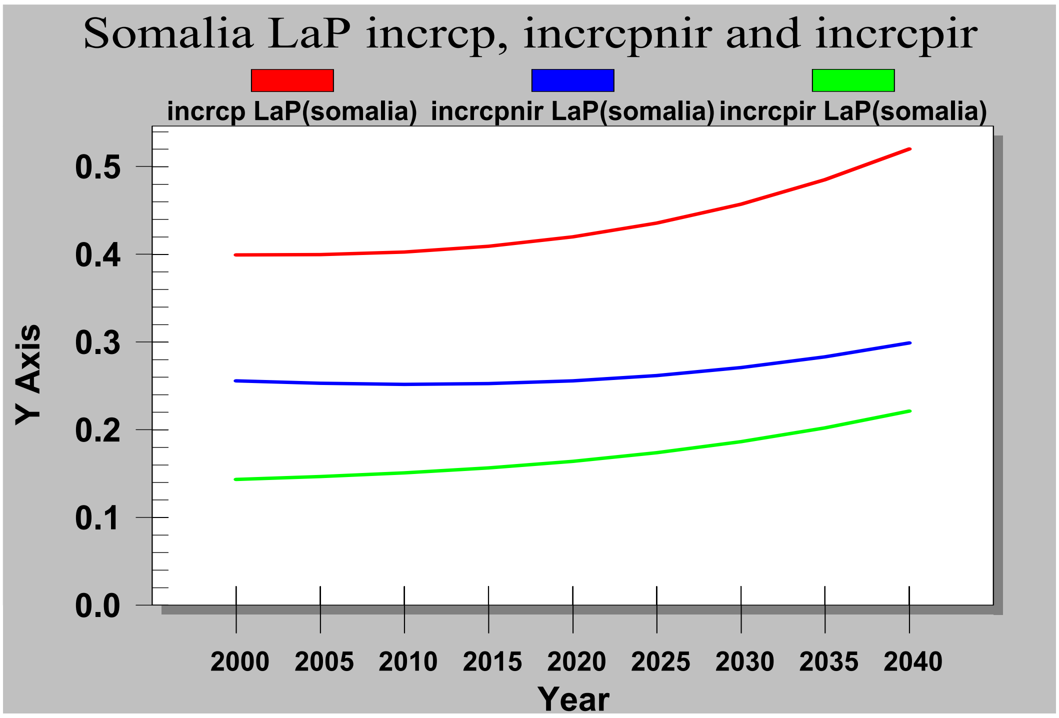
We will also come back to these conclusions later.

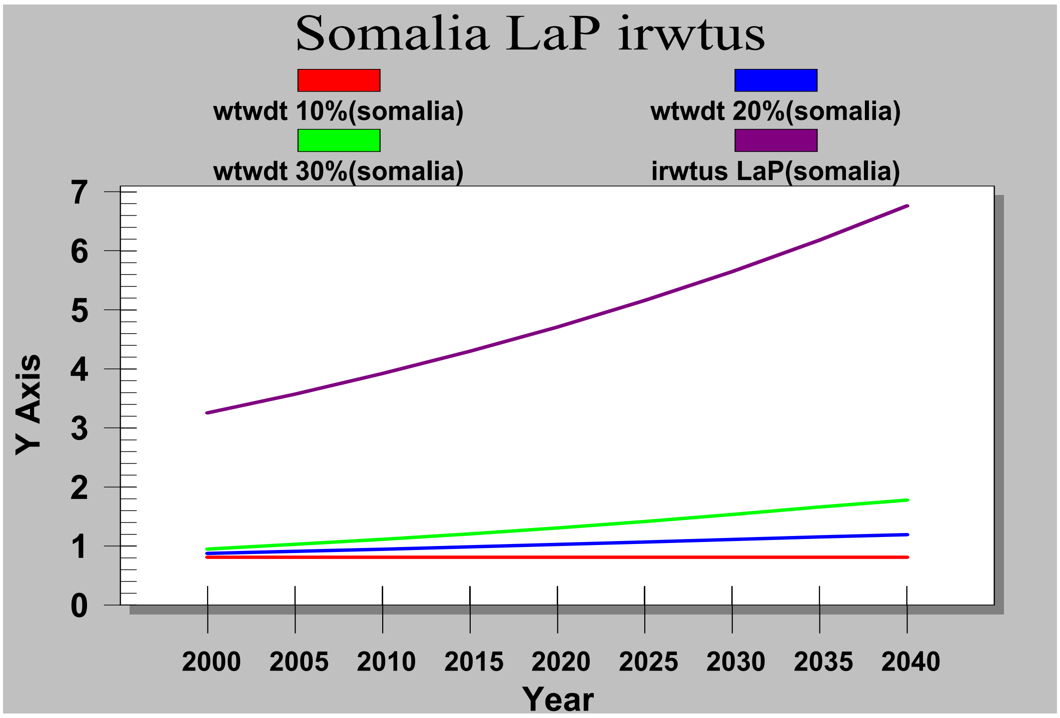
But again a new check of the validation of our methodology, models and, in general, data and procedure is a clear result of the comparison of Figures 8.23.-25.

The patterns, the order of magnitude and, specially again, the order of the country problematique are so similar from the point of view of our first (now, logically, is the scenario L(3H/4) that is comparable) and second level models.

Particularly speaking, the main difference between the results of the two level models are a significant difference in the pattern of Somalia scenarios in this two levels models. But the following Figures 8.26. show that we can not have in Somalia, at our disposition, the water that we need in order to achieve this LaP scenario (we will have a detailed explanation of this aspect in the next section 8.7.1.).

Figures 8.26.


Somalia LaP incrcp, incrcpnir and incrcpir
incrcp LaP(somalia)
incrcpnir LaP(somalia)
incrcpir LaP(somalia)
Y Axis
0.0
0.1
0.2
0.3
0.4
0.5
2000
2005
2010
2015
2020
2025
2030
2035
2040
Year


Somalia LaP irwtus
wtwdt 10%(somalia)
wtwdt 20%(somalia)
wtwdt 30%(somalia)
irwtus LaP(somalia)
Y Axis
0
1
2
3
4
5
6
7
2000
2005
2010
2015
2020
2025
2030
2035
2040
Year

After these particular explanations of consistency, practically we do not need to add anything really new except to emphasize the remarks/conclusions of the sections before on the validation aspects of the second level model and, now, about the power of our methodology of hierarchical approach to our issues that, for example, allows us to detect, quickly and efficiently, the non feasibility of our assumptions/results in our scenarios.

8.7. THE WATER OPTIMISTIC POTENTIAL, WaP, SCENARIO

8.7.1. POTENTIAL EXPANDING IRRIGATION: CONSTRAINT OR CHALLENGE?

Following the line which is started in sections 8.6.1. and 8.6.3. and, because we really want to see, separately, the effects of the maximum potentialities of the land agricultural policy and the water agricultural policy, we will now consider the maximum potentialities of this last water agricultural policy.

This is another of the controversial aspects of our agriculture issue. Indeed data are the most ambiguous or contradictory.

But again as mentioned before, irrigation is clearly the best way that we know for improving the yields of land, directly, and indirectly through the improvement in cropping intensity.

But also there are several constraints when we want to implement this.

First of all the cost of investments in the necessary infrastructures. But we have decided not to take this into account in our study, because if this is feasible, it is one of the most sustainable way to solve our problematique. This is true if we really internalize the real costs of all other kind of solution and/or not solution.

Furthermore in our countries, which lands are mostly semi-arid and arid, the quantity of water that we need, by comparison with the same level of primary normal irrigation, is obviously bigger than for example in Europe. As a magnitude of order, in Europe we use 5000 cubic meters of water per year for irrigating one hectare of land, whereas in our countries on average we need 20000 cubic meters. In all the situations, the investments in new methodologies and technologies should be grateful.

In terms of the annual renewable water resources, all of our countries are (remember chapter 7) in a very scarcity situation, This will be worst each day because of the increasing population.

Thus, it seems that irrigation is not a possible driver alternative to avoid the problematique.

But in chapter 7, and always if we put the sustainable general point of view in front of all the others, we focus on the subject from a challenging approach. Due to the under development, in general, the water withdrawal for these countries is really small (and smaller than many countries in the world) by comparison with their renewable resources. The resources could be scarce but, at least, we must use it. If we remember the discussions and the results of chapter 7 we can conclude that we can affront this point as a challenge in order to withdraw until, may be, a 20% of total renewable water resources

So we take this potential position (could be the 30% but we think that it is too optimistic). We assume clearly that, on average, we will need 20000 cubic meters per year for irrigating one hectare of land, and then we can compute the potential amount of land for irrigation. We also need to take another hyphotesis on the cropping intensity which obviously, is also related with the total water used. We assume, logically, the potential position that was showed in the table of Figure 8.21. In summary the key driver relationship will be the following:

aglandir = irwtus / kcrintir * kirwthc

where it is obvious that

kirwthc

for our countries is on average 20000 cubic meter per year per hectare, and

irwtus

is the water withdrawal that can be used for irrigation (the 20% of total renewable water resources -see chapter 7).

We would like to note that this is a notable different approach than the usual and as a reality. For example if we look at the date on cubic meter per year per hectare irrigated (section 8.3), we can see enormous differences between countries on this number. Usually they use the water that is easiest available to them, sometimes in a very inefficient way. We try, always, to compute the general potential challenge.

With the assumptions and the relationship explained and the data that we have in two points of this study (chapter 7 and section 8.3) we can build the following table of Figure 8.27..

As usual, Somalia is a particular country with a lot of contradictions between the data that we have and, basically, with the ones we do not have. So we decided again to follow some consistent path with the other countries and use the general information that we have. In fact this only means that we have decided "to do mathematically compatible" the data that we have from the literature with its unfeasibility, in agreement with the last discussion of section 8.6.4.. There, for computing the scenario results of Figures 8.26., we have used the equation and the assumptions of this section. The results were not feasible in the sense that the water used for irrigation was finally bigger than all the renewable water resources of Somalia.

Figure 8.27.

	AGLANDIR 1990	AGLANDIR POTENTIAL	CONSTANT RATE IN A 50 YEARS PERIOD
ETHIOPIA	190	1331	4,0
SOMALIA	180	73	-1,8
KENYA	60	244	2,85
UGANDA	9	471	8,25
RWANDA	4	76	6,1
BURUNDI	14	43,5	2,3
REGION	457	2238,5	3,2

8.7.2. THE WaP SCENARIO

We have just finished showing that in our stressful case study region, two countries, Uganda and Rwanda, have a major potentiality than the Sub-Saharan Africa region as a whole (the potential 5,2% rate of table of Figure 8.20.). But as an aggregate region and in the other countries the potentialities are minor than this more general potential.

But in difference what happened with the country to country potentialities of land, now the potentialities for water policy are always, except for Somalia, bigger than the general trends of Sub Saharan Africa region as a whole, according to the comparison between the tables of the Figures 8.19. and 8.27..

So now, as a last step of our study and following exactly the same procedure in the section before, we decided to build a new scenario that will reproduce all the particular potentialities of the countries of our case study region, according to the table of the Figure before, which is called the Water Potential Scenario, WaP, because it will show us the real maximum potential specific country to country possibilities, from this water agricultural policy point of view.

Again the table database that includes all the characteristics of this new WaP scenario is in the following Figure 8.28.. In the direction to represent the total maximum potential of agricultural water, we have mentioned that we will also assume the potential cropping intensity for the irrigated land, in agreement with the references cited.

We should notice that, finally, with this next and last step of our study we are determining the real potential of these countries as a maximum food self-supporting that they can achieve.

Figure 8.28.: WaP Agricultural Scenario Data Table

VARIABLE LONG NAME	VARIABLE SHORT NAME	DATA VALUE	COMMENTS
Agricultural Land	Agland	Country data from section 8.3.	(1) Arable and permanent cropland
Agricultural Land Rate	Ragland	Country data from Figure 8.22.	
Agricultural Land Irrigated	Aglandir	Country data from section 8.3.	
Agriculture Land Irrigated Rate	Raglandir	Country data form Figure 8.28.	
Agricultural Land Non Irrigated (or rainfed)	Aglandnir	Compute	
Calorie Yield	Calyld	2800Kcal/Kg	See section 8.2.1.
Yield Land Non Irrigated	Yldpnir	1300Kg/He	See section 8.2.1.
Yield Land Non Irrigated Rate	Ryldpnir	1,4	Constant
Yield Land Irrigated	Yldpir	2400Kg/He	(2)
Yield Land Irrigated Rate	Ryldpir	1,6	Constant
Cropping Intensity Non Irrigated Land Coefficient	Kcrintnir	0,55	(3); to 0,77 linear
Cropping Intensity Irrigated Land Coefficient	Kcrintir	0,75	(3); to 1,25 linear

Again we use GLOBESIGHT and show the results in the subsequent Figures and we will discuss the corresponding remarks/conclusions.

Figure 8.29.

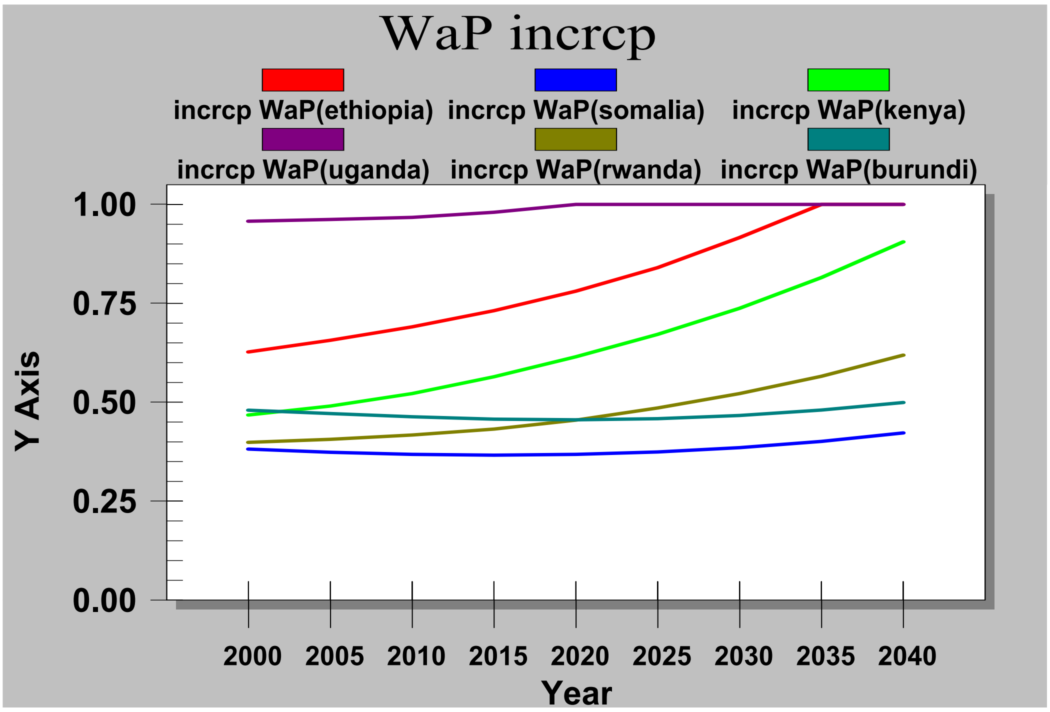


Figure 8.30.

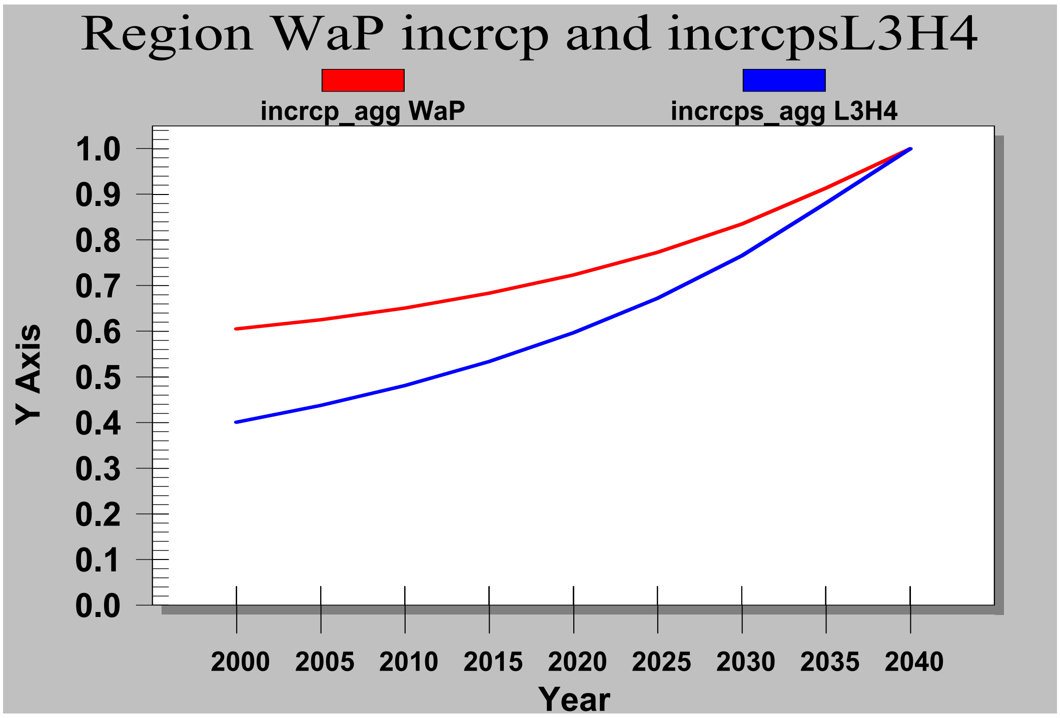
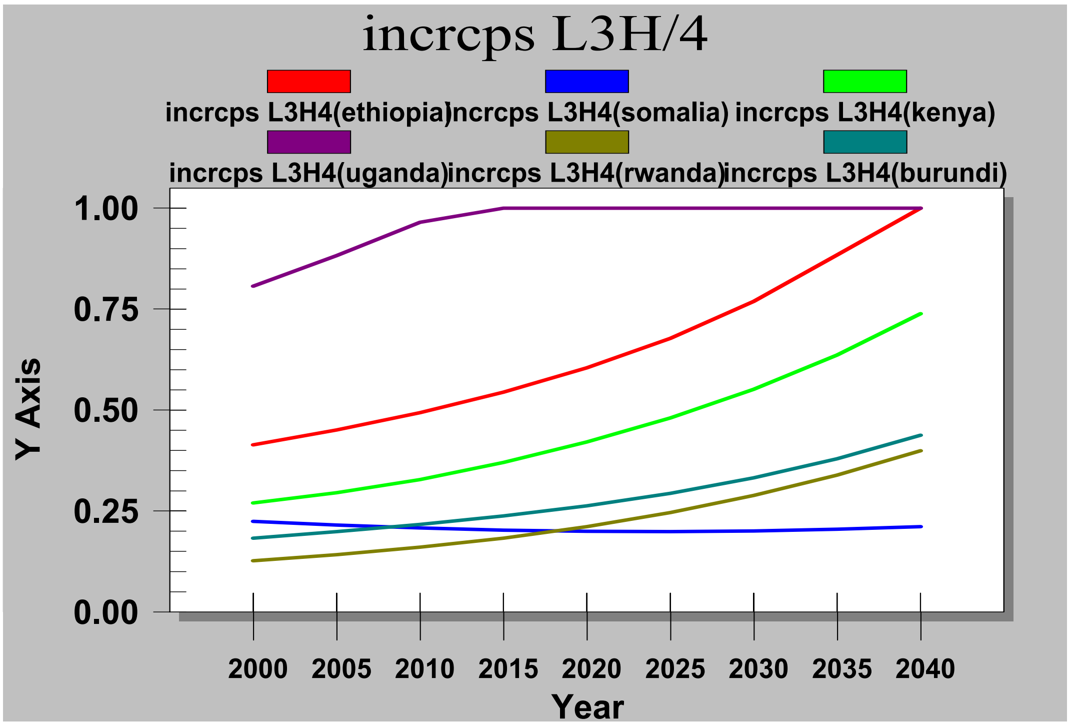


Figure 8.31.



As a first remark/conclusion we can write exactly the same as in the section before. The water potential policies allow the countries to give another significant step in the direction that is defined for the land potential policies.

For Uganda, Ethiopia and Kenya the potential possibilities to use more land and more water for agricultural proposal seems to be a real challenge for their future.

The other countries (Rwanda, Burundi, Somalia), seems finally to be condemned, again and definitively, to suffer the big problem of being unable to be food self-security. In fact the effects of water policies are only remarkable for Rwanda because it is using really a very small percentage of its renewable water resources.

In fact the main new conclusion of this scenario could be achieved comparing with the scenario before, and asking ourselves about the significant of the water potential policies related with the land potential policies. See the following Figures.

Figure 8.32.

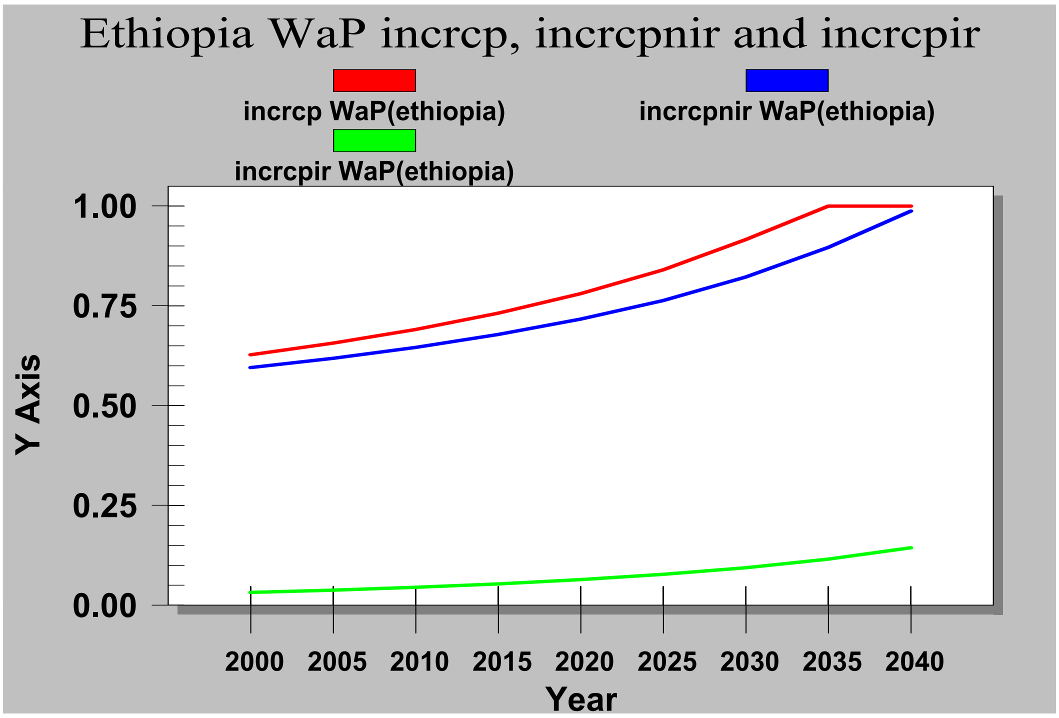
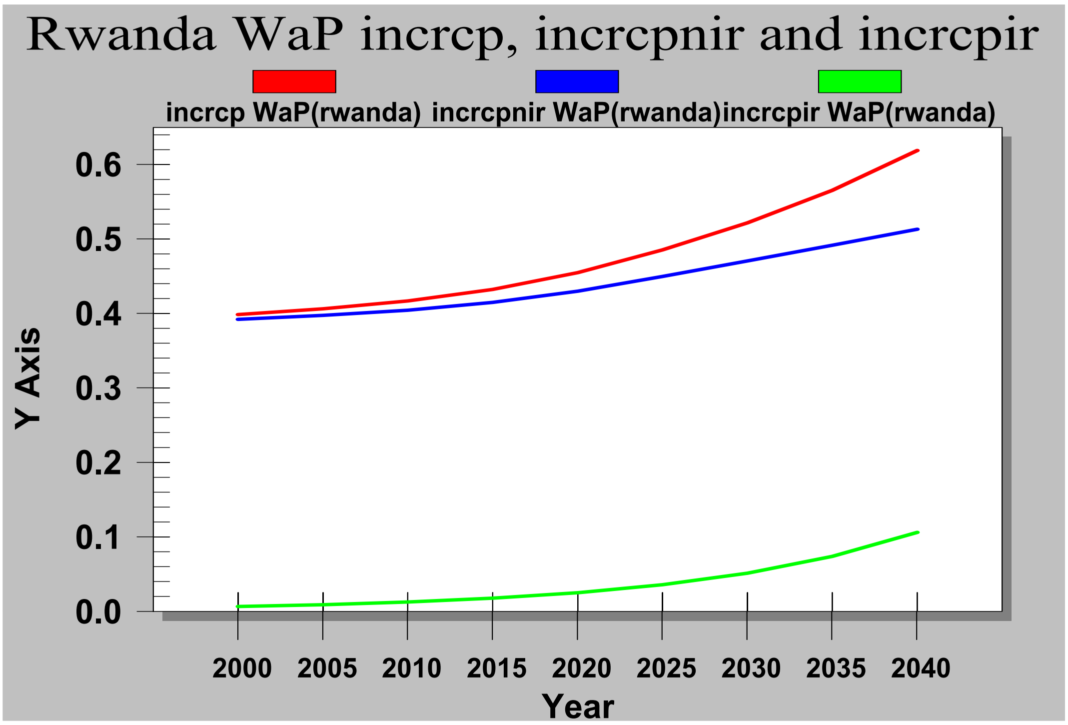


Figure 8.33.



These Figures show, respectively, the results for the two countries (leaving Uganda in a separate position) of the region in which the results of the water policies are more significant. Once they have arrived to their maximum land potential, the maximum water policy means an improvement between, approximately, 12,5% (Ethiopia) and 16% (Rwanda) with respect to the potentiality achieved with the land policies.

If we remember that the potentialities of land improvements was small in Rwanda and big in Ethiopia we can conclude, at this level of analysis, that water potential policies could be really relative significant, but may be not extremely in absolute point of view, in the countries of our case study region.

But this is really a rude conclusion because there are a lot of other aspects that we need to take into account in order to be precise about the real pondered weight of these two kind of policies. And in spite that this is not the goal of this study we want to note here that with our potential water policy we are going (according tables of Figures 8.21. and 8.27.) from 1,6 % to 4,2% of irrigated land in Ethiopia and from 0,35% to 5,85% of irrigated land in Rwanda. And these levels the percentages of irrigated food are absolutely in agreement with the world tendency: 40% of food production from 16% of irrigated land).

8.8. COUNTRY TO COUNTRY UNDER THE LIGHT OF THE RESULTS OF ALL THE SCENARIOS

We have another possible perspective to show, finally, the main results of our study. Country to country we can show, together, our carrying capacity index for the country from the four scenarios that we have built and showed.

We should remember that with the WoT scenario (red color in the following Figures) we have represented the projection of the potential initial (1990) level of carrying capacity. With the **BaUo** scenario (blue color in the following Figures) we have represented the potentiality's that give us the yields improving. The LaP scenario (green color in the following Figures) represents the effects of the potential land policy. And the **WaP (**the brown color in the following Figures) represents the effects of the potential water policy.

Watching then these following Figures 8.35. to 8.41, we can remark country to country the following summary conclusions:

Ethiopia and finally the case study region as a whole has, in the maximum potential (sure utopic) perspective, the chance to be food self-supported. It is necessary, if it is really possible, to triple the land currently used now in Ethiopia.

Somalia, for whom the accurate scenario (in absence of more data) is really the WaP scenario, is finally, in practically all the scenarios, in the worst position of our problematique.

Kenya follow the directions of Ethiopia. Because the potential land is closer to the used than for Ethiopia, the effect of yields (BaUo) is most significant.

Uganda, with some appropriate agricultural policy is out of the problematique.

Rwanda has its chance in the water policy. It will always be a non food self-supporting country but at least it can improve.

Burundi is closer to Somalia with, remember chapter 6, population density as a deeper addition problem in the problematic.

Figure 8.34.: Ethiopia

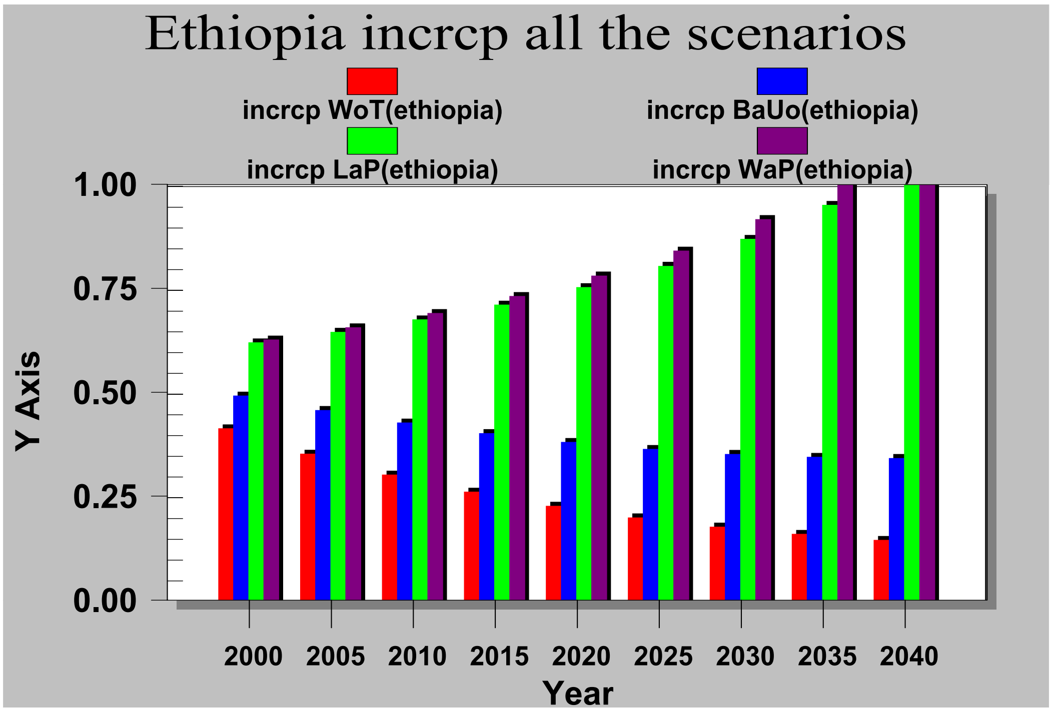


Figure 8.35.: Somalia

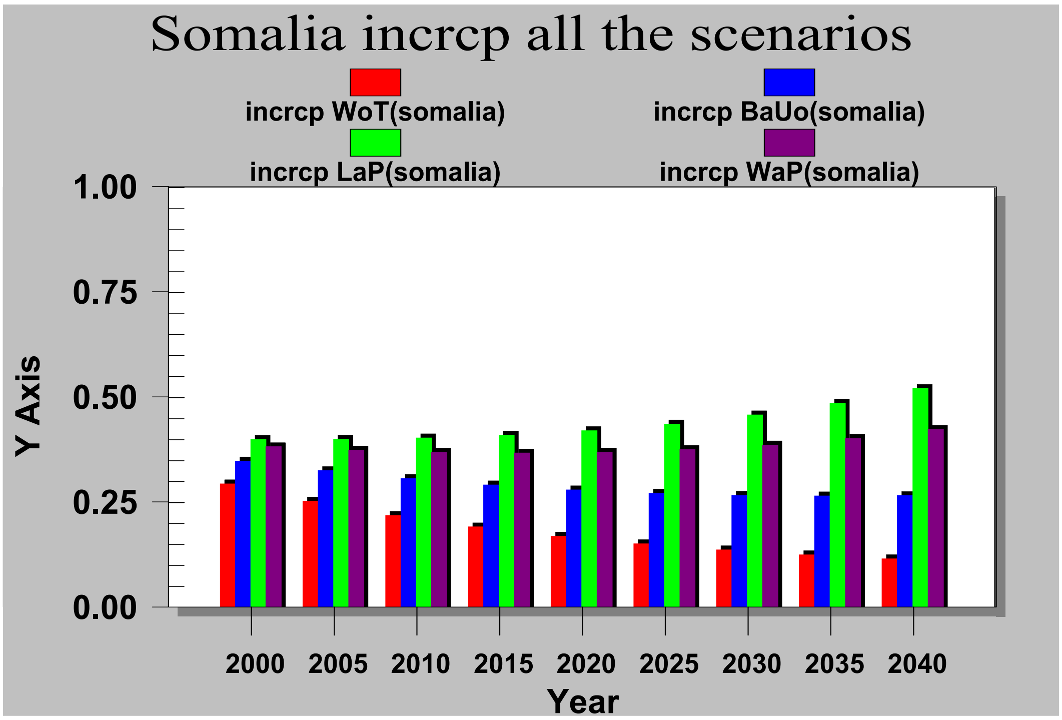


Figure 8.36.: Kenya

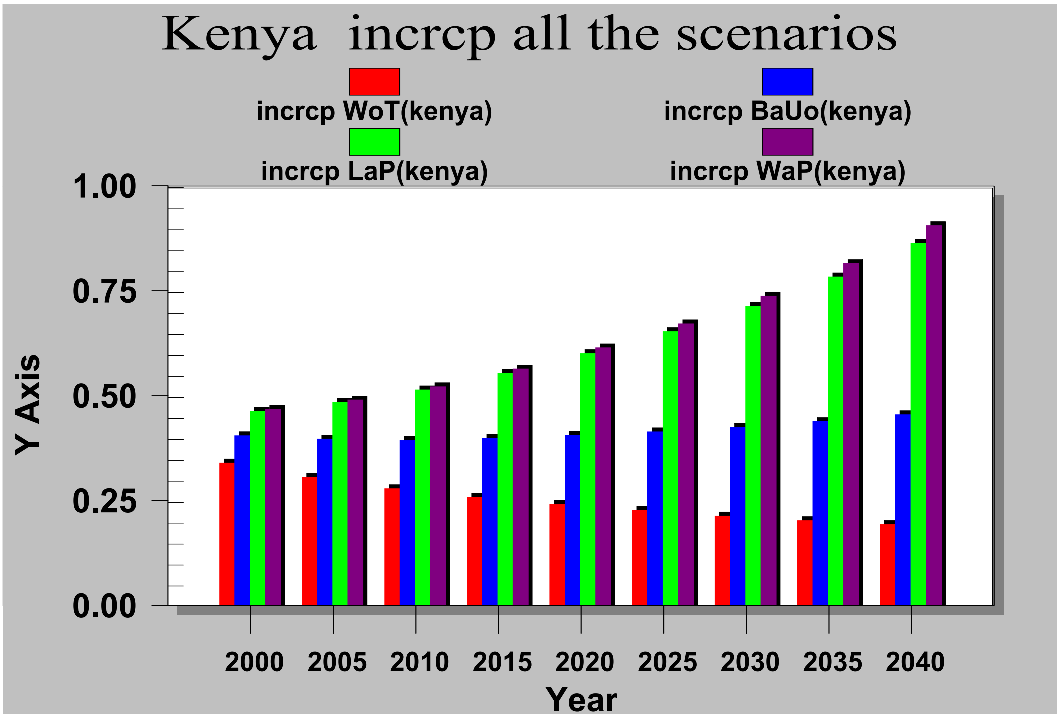


Figure 8.37.: Uganda

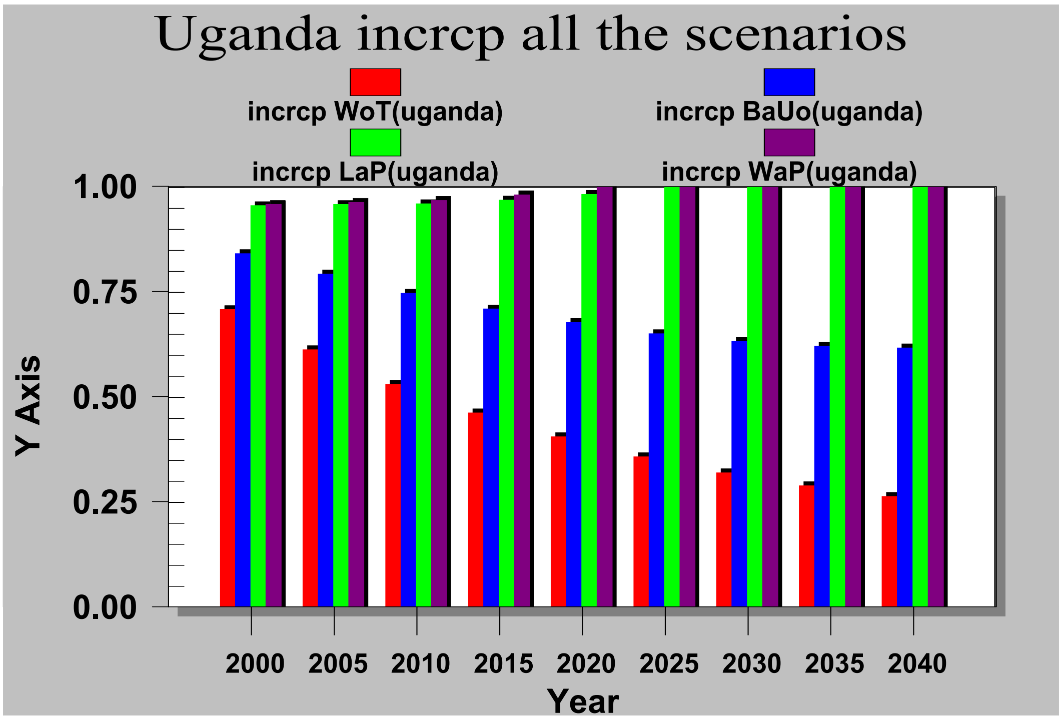


Figure 8.38.: Rwanda

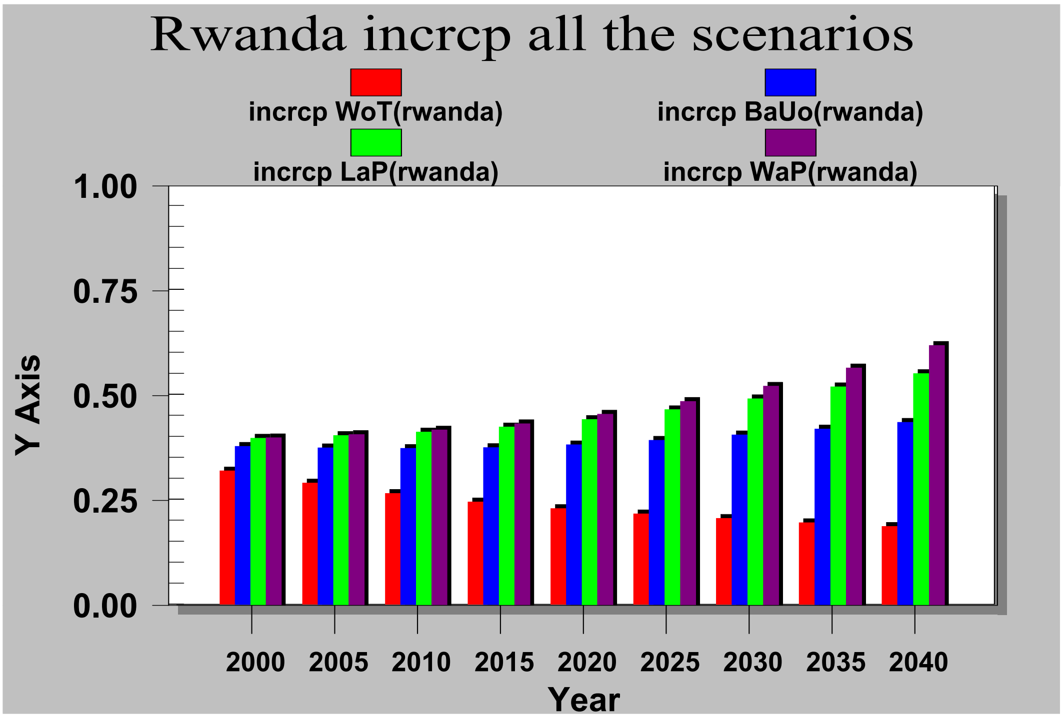


Figure 8.39.: Burundi

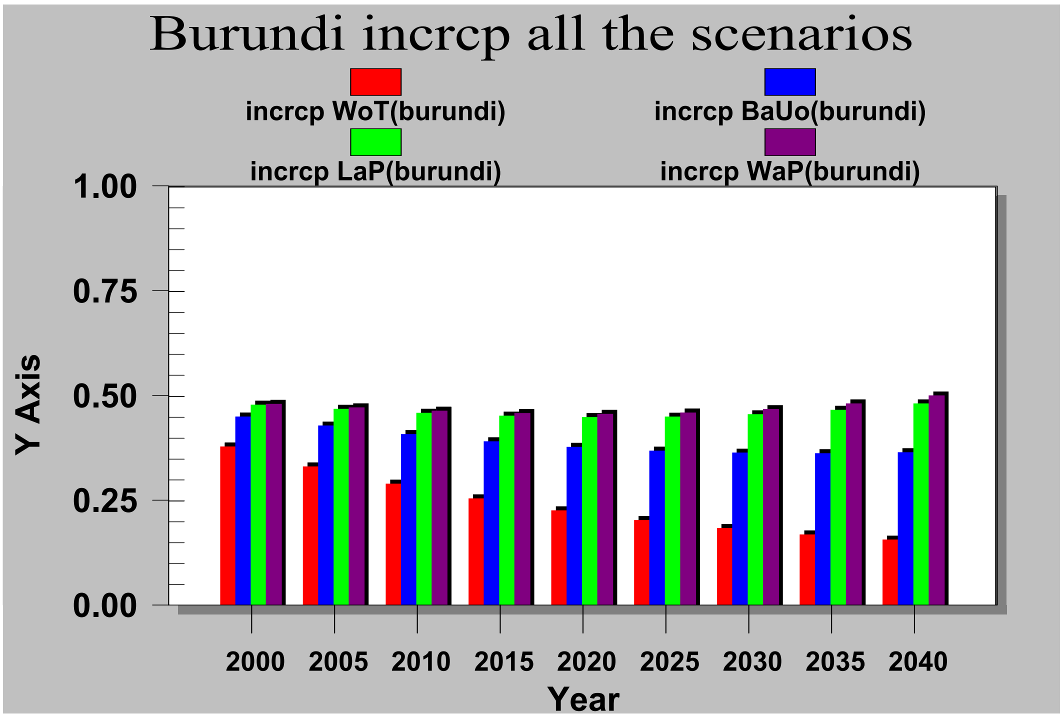
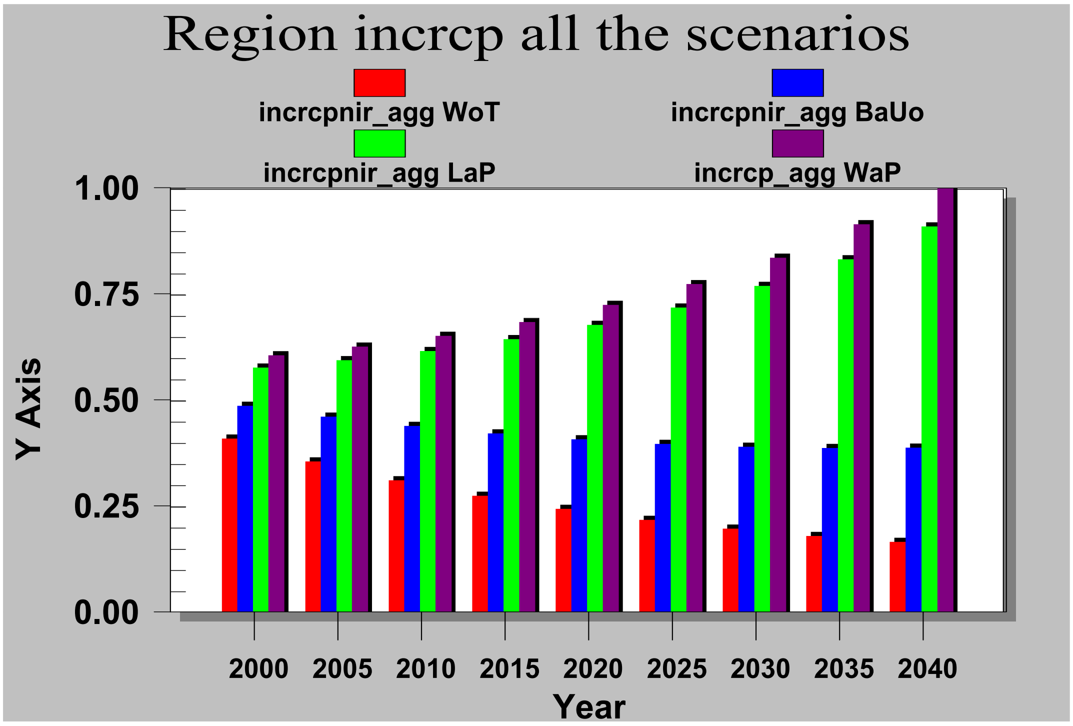


Figure 8.40.: Case Study Region



8.8.1. FINAL REMARKS AND CONCLUSIONS

It is clear that practically we can repeat here the entire list of remarks and conclusions that we have written scenario by scenario.

But here with the emphasis that we now facing, on time, the maximum or indeed the ideal or utopic possibilities that these countries have from their own land and water resources, using the actual technologies that are used in the "developed" world. The last part of the affirmation comes after we identify the results of the LaP and WaP scenario with some close level to the high input level about the FAO/IIASA/UN report.

Because of this, we should alert definitively, clearly and with rotundity, that the increasing population in these countries, and in spite of the best feasible possible policies in agricultural and water resources, will bring these countries towards extreme difficulties and a very stressful situation, similar to what Rwanda had experience in the 90's (remember the last discussion in chapter 6).

When we add to this conclusion the real political, economical and social situation of the region we must write with the same rotundity that if there is not a very important international intervention, what we have mentioned in the last paragraph will definitely be realized.

This is definitely true, from our present knowledge and perspective, for Somalia, Burundi and Rwanda. Uganda is the country that has more own possibilities "to exit this limit situation" and can play a role of a "good neighbor" for Burundi and Rwanda. And Ethiopia and Kenya are in the middle situation, although still problematic, but for sure they can represent one or other futures for the entire region.

The strong emphasis that we are making is based on the potential (utopic, top, borderline) character of our study. Any step was done without chose always this perspective. So the final result is, without any doubt (from our present knowledge), utopic and pretty sure impossible to achieve in practical. Adding to this the long road that is necessary to follow to arrive at this "final", with a general permanent non food self-security situation, the emphasis is, from our point of view, absolutely justified.

8.9. FINAL REMARKS AND CONCLUSSIONS AROUND THE WHOLE STUDY

1. On the countries of our case study region

1.1. We first refer here to the conclusions in enough details and reiterate, basically, in this last chapter.

1.2. Secondly we want to emphasize that, essentially, bad experiences ought to be our best teachers. So we need to call the attention of the national and international institutions around the region. We know so that we can avoid that other 90‘s Rwanda’s will happen. We can rewrite here the sentence that is written in the section before:

We should alert definitively, clearly and with rotundity, that the increasing population in these countries, and in spite of the best feasible possible policies in agricultural and water resources, will bring these countries towards extreme difficulties and a very stressful situation, similar to what Rwanda had experience in the 90’s (remember the last discussion on the chapter 6).

When we add to this conclusion the real political, economical and social situation of the region we must write with the same rotundity that if there is not a very important international intervention, what we have mentioned in the last paragraph will definitely be realized.

The strong emphasis that we are making is based on the potential (utopic, top, borderline) character of our study. Any step was done without chose always this perspective. So the final result is, without any doubt (from our present knowledge), utopic and pretty sure impossible to achieve in practical. Adding to this the long road that is necessary to be followed to arrive at this “final”, with a general permanent non food self-security situation, the emphasis is, from our point of view, absolutely justified.

1.3. Concretely, the clearest challenge of the region in the direction to, at least, fight against the problematique is to start, immediately, expanding agricultural land policy. Unbelievably stopped in the 80’s and 90’s, this is, from the absolute point of view, the clearest possibility, as a policy and as an absolute result, that we have.

1.4. Furthermore in this obvious but important expansion land police, we need to improve a very important water police. This it is also essential from the point of view of domestic use for a growing population. From the agricultural point of view, relatively speaking it is also important because it means another contribution in the direction of food self-supporting. Absolutely speaking but, it should be necessary to analyze which is the best way to use the water in agricultural, whether in intensive irrigation (our classical approach) or in supporting rainfed water when it is scarce (often in our countries), because if not it could be impossible to achieve, indeed even with biotechnology, the yields that we need and expect to obtain in order to really contribute to support food population necessities.

1.5. Specifically the data tables of the Figures 8.21. and 8.27. ought to be the main targets of the national and international policy-makers in order to develop, from a sustainable local view in a global approach, the next investments in the area.

1.6. These conclusions, basically from this chapter 8, are fully consistent with the first general conclusions of the chapter 6. But now we really know, country by country, where exactly are the problems and what are the possible targets in order to improve them. See, for example, the remark before.

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2. On the FAO/IIASA/UN report

2.1. An excellent and absolutely a life reference in our issue. A wonderful job with many points of very good general and concrete approach.

2.2. The high input level of potentialities should be revised, at least in the light of the region studied in this work -which should be significant in decreasing sense. Because even through biotechnology will achieve in this region the results that we expected from the green revolution (which were true in Asia but not in Africa), we are always in front of a top ‘developed” level under very opposite conditions. **This is also important because this high input level possibility of the report is often cited as the positive answer to the question of the future food self-sufficiency in the world. This is so relevant a point that, after our study, we believe that the results of this reference should be thoroughly revised because there are some important distance from the reality to this potential.**

2.3. Some additional remarks should be noticed to the last conclusion. The report included between others (remember chapter 6) the following assumptions, significantly different from our approach,: a) at all levels of inputs it assumes that the land available is the potential; b) it takes into account, not the standard FAO Daily, if not the country specific requirements; c) degradation (the opposite effect that we can have when human impact is stronger and the earth come back us some decreasing pattern factor). The point b) does not need more comments than we did in the earlier section 8.1.2.. At the opposite, if all that we have just mentioned in all this remark is that, and if point a) is true, then we think that, probably in agreement with the conclusions of the section 8.4 -the WoT scenario-, the general situation in 1990 in our case study region was really equivalent, technologically speaking, to the intermediate level of inputs of the FAO/IIASA/UN report. So, according to our first "vision" in chapter 6, we again have more consistency. The consequences of the point c) are so quantitatively irrelevant in the report, that we really think that it should be worse in reality.

2.4. The emphasize in this necessary revision of the high level of inputs remark, is coming, we would also like emphasizes this, from the junction of all this remarks 1 and 2. If in spite that our conclusion that the potential level of land and water agricultural policy is not achieved in practical, we see that the corresponding results are a little bit lower than the high level of inputs of FAO/IIASA/UN report, we do not need to add anything more.

2.5. After our work and these remarks, we think that the results of the report can never be used without a more detailed and concrete analysis even at the country level. In fact the report itself insist in this.

2.6. Separate to the other remarks is the following: the non-appropriate translation of the international data, studies and reports to the international and national decision-makers. This is already known. But this is the only explanation to the absolutely incorrect policy in Rwanda. We knew it but we did not do anything.

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3. On our Carrying Capacity Second Level Model, including the land and water aspects of the agricultural reality.

3.1. A very promising and future successful model that with not many subsequent developments could be an inestimable way to really approach towards, at the same time potential but concrete possibilities, the problematique of carrying capacity, in the directions and concretions of our study.

3.2. It finally has the properties that we wanted. Understandable, efficient and accurate, if the data are accurate, in a pluridisciplinary point of view and study.

3.3. It is probably proper in this section to do the summary of the main steps that are necessary to use the model for other countries-regions. Furthermore these steps represent the main results of our model work and should be presented as conclusions of the work.

3.3.1. To identify, section 8.2., **one equivalent cereal grain and its constant calorie yield (the most general mean value of this number in the region).**

3.3.2. To identify, section 8.2., **an initial (1990) potential yield productivity of the land for this equivalent cereal grain;** obviously the initial year is not any constraint.

3.3.3. To identify, appendix A.2., the regional trends/potentialities of the yields production and the cropping intensities.

3.3.4. To identify the general, but finally particular, trends and potentiality's of the land and water agricultural policies, "possible" in the region.

3.3.5. To use an appropriate methodology of analysis.

3.4. It is not a result, but definitively is another of the main goal and assumption of the study, that have allowed us to arrive at the other remarks and conclusion, and so we want to collect here explicitly: the conceptual and practical interest (even at the level of the decision makers) to take a sustainable development local approach in a global view framework to the carrying capacity issue; in other words the local potential approach to the food self-security of the countries-regions.

3.5. The sustainable approach should be completed with the inclusion, this is clearly one of the first complementary developments that is needed, of the "future solidarity". If we remember one of the definitions of carrying capacity as "*the maximal population size of a given species that an area can support without reducing its ability to support the same species in the* *future*", we can see that, because of the strong problematic of the region, we have put the maximum in a first relevant position. “Future solidarity”, i.e., not degradation, must be included in our model.

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4. On the global methodology

4.1. Continuing in the direction of the conclusion 3.3.5. is the complete methodology, **the integrated assessment with reasoning support tools**, that really allows us to build and to use in the way mentioned in our agricultural (land and water) model.

4.2. Especially, the interaction of the different level models (carrying capacity first level model in chapter 6 and carrying capacity second level model in chapter 8) in the hierarchical point of view is shown again to be extremely useful in order, not only to obtain results, if not in the development of the models that are necessary to obtain these results.

4.3. Extremely significant is the powerful of the last remark in the direction of the own validation of the models. We could remember to express the following partial remarks that we have written in the text:

> From the remarks and conclusions of section 8.5.1. on the WoT scenario:
>
> **This last remarkable aspect, together with the facts that the patterns (obvious) and the order of magnitude of the problematique (another important result), that we have from the two models, are so similar, allows us to say that the first and more more important conclusion of this comparison is the validation of the model that we have created. It could not be any luck that the combination of the real data of the countries and the region with some key driver equations and hyphotesis give us a result so similar to the results from the report from FAO/IIASA/UN. It is a validation, we insist, because the similarity of the results is not only the general order of magnitude but also the exact sequence of this order of magnitude for the countries of the region.**

> From the remarks and conclusions of section 8.5.4. on the LaP scenario:
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> **After these particular explanations of consistency, practically we do not need to add anything really new except to emphasize the**

remarks/conclusions of the sections before on the validation aspects of the second level model and, now, about the power of our methodology of hierarchical approach to our issues that, for example, allows us to detect, quickly and efficiently, the non feasibility of our assumptions/results in our scenarios.

4.4. Really take us off to a deeper comprehension of the complexities, uncertainties and pluridisciplinarieties of global earth/human issues.