A SIMPLE POPULATION MODEL

Harald Rybka, Jason Wong, Jorge Rivas
RISE (**R**esearch **I**nternship of **S**cience and **E**ngineering) Intern
Johannes Gutenberg University, Mainz
and University of Maryland
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OUTLINE

1. Introduction to VENSIM
2. Limits to Growth – World3 model

3. Basic New Model / Structure
4. Improved Basic Model
   - results – global

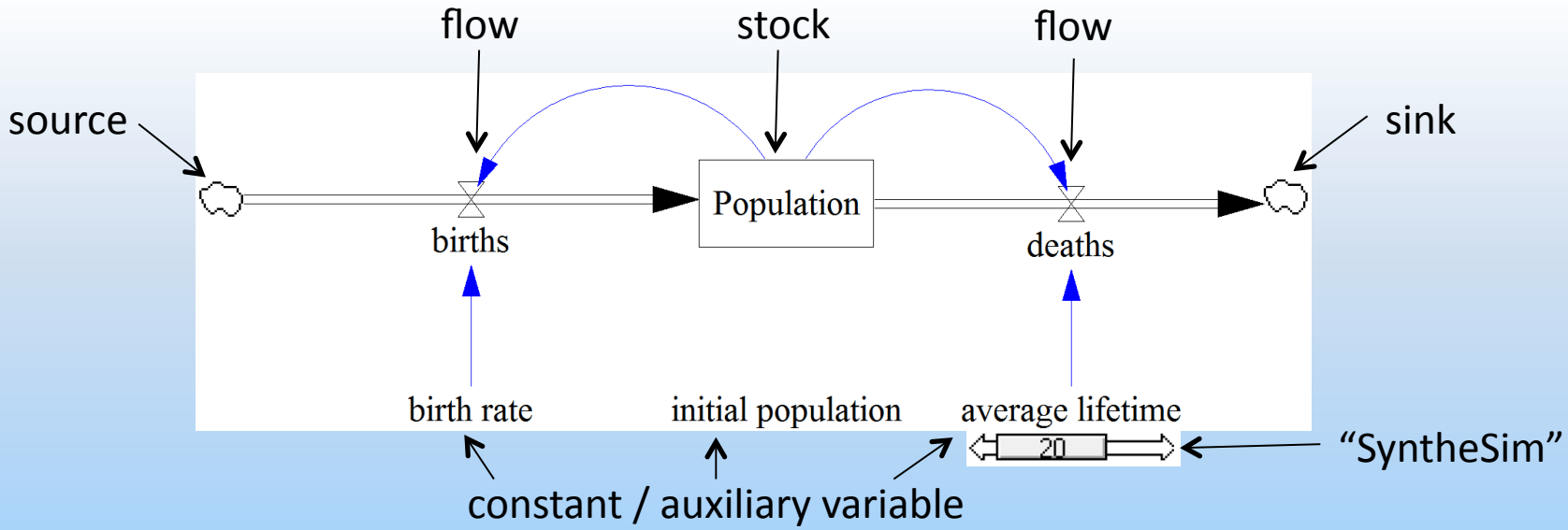
5. Improvements and Problems

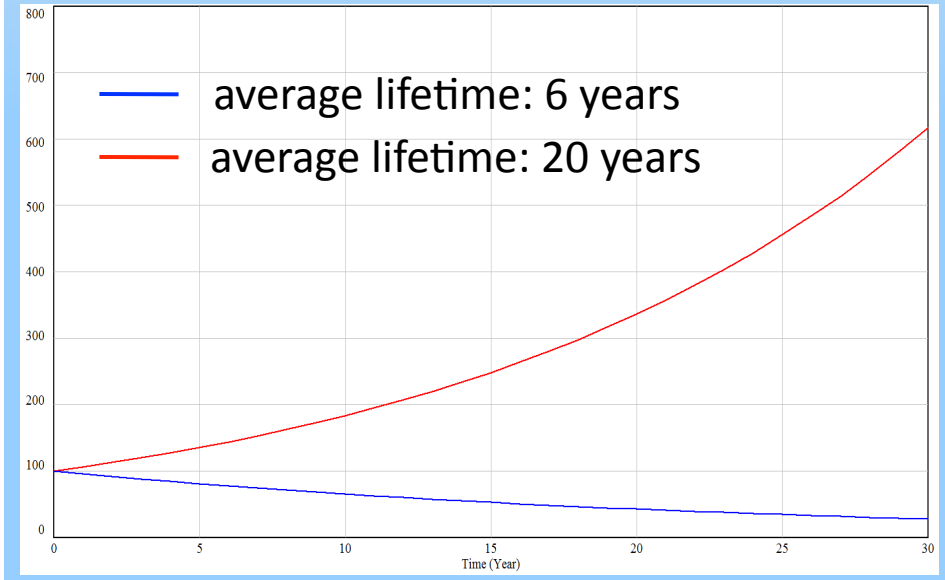
- VENSIM – simulation software
  - used for analyzing and simulating dynamic feedback modeling
  - identifying leverage points and causal loops
  - similar to “STELLA”

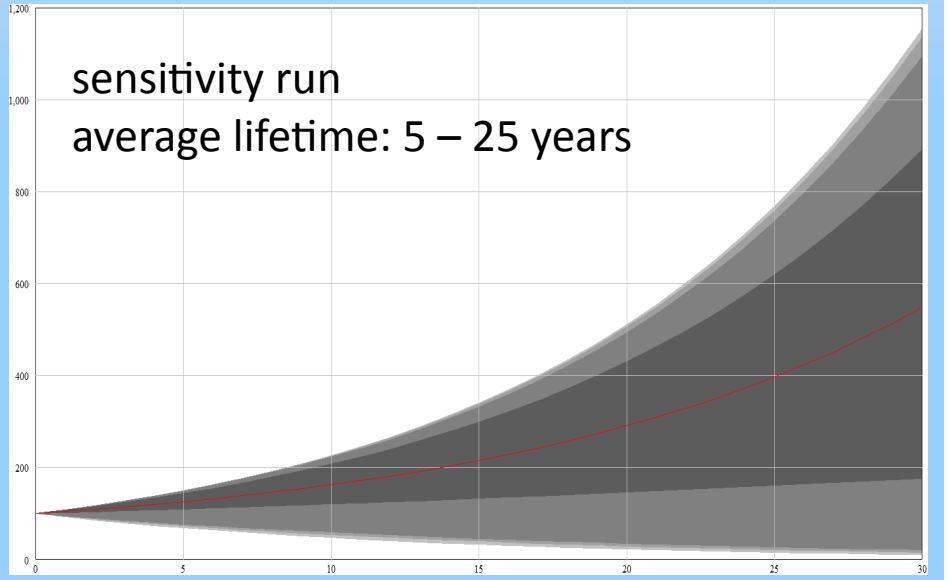
Results:

- use “SyntheSim” mode
- different effects can be simulated with sensitivity simulations

INTRODUCTION TO VENSIM — AN EXAMPLE



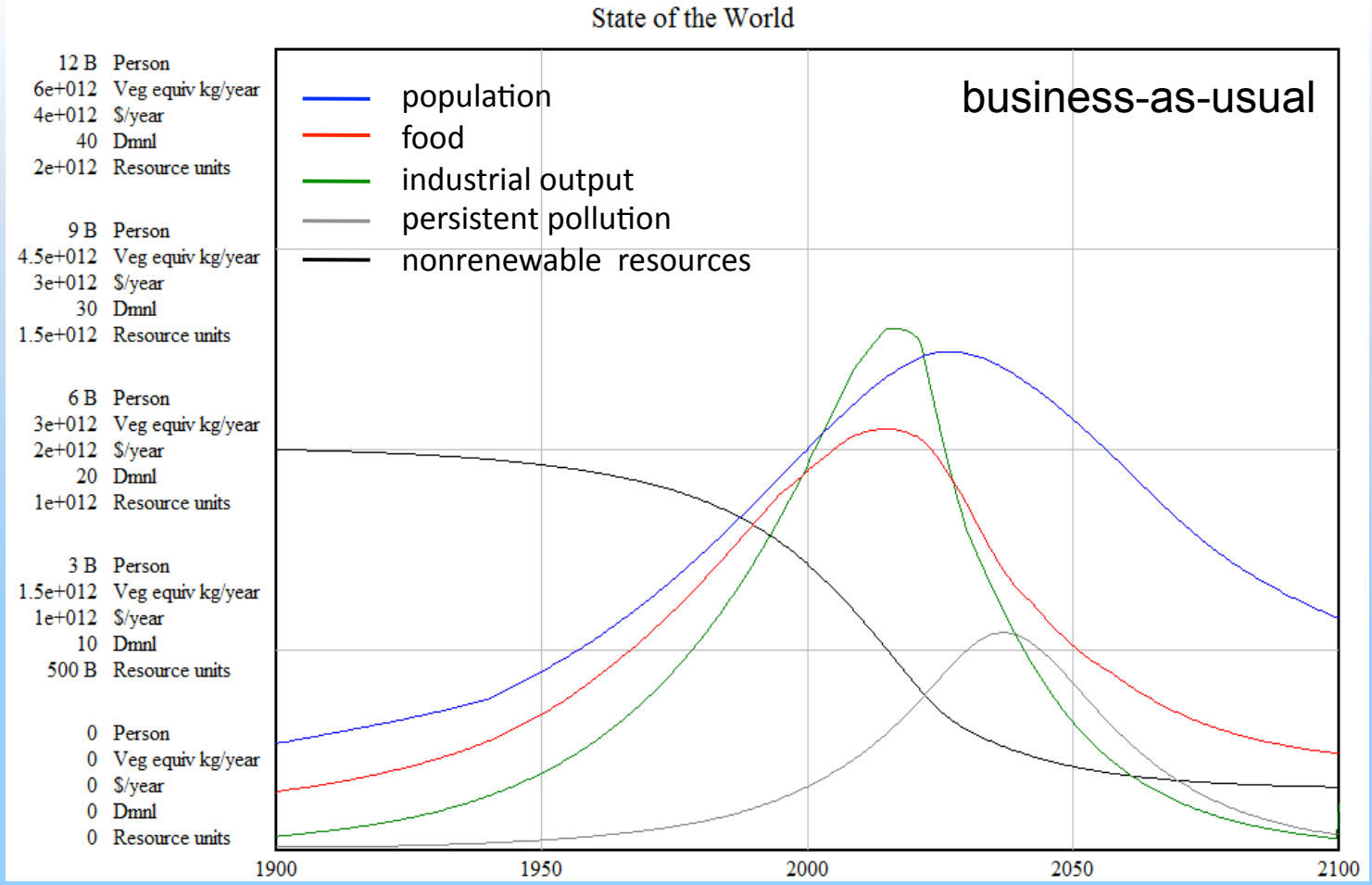




LIMITS TO GROWTH – WORLD3 MODEL

- created by Donella Meadows, Jørgen Randers, Dennis Meadows (authors of the book: Limits to Growth, 1972, 2004)
- computer simulation of interactions between:
  - the population system
  - the industrial system
  - the food system (agriculture and food production)
  - the non-renewable resources system and
  - the pollution system
- ten different scenarios present results from 1900 till 2100
- results varies from stabilization to collapse in the future
  - depending on several variables (e.g. nonrenewable resources)

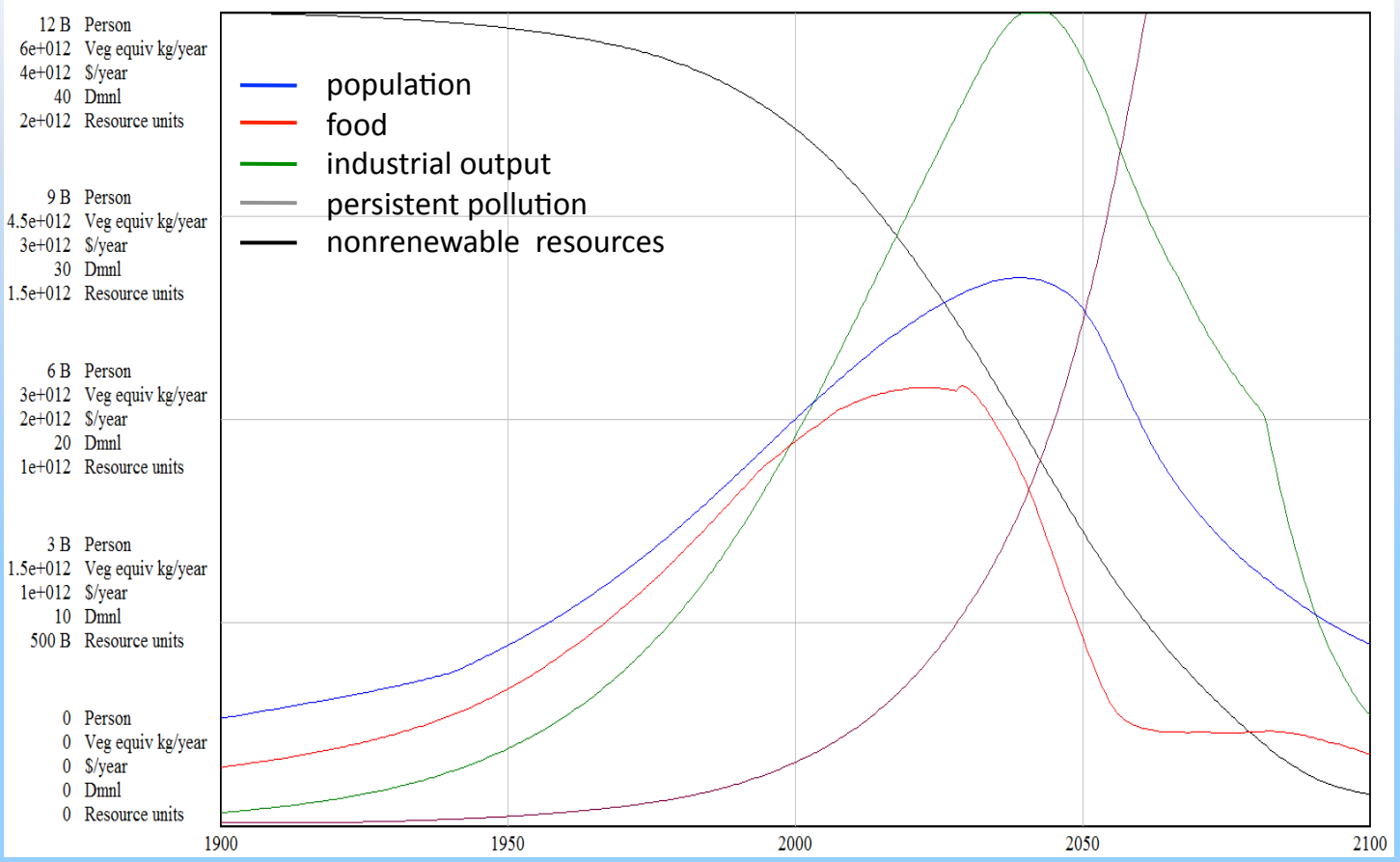
WORLD3 MODEL – STANDARD RUN: agrees with obs. 1970-2000 (Turner, 09)



population collapses because of
- decrease of food and health services
- increase costs of nonrenewable resources

WORLD3 MODEL – SCENARIO 2

doubled initial nonrenewable resources

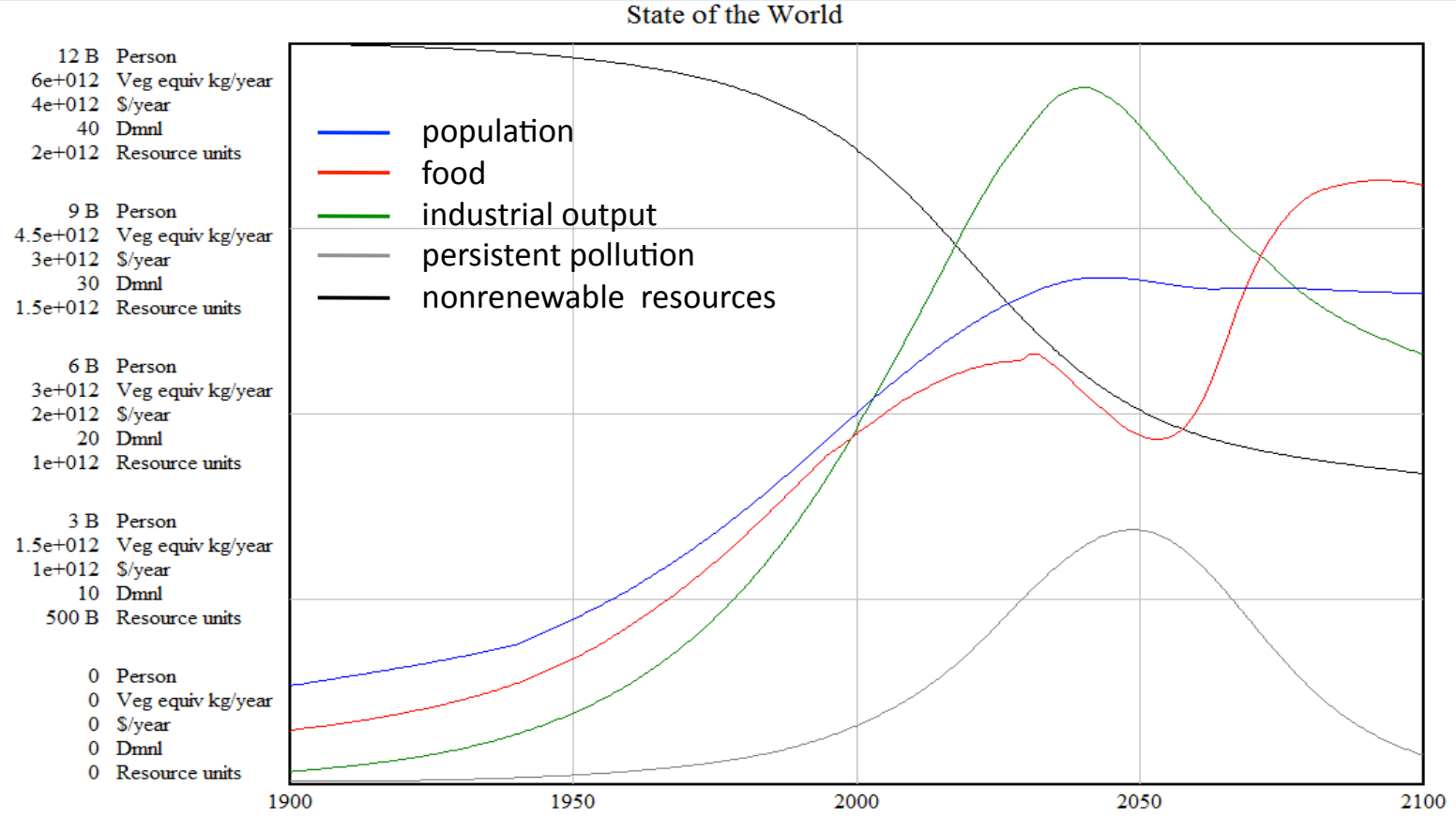


nevertheless: population collapses about 20 years later

WORLD3 MODEL – OPTIMISTIC (STABILIZED) SCENARIO

Compared to Standard Run:

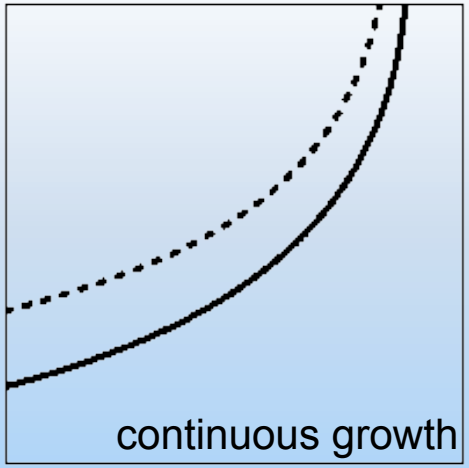
- doubled nonrenewable resources
- improved pollution control
- increase of land yield
- reduced land erosion

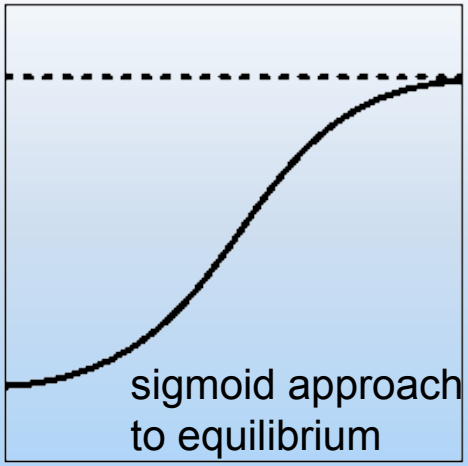


stabilized population with the right policies

WORLD3 – TYPES OF POSSIBLE SOLUTIONS

STABLE – no overshoot

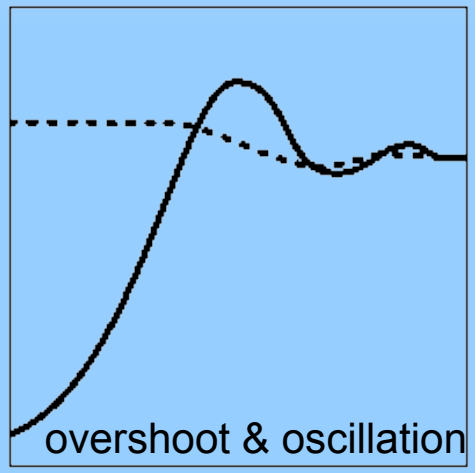


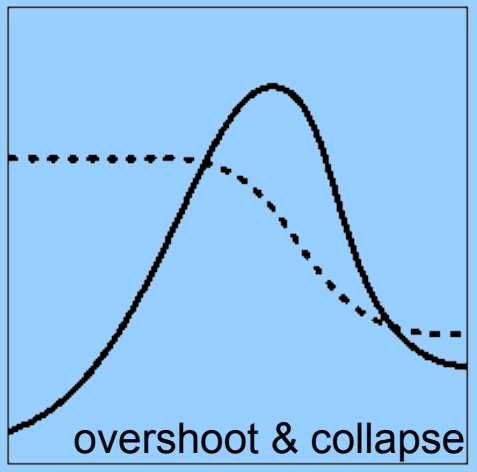


----- carrying capacity

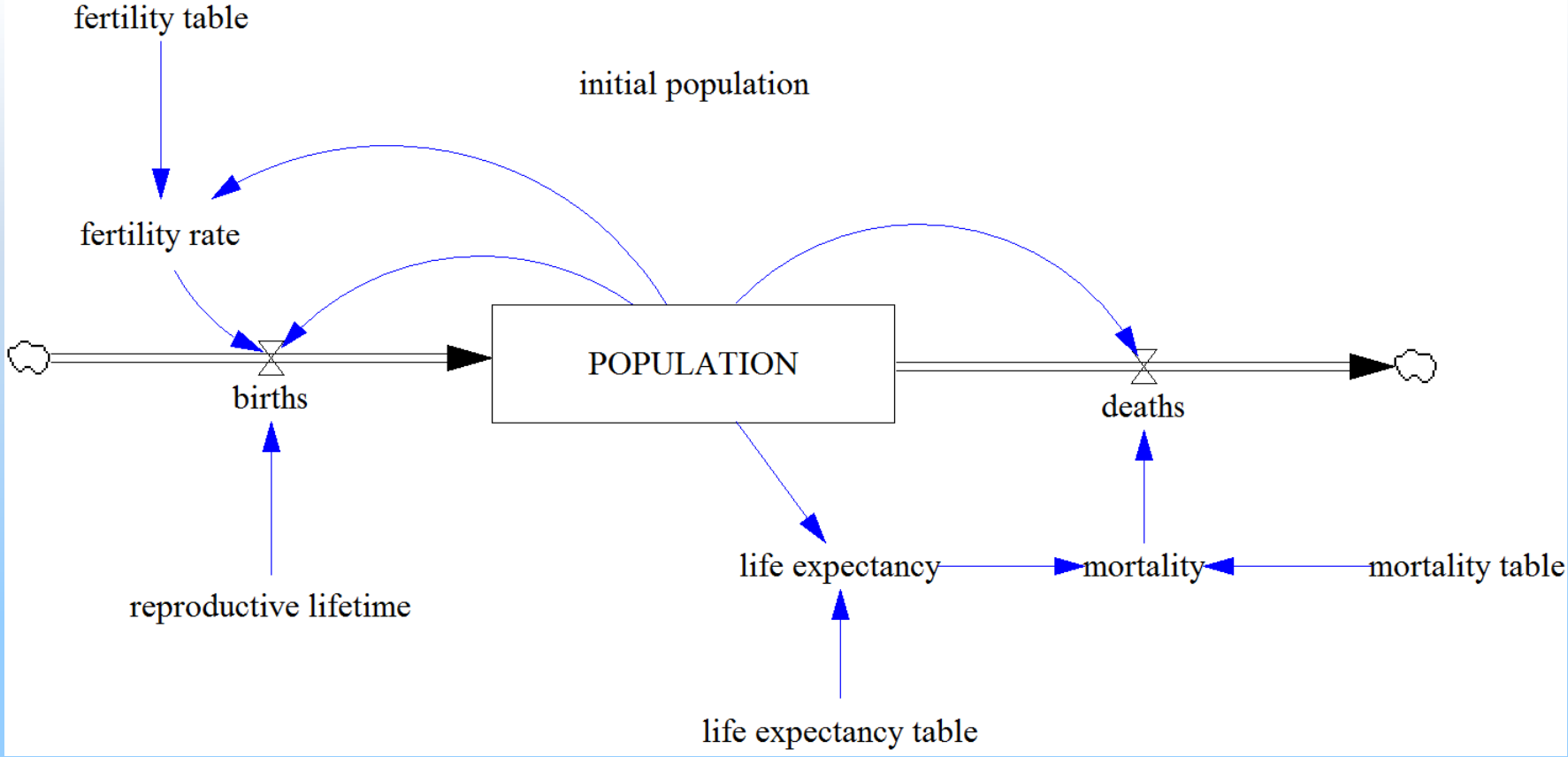
—— population

UNSTABLE - overshoot





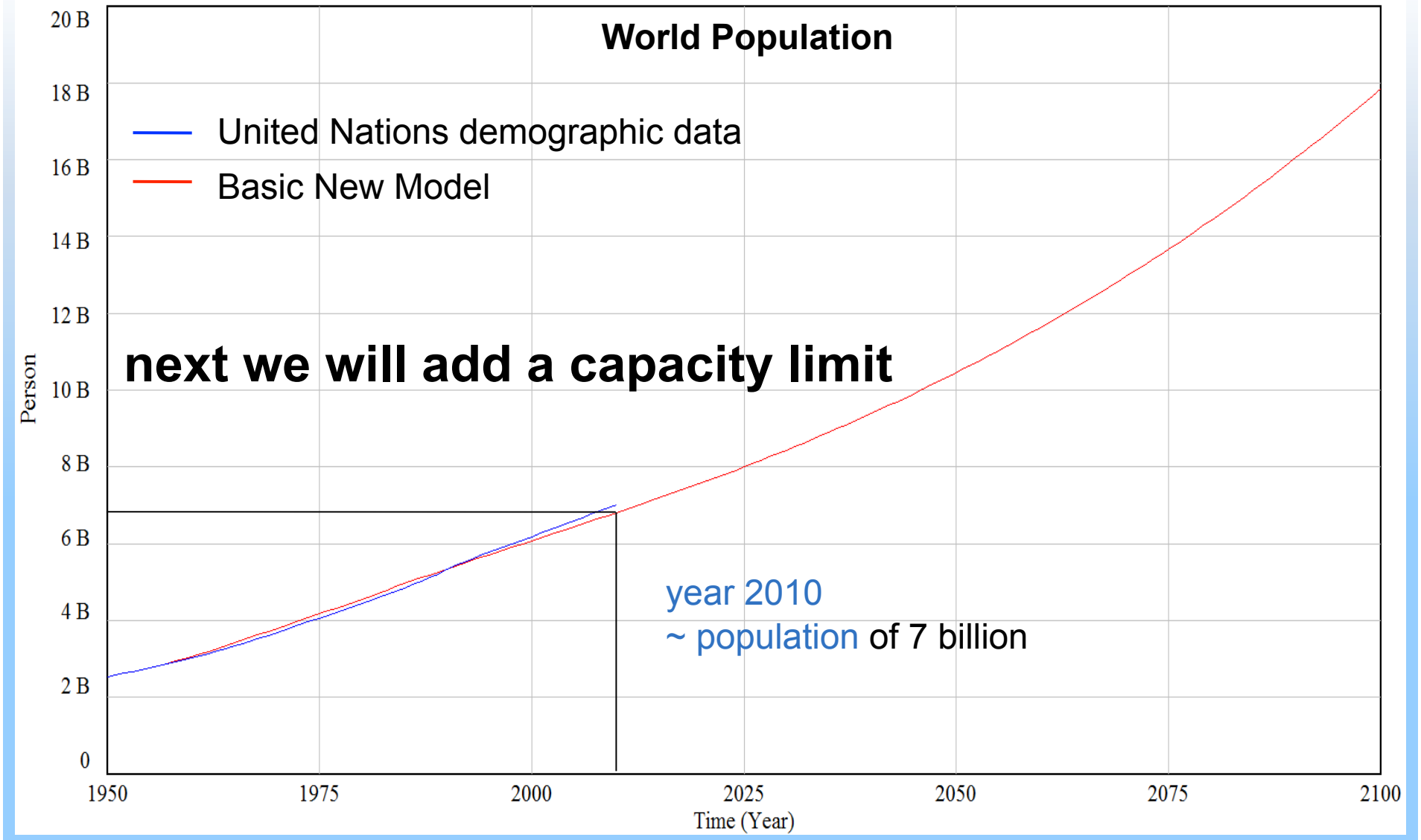
BASIC NEW MODEL



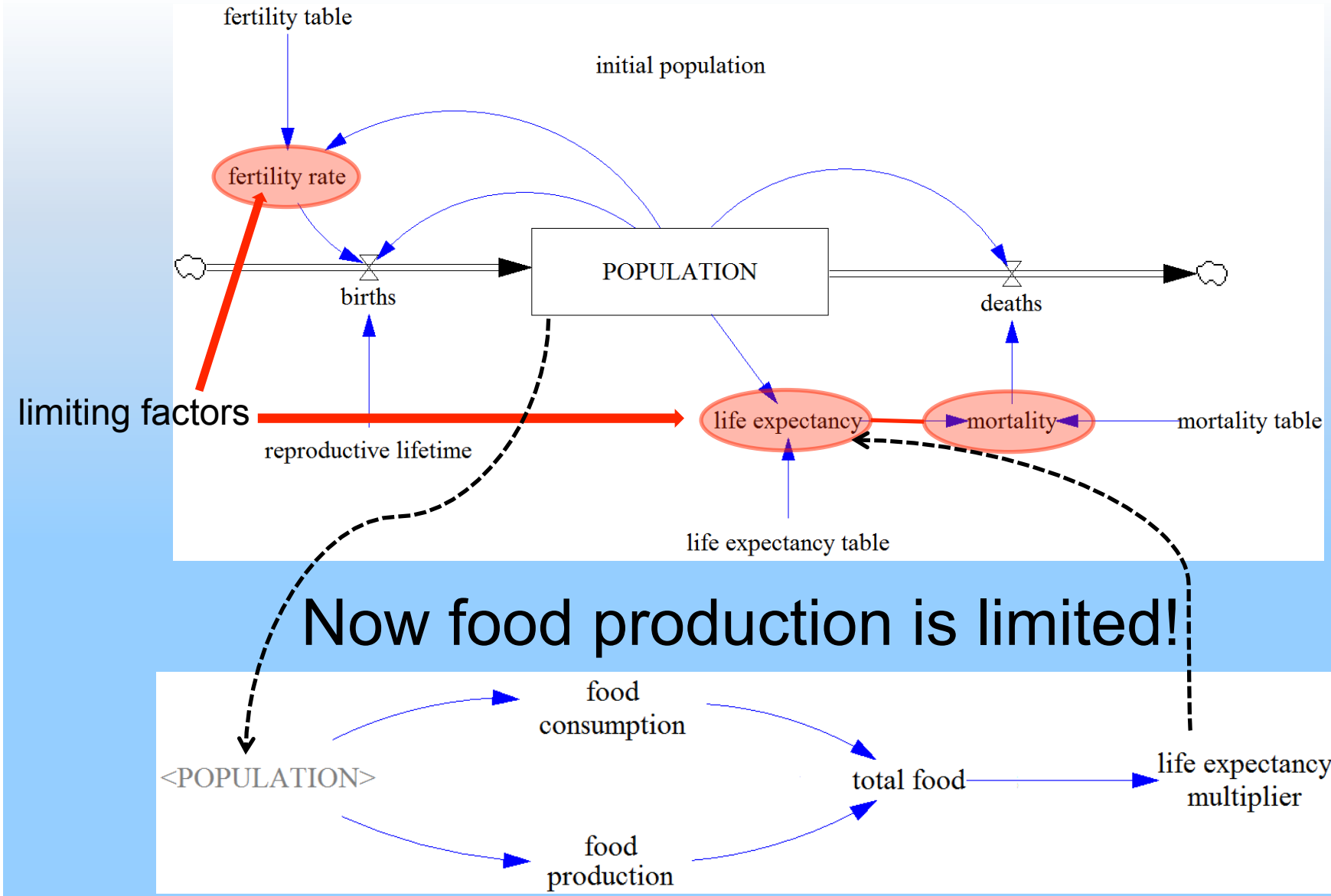
simulate World population via fertility and life expectancy

assumption: carrying capacity of the world is unlimited!!!

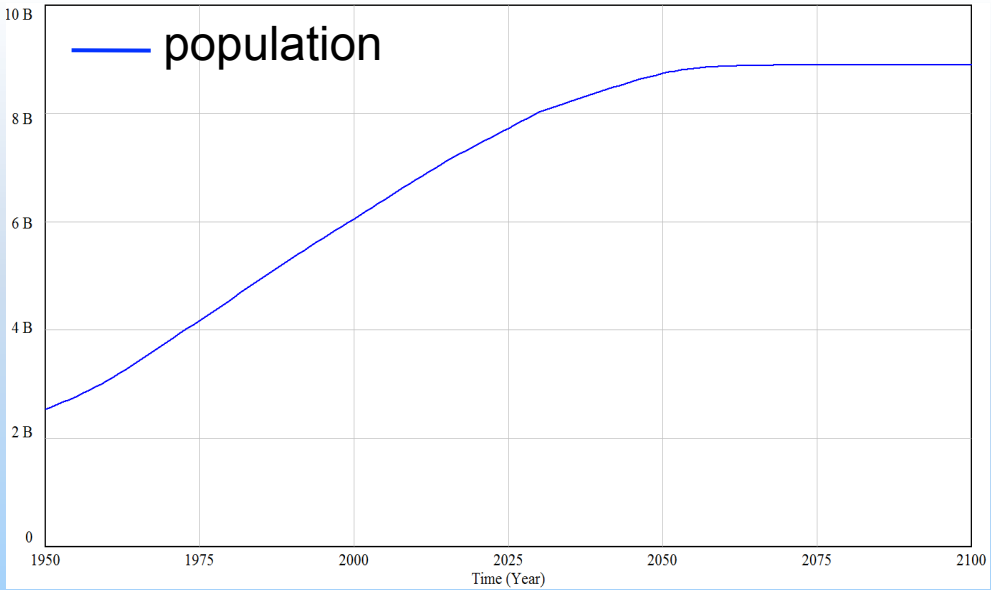
BASIC NEW MODEL - RESULT



BASIC NEW MODEL WITH LIMITS



BASIC NEW MODEL WITH LIMITS - RESULTS



population approaches
8.9 billion people

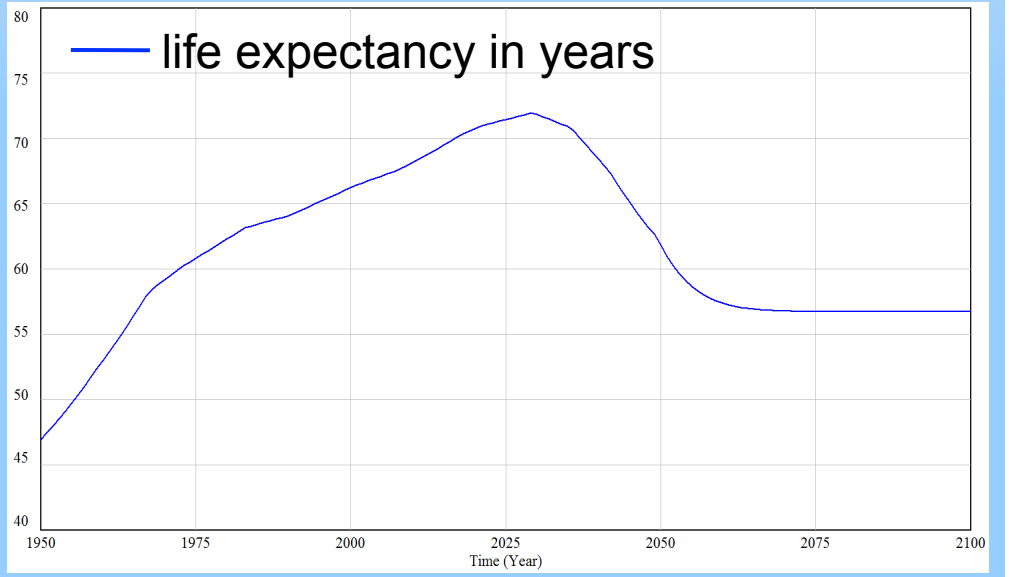
Setup:
food production = food consumption
for a population of 8 billion

consumption per capita is a constant

notes:

overproduction has no positive effect on life expectancy

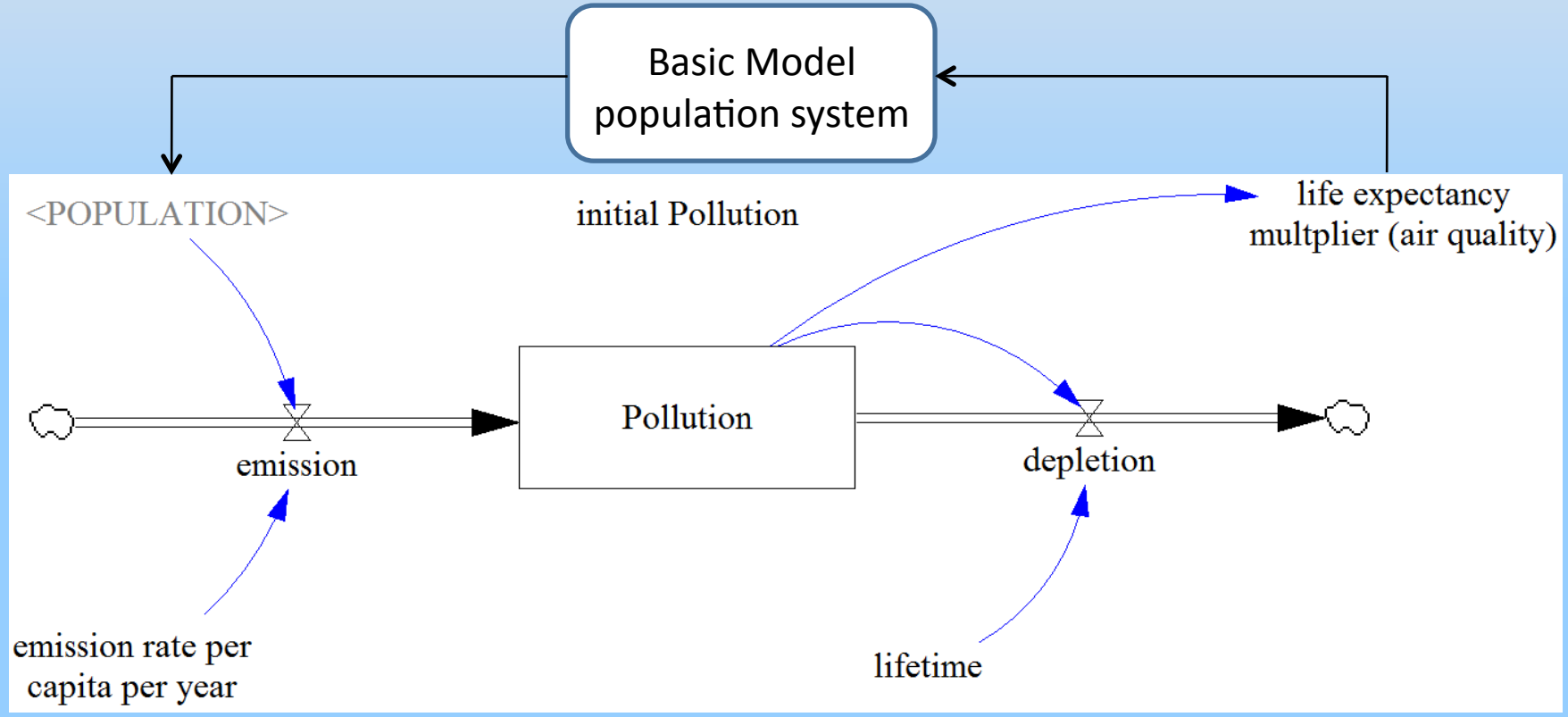
life expectancy collapses after year 2030 because of malnutrition



BASIC NEW MODEL – NEW VARIABLE: POLLUTION

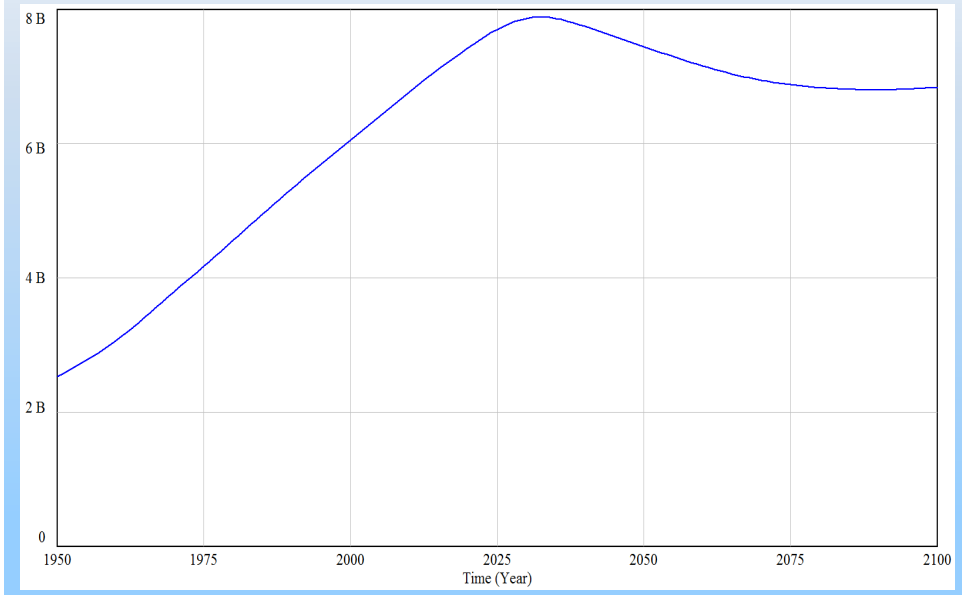
before agriculture was proportional to the population

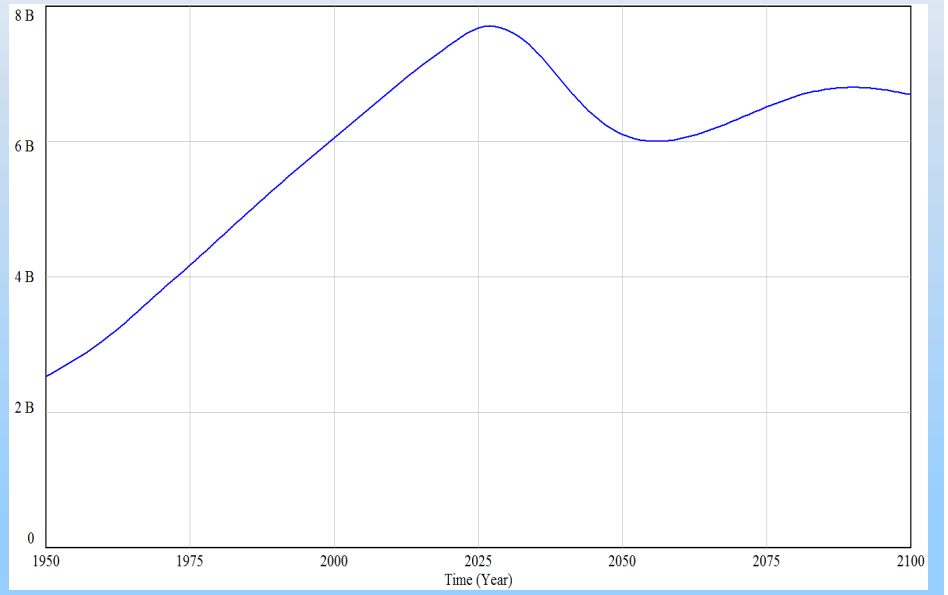
now we add instead of agriculture a new variable: pollution



COLLAPSE OR OSCILLATION?

POPULATION





collapse or oscillation depends on pollution impact on life expectancy

BASIC MODEL WITH AGE-COHORTS AND FAO AGRICULTURE DATA

Improvements:

- demographic system divided in age-cohorts
  → more details about demographic characteristics

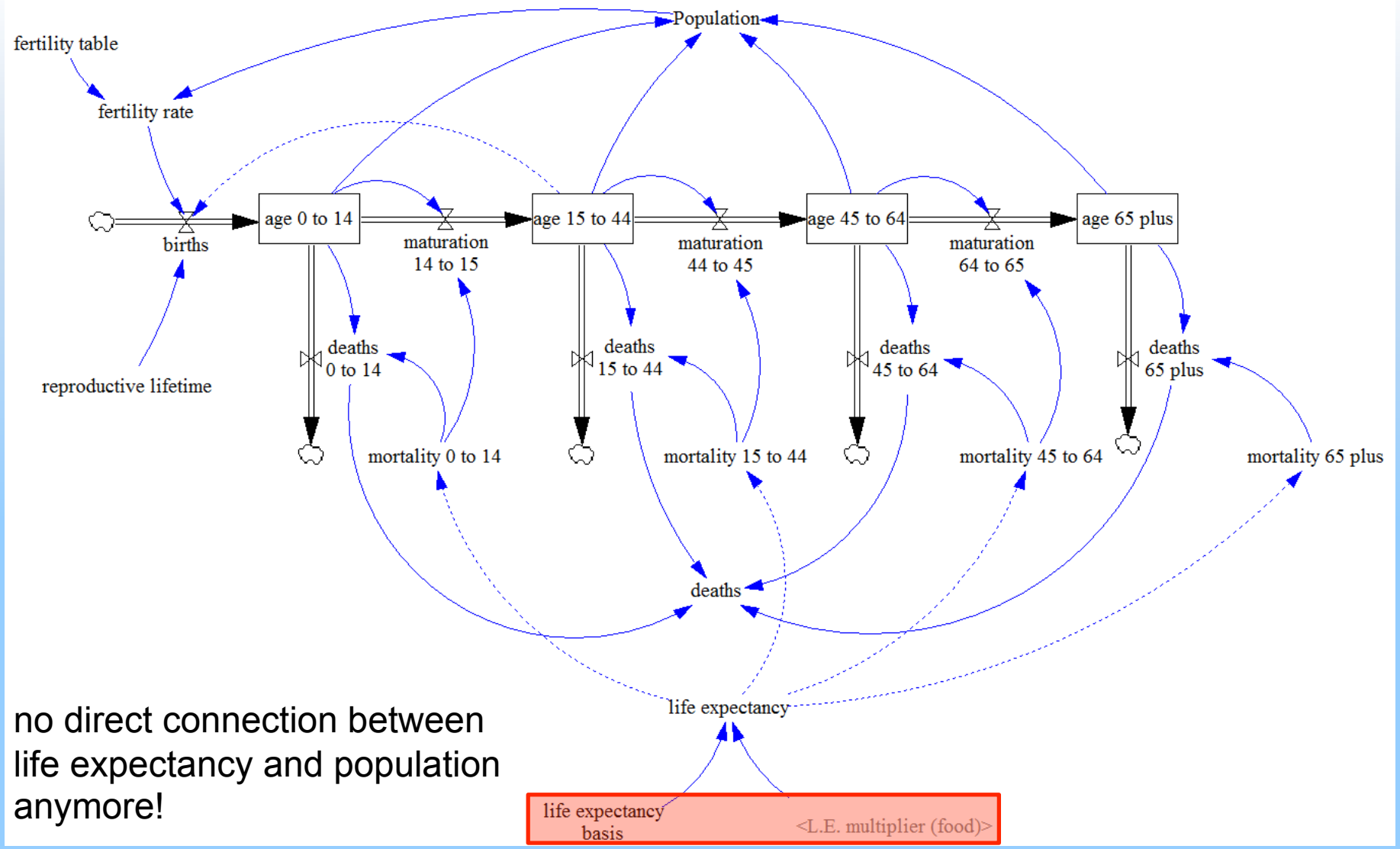
- more complex agriculture system
  → based on FAO (Food and Agriculture Organization) data

- many variables show a sigmoid trend
  → production of meat and cereals, increasing arable land, land yield

- calculation of life expectancy restricted to food consumption
  → cutting-off connection between life expectancy and population

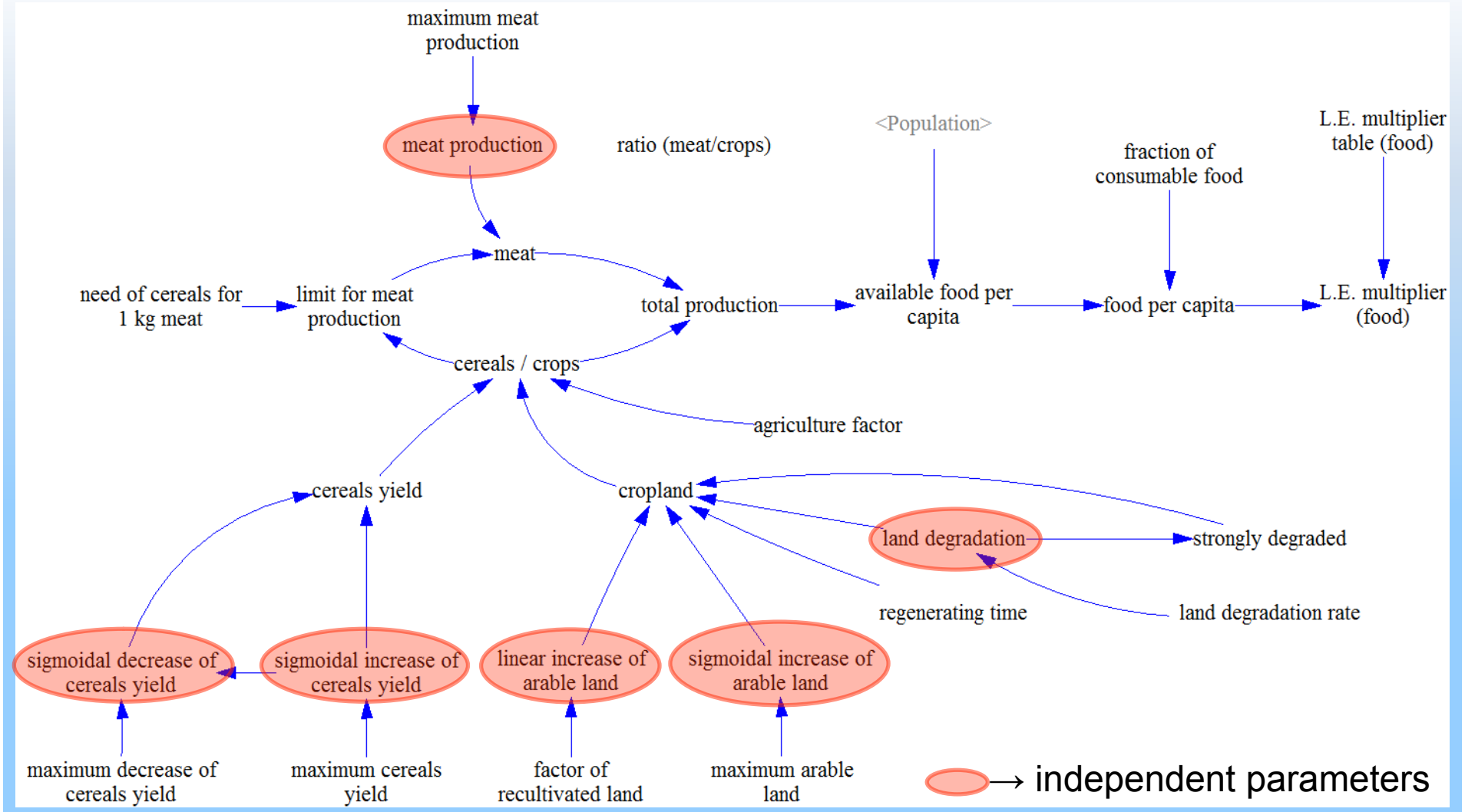
- different scenarios can be simulated

BASIC MODEL – DEMOGRAPHIC SYSTEM

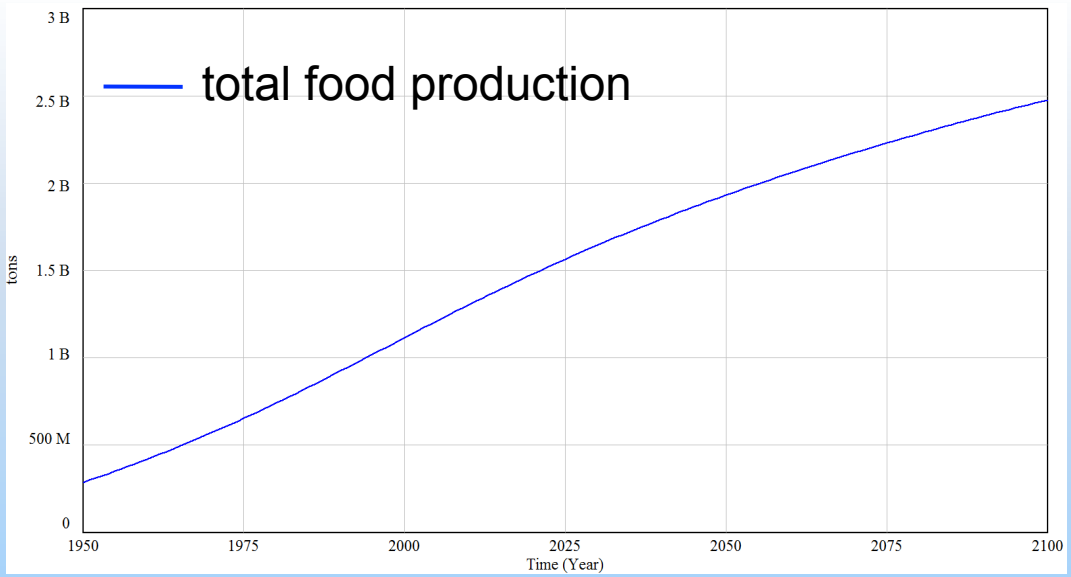


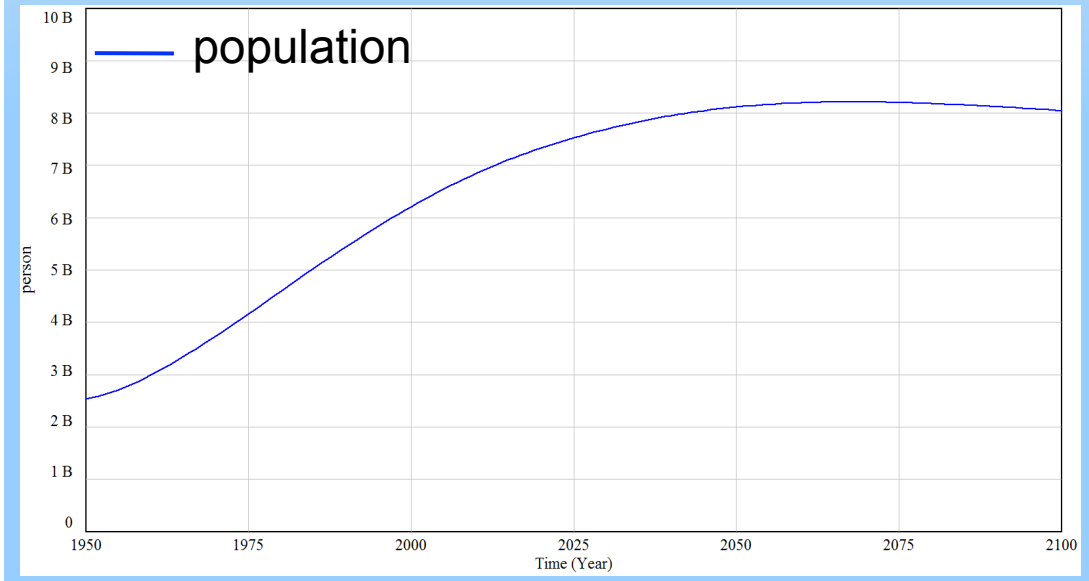
no direct connection between life expectancy and population anymore!

BASIC MODEL – AGRICULTURE SYSTEM



BASIC MODEL – OPTIMISTIC SCENARIO





assumptions:

- total food production increases ~ constantly

- max. life expectancy 90 years

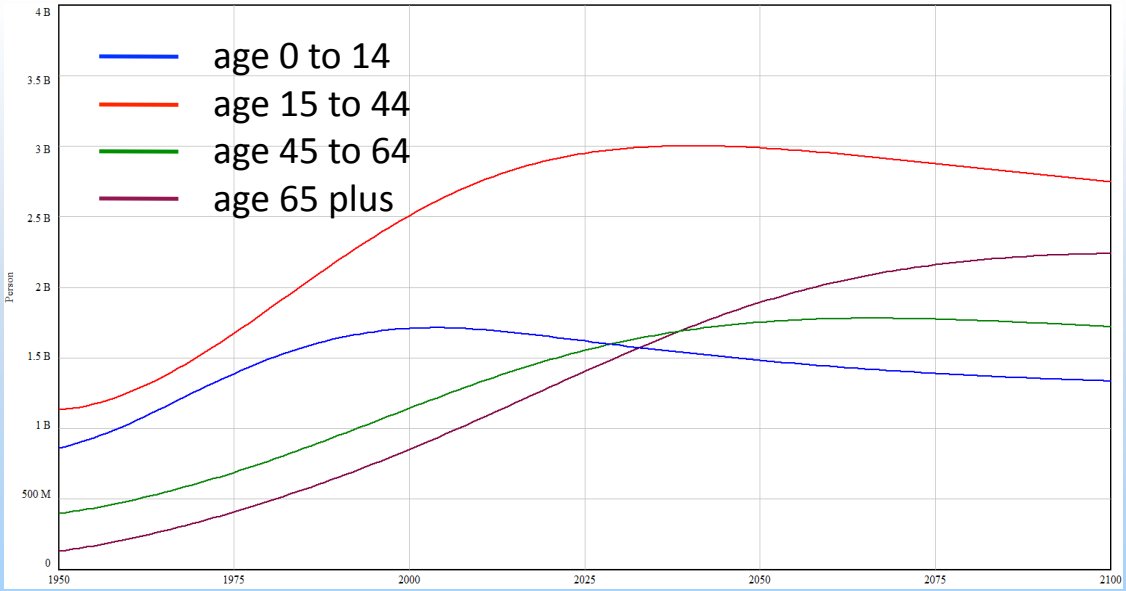
- fertility rate does not increase in the future

nevertheless:

→ population decreases

WHY?

BASIC MODEL – OPTIMISTIC SCENARIO

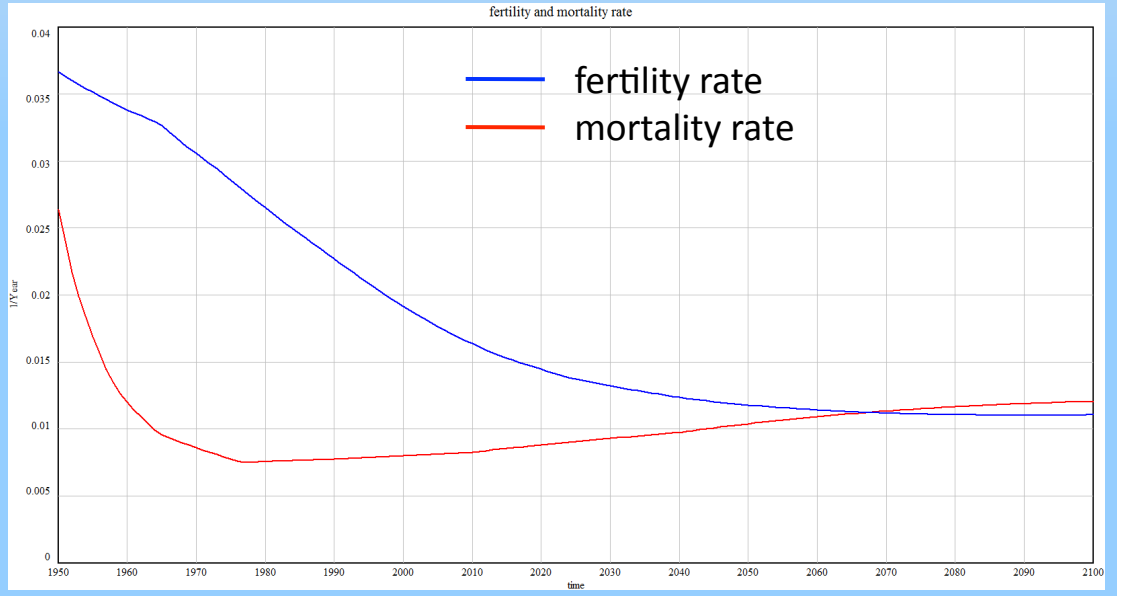


reason for decreasing population:

→ age distribution change

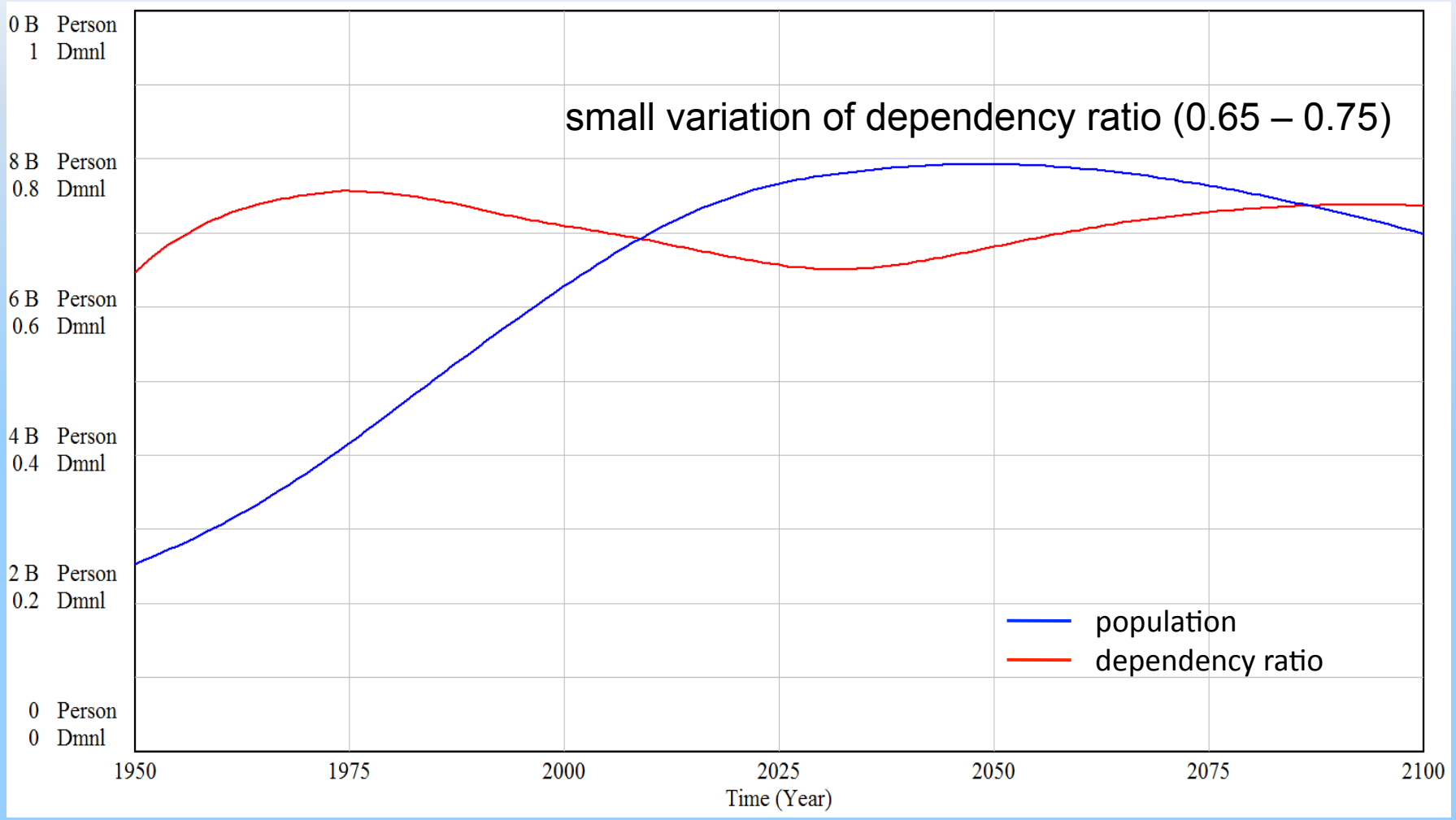
higher mortality rate for older people

→ increasing overall mortality rate

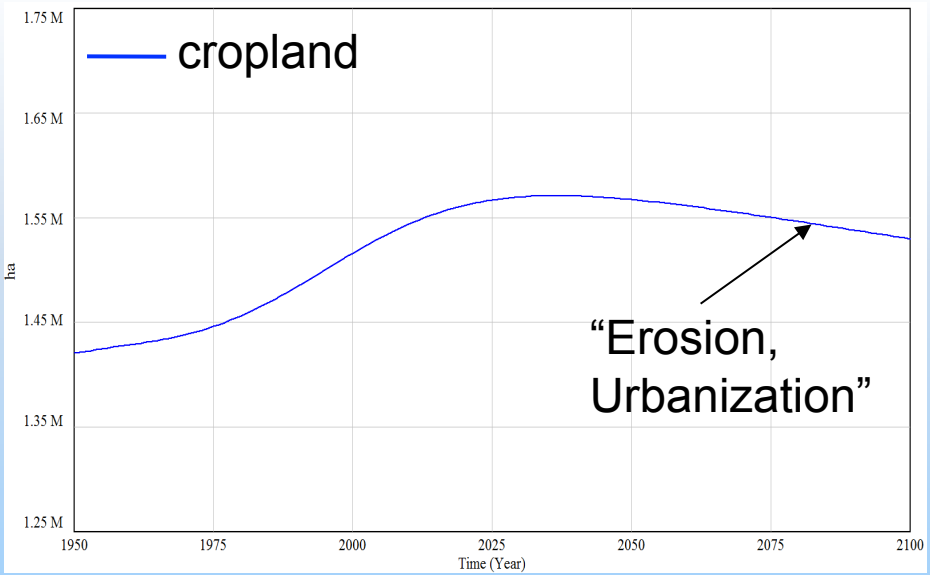


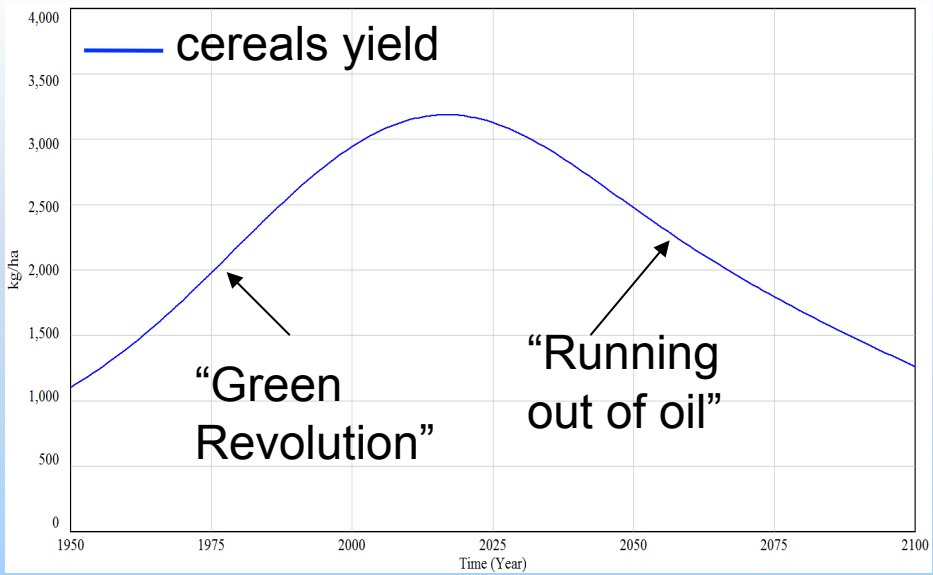
DEPENDENCY RATIO - dependent/working population

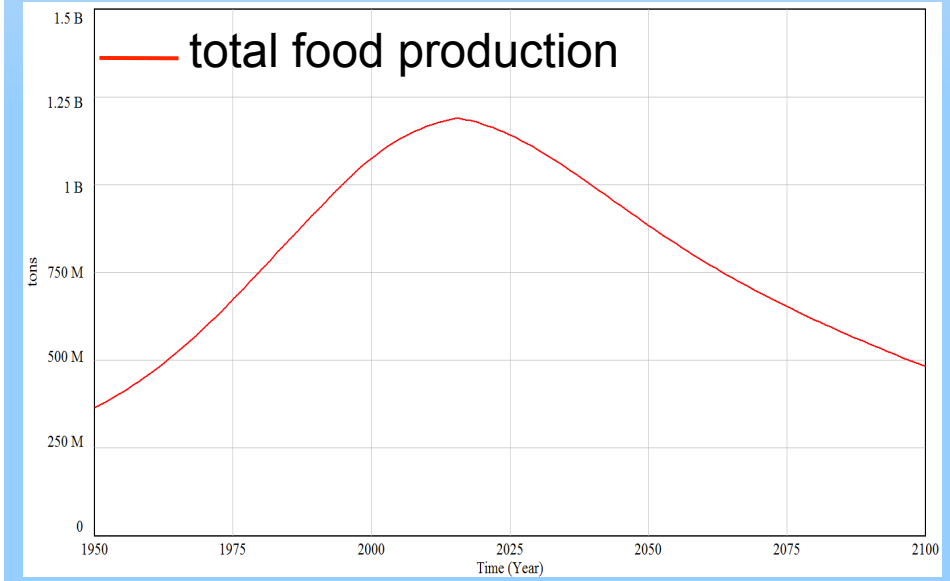
dependency ratio = (population 0 to 14 + population 65 plus) / population 15 to 64

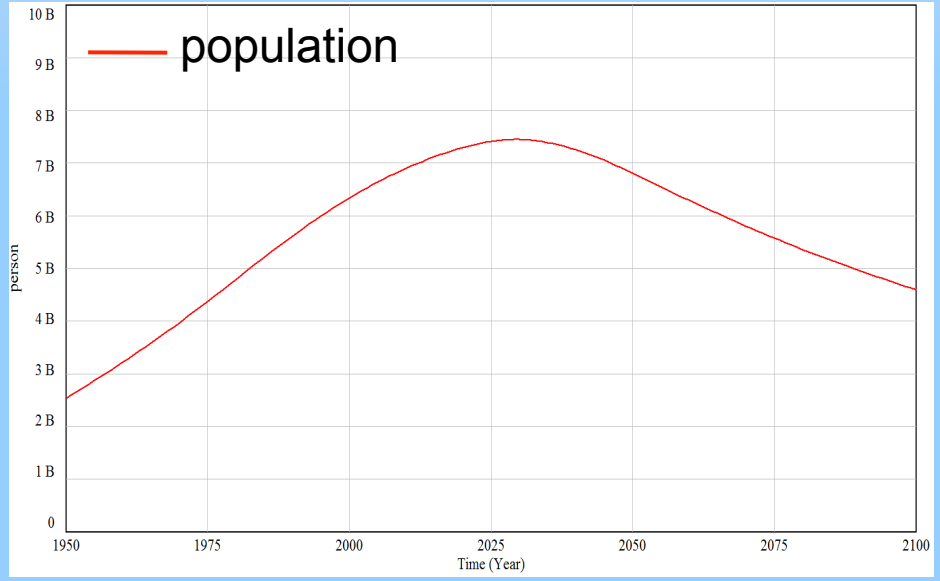


BASIC MODEL – PESSIMISTIC SCENARIO







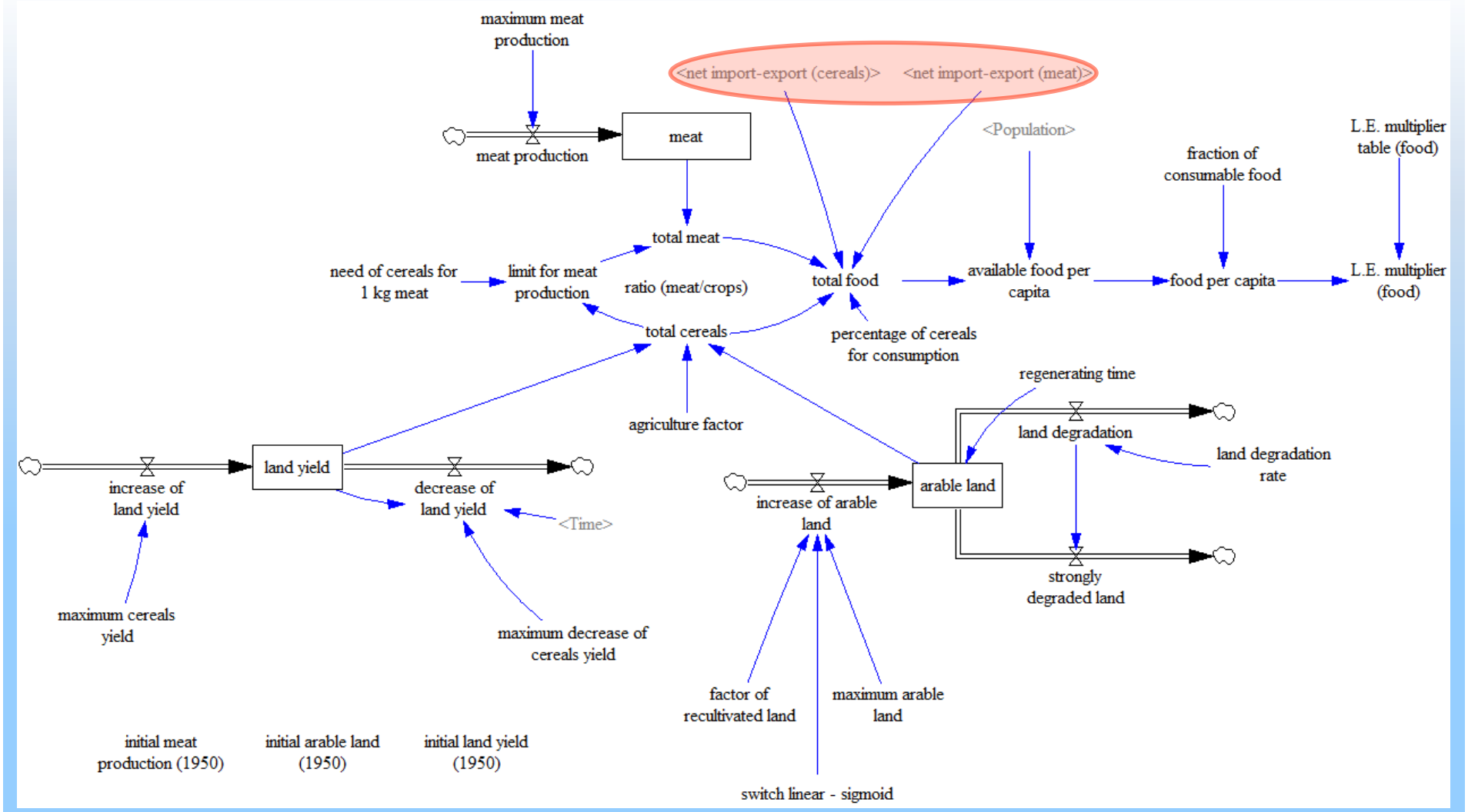


FUTURE IMPROVEMENTS – INTRODUCE REGIONAL POPULATION MODELS

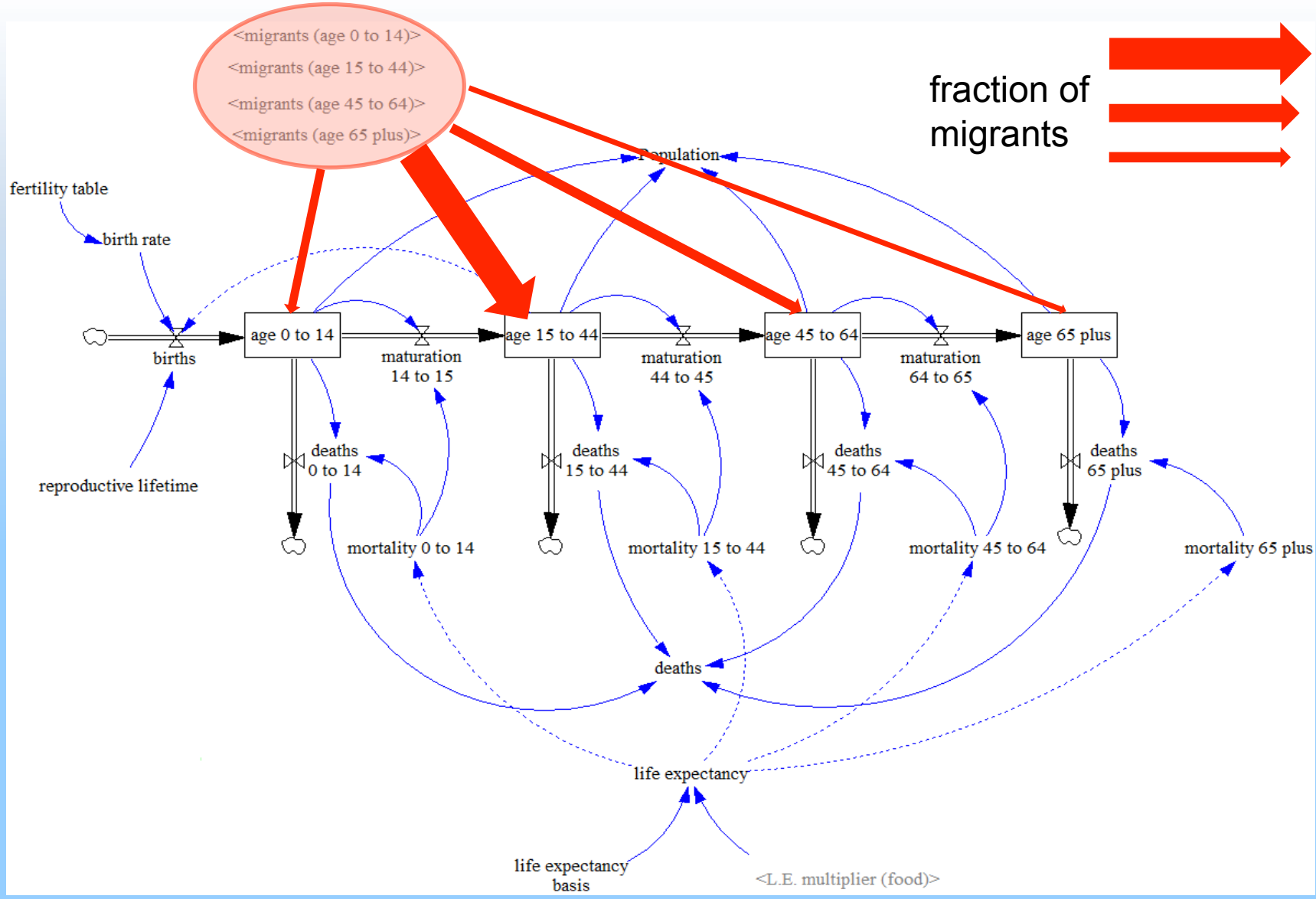
Required changes to simulate regions:

- change variables into arrays → no need to make several models
- most regions are not self-sufficient → need to include imports and exports
- add migration rate → dividing migrants in age-cohorts

SCHEMATIC OF THE REGIONAL MODELS



SCHEMATIC OF THE REGIONAL MODELS



ISSUES WE HAVE TO DEAL WITH

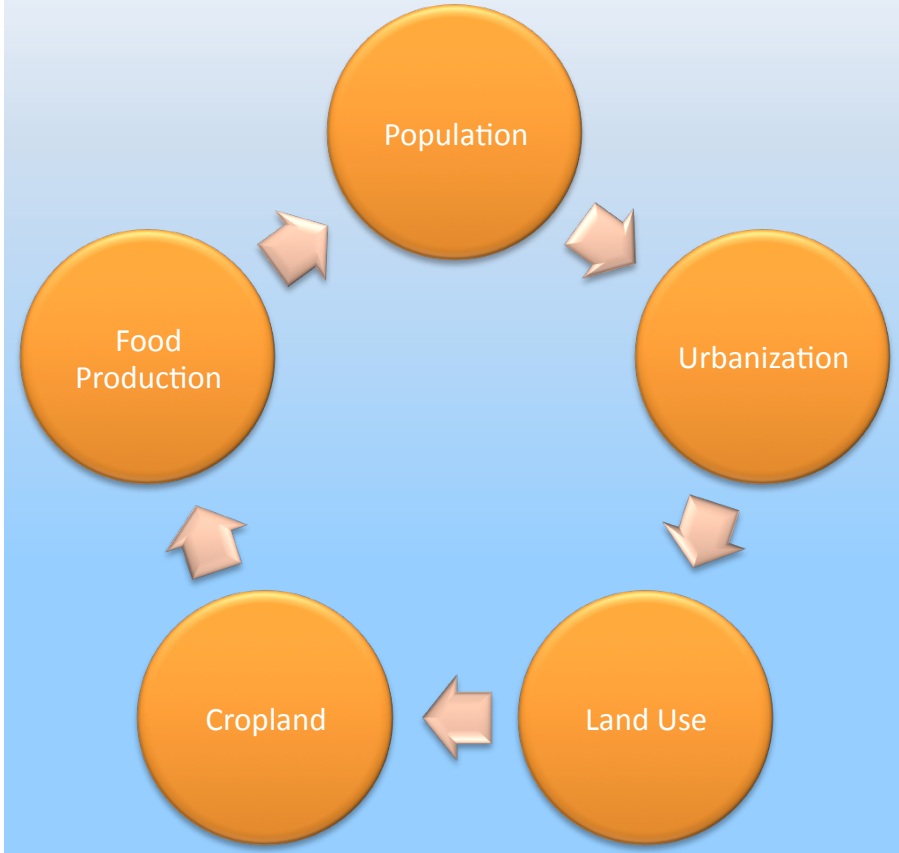
- migration should be related to economic and demographic status

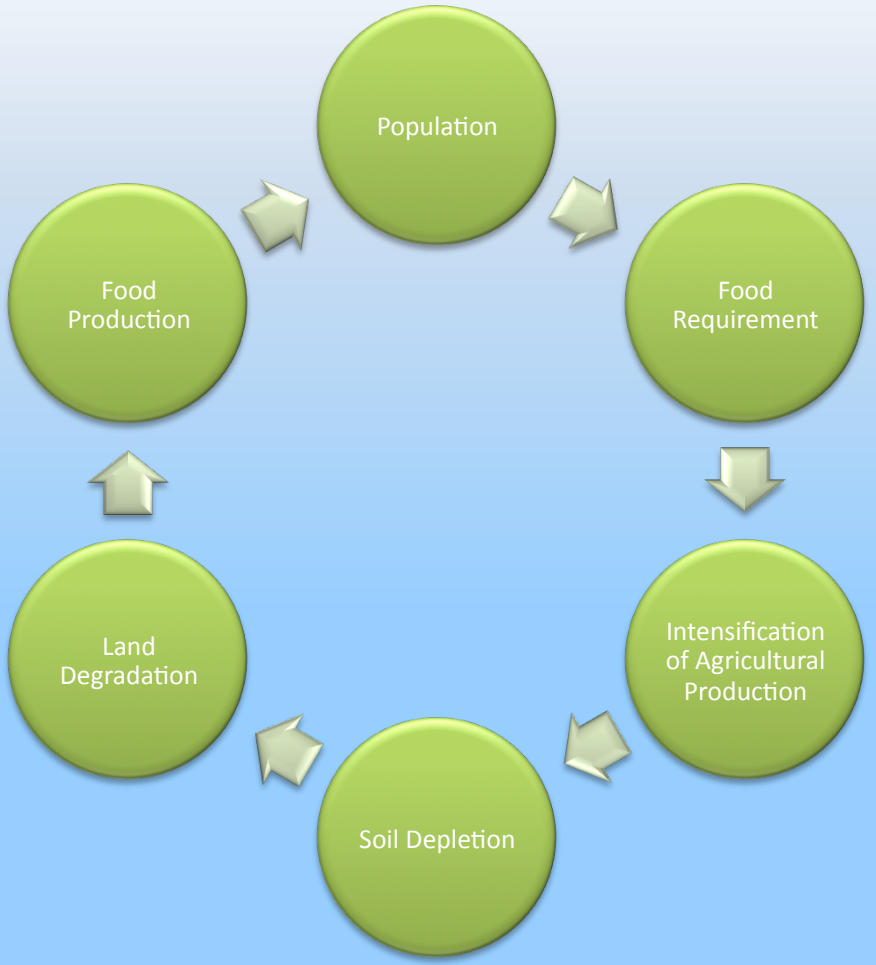
  (not much data for age-distribution of migrants)

- imports and exports should be related to economics and food requirement

→ Most important: we have not yet included an economic subsystem

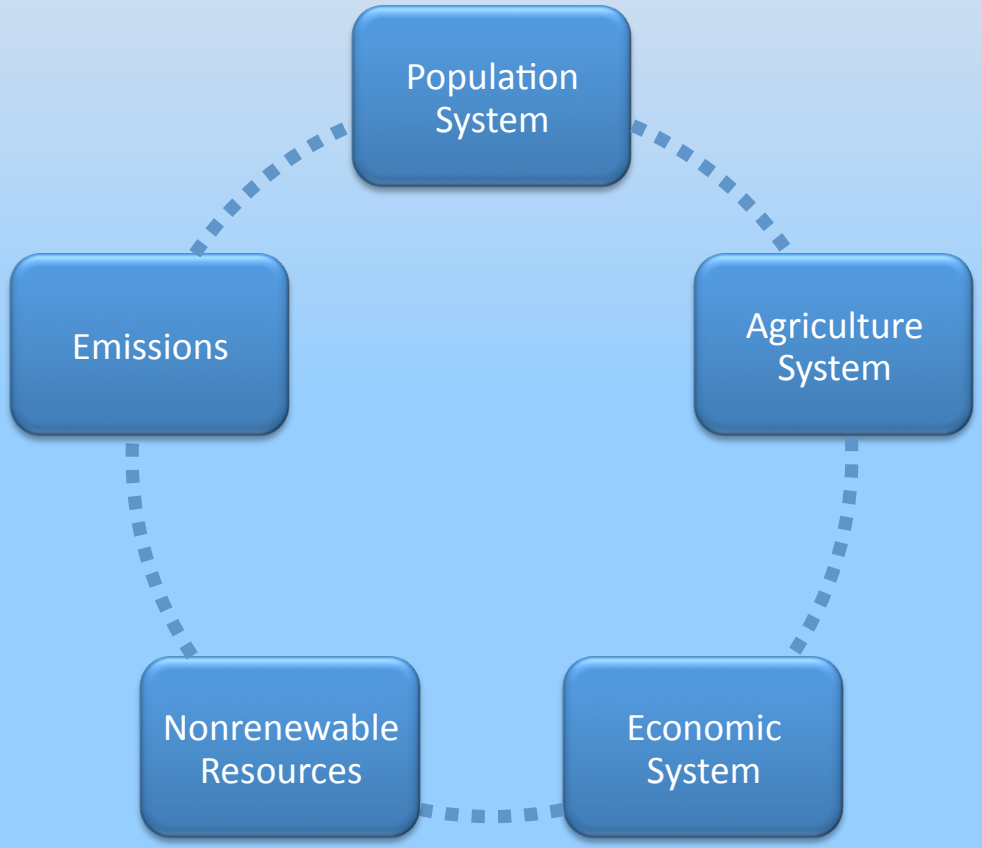
WE NEED TO ADD FEEDBACKS SUCH AS





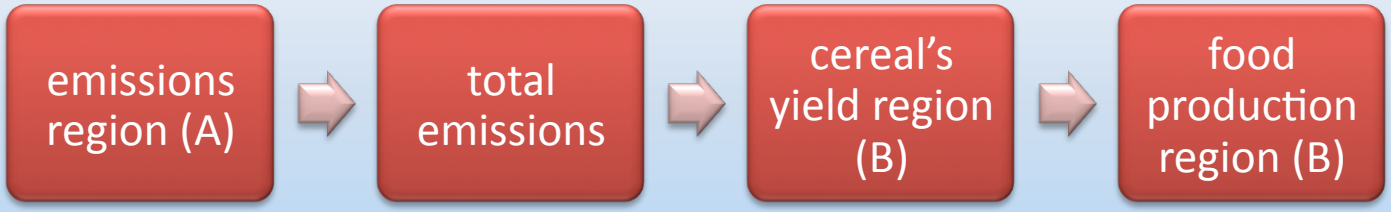
OTHER FUTURE DEVELOPMENTS

- display real data for comparisons
- add new systems like economy, emissions, nonrenewable resources, etc.



OTHER FUTURE DEVELOPMENTS

- add interactions between regions (A) and (B) such as



- add indicators for population *Quality of Life*
  - *Human Development Index*
  - *Ecological Footprint*

…IN THE END

…”We still see our research as an effort to identify different possible futures. We are not trying to predict the future. We are sketching alternative scenarios for humanity as we move toward 2100.”…

Donnella Meadows,

Limits to Growth – The 30-year Update