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A *World3* analysis of the response of population-resource dynamics to loss of insect pollinators of food crops

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Abstract

Estimates of the fraction of food production lost due to the loss of insect pollinators of food crops range from 5% to 35%. Although loss of food production can clearly be caused by loss of food-crop pollinators, the effect of food-crop pollinator loss on other population-resource dynamics regimes is less clear. To gain some insight into the latter, I used a well-characterized population-resource dynamics simulator, World3, to compute the sensitivity, within World3, of the five World3 population-resource "sectors" (i.e., population, agriculture, capital, non-renewable resources, and pollution) to loss of insect pollinators of food crops, in nine World3 "Benchmark Scenarios", ranging from the practices of the 20th century to a sequence of scenarios that implement birth control and pollution controls, increase industrial and agricultural investment, and improve food production technology, resource conservation practices, and resource extraction efficiency. In World3, all but one of the Benchmark Scenarios leads to a population collapse. The results of the present study strongly suggest if our primary population-resource management objective is to avoid such a collapse, even a +/- 30% change in land yield due to variation in the population of insect pollinators of food crops has little significance. This is a hypothesis that can, in principle, be assessed through empirical investigation.

Keywords: Population-/Resource Dynamics; Insect Pollinators; World3

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1. Introduction

Estimates of the fraction of food production lost due to the loss of insect pollinators of food crops, in *today's* world-system state, range from 5% to 35% (Aizen et al., 2009; Aizen et al., 2019; Ritchie, 2021). The lesser of these values represent estimates of the decline in food production (measured in mass units) due to insect-pollinator loss in high-income countries; the greater of these two values represents the *number of food crops* that at least partially depend on insect pollinators (Klein et al., 2007; Ritchie, 2021). Some food crops, notably today's dominant cereal hybrids, in *today's* world-state, have no direct dependence on insect pollinators.

Although the loss of food production can clearly be caused by loss of food-crop pollinators, the effect of food-crop pollinator loss on other population-resource dynamics sectors (such as population, capital, non-renewable resources, and pollution) is less clear. It is also unclear how, on the basis of today's world-state alone, we could extrapolate the estimated loss of food production due to the loss of insect pollinators of food crops, to other plausible world-states – for example, to a climatic state in which today's cereal grains are no longer viable (see for example Horner (2025a)).

To try to gain some insight into these questions, the present study used the *World3* population-dynamics simulator (Meadows et al., 1974; Cellier, 2019; Bardi and Pereira, 2022; Nebel et al., 2023; Wolfram, 2019) to compute bounds on the sensitivity, *within World3*, of population-resource dynamics to loss of insect pollinators of food crops. Section 2 provides an overview of *World3* that sets the context for the experiments reported in Sections 3 and 4.

Strictly speaking, this paper concerns only the response of the *World3 simulator proper* to a specific range of variation of a specific *World3* parameter. Any results from the numerical experiments described in the paper should be regarded as *hypotheses* that could, at least in principle, be empirically tested.

2. Overview of *World3*

The *World3* simulator (Meadows et al., 1974; Cellier, 2008; Cellier, 2019; Wolfram, 2019; Bardi and Pereira 2022; Nebel et al., 2023) is a system of approximately 330 system equations and 330 system variables that model the dynamical interaction of what *World3* calls "sectors": world population, pollution, agriculture, capital, and non-renewable resources. Recent assessments (Turner, 2008; Turner, 2014; Randers, 2012; Nørgård et al., 2010; Herrington, 2020; Nebel et al., 2023; Bardi and Pereira, 2022) of *World3* (especially *World3*'s Benchmark Scenario 1; see Section 2.1 of this paper) show that *World3* has predicted the trajectories of *World3*'s sectors, including global population and food production, well for Years 1900 - 2020.

For example, Table 1 compares the population predictions of *World3*'s "Business as Usual" (BAU) scenario (see Scenario 1, Section 2.1) with UN estimates (United Nations, 2019) of the world population, 1980 to 2020. Similarly, Table 2 compares *World3*'s BAU Scenario predictions of world food production per capita per year with UN estimates of that quantity.

The *World3* BAU Scenario food production per capita per year magnitudes evidently agree well with UN estimates of the same, 1970-2000. The BAU predictions for food production are somewhat more pessimistic than UN estimates for 2010 and 2020.

Table 1. Comparison of some World3's population predictions (from the "Business as Usual" (BAU) Benchmark Scenario; see Section 2.1) with the UN estimates (United Nations, 2019). Population is rounded to two significant figures; percent difference is computed as [(World3_prediction – UN_estimate) / UN_estimate] and is rounded to one significant figure.

Year	*World3* prediction of world population (billions, from BAU Scenario)	UN estimate of world population (billions)	Percent difference between *World3* prediction, and UN estimate, relative to UN estimate
1980	4.6	4.5	+2
1990	5.4	5.3	+2
2000	6.2	6.1	+2
2010	7.1	7.0	+1
2020	7.9	7.8	+1

Table 2. Comparison of *World3's* Benchmark Scenario 1 ("BAU") prediction of world food production with UN estimates (Roser and Ritchie, 2022) of the same. Food production units are vegetable-equivalent kilograms per person per year. Percent difference is computed as [(World3_prediction – UN_estimate) / UN_estimate].

Year	*World3* prediction, Benchmark Scenario 1 ("BAU")	UN Estimate, normalized to *World3*'s 1970 prediction	Percent difference, relative to UN estimate
1970	**384**	**384**	**0**
1980	**407**	**400**	**+2**
1990	**425**	**416**	**+2**
2000	**430**	**432**	**-0.5**
2010	**416**	**448**	**-7**
2020	**390**	**464**	**-16**

2.1. The *World3* benchmark scenarios

Meadows et al. (2004), Cellier (2019), Bardi and Pereira (2022), Wolfram (2019), and Nebel et al. (2023) describe nine *World3* scenarios that span regimes ranging from continuing the practices and policies of the 20th century (called the "Business as Usual" scenario (BAU)), to a sequence of scenarios that increasingly diverges from the BAU through increasing:

- birth control and pollution controls
- industrial and agricultural investment
- food production technology
- resource conservation practices
- resource extraction efficiency

I will call these nine Scenarios "the *World3* Benchmark Scenarios" or "the Benchmark Scenarios". Collectively, the Benchmark Scenarios provide a de facto baseline for analyzing the sensitivity of *World3* predictions to variations in *World3* parameters and initial conditions. By default, the duration of each Benchmark Scenario spans simulated calendar years 1900 - 2100. Following is a high-level description of Benchmark Scenarios 1 (the "BAU" scenario) and 9. Details of these, and of Benchmark Scenarios 2-8, can be found in Meadows et al. (1974), Meadows et al. (2004), Cellier (2019), Bardi and Pereira (2022), Wolfram (2019), and Nebel et al. (2023).

Benchmark Scenario 1 (the "business-as-usual" (BAU) scenario; Meadows et al., 2004, pp. 168-171). In Benchmark Scenario 1, the practices and policies of most of the 20th century continue without significant deviation. As a result, population and production increase until growth is arrested by increasingly inaccessible resources. Increasing investment is required to maintain resource flows. That investment, which must be re-directed from other sectors of the economy, leads to declining output of both industrial goods and services. The decline of industrial goods and services causes a reduction in the food supply and in health services, thereby decreasing life expectancy, resulting in a population "collapse" (nominally defined as a 50% reduction of population size in less than ~50 years), beginning calendar year 2030.

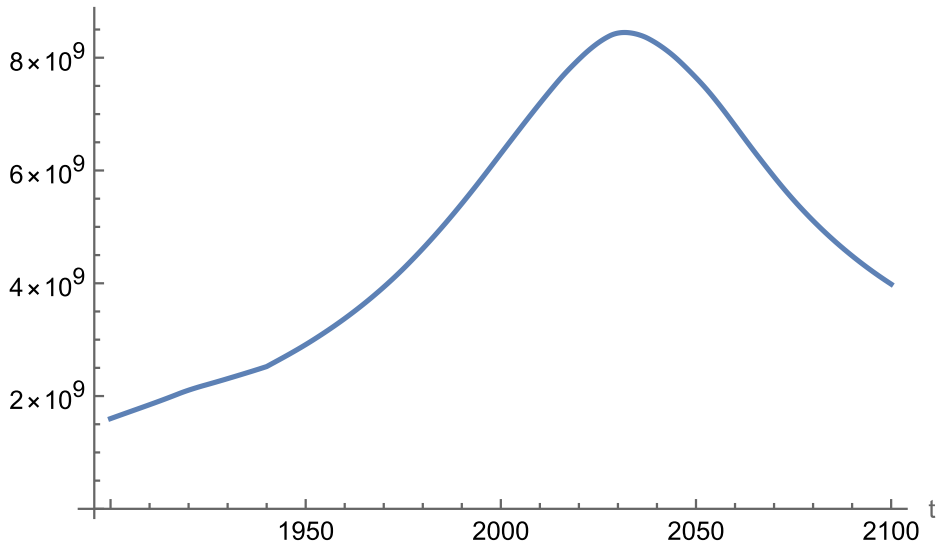


Figure 1. World population (number of persons) by time. World3, Benchmark Scenario 1 ("Business as Usual" (BAU)). Horizontal axis is calendar year. Note the population collapse beginning about Year 2030.

Figure 1 shows population as a function of time in *World3* Benchmark Scenario 1. Figure 2 shows food production as a function of time in that Scenario.

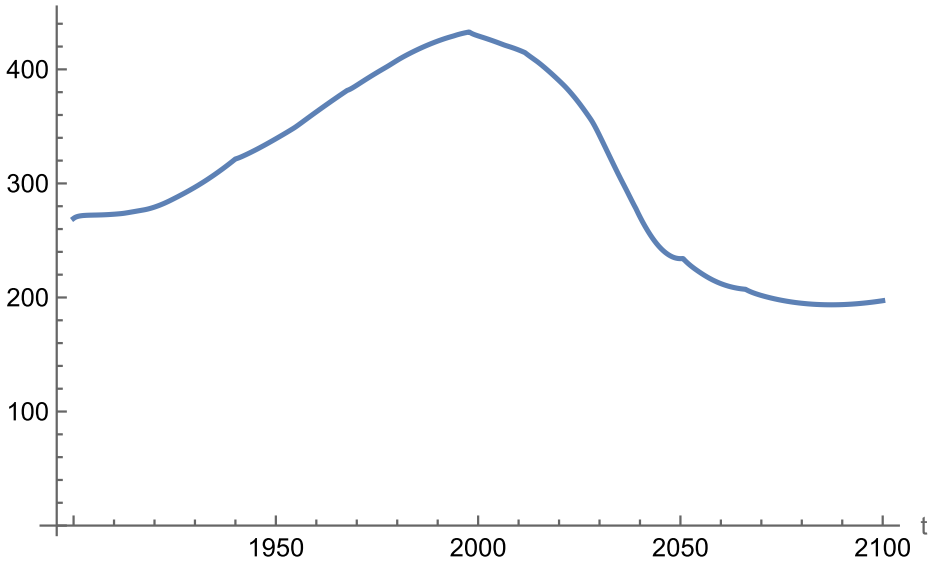


Figure 2. World food production (in vegetable-equivalent kilograms per person per year) by time. *World3*, Benchmark Scenario 1. Horizontal axis is calendar year. Note the drop in food production beginning about Year 2000.

Benchmark Scenario 9 (Meadows et al., 2004, pages 244-247). In this scenario, population and industrial output are intentionally limited. In addition, technologies are added to aggressively abate pollution, conserve resources, increase land yield, and protect agricultural land. As a consequence, the planet's 8 billion people enjoy a high standard of living, and the human ecological footprint continuously declines.

Figure 3 shows population as a function of time in *World3* Benchmark Scenario 9. Figure 4 shows food production as a function of time in Benchmark Scenario

Summarizing the results shown in Figures 1 – 4 and Horner 2025, in Benchmark Scenarios 1 - 8 population/resource dynamics are strongly dominated by population growth overshooting the global supply of various essential resources, resulting in a population peak followed by a population crash (see, for example, Figure 1). In its most rudimentary form, this behavior is the classic Malthusian catastrophe (Malthus, 1798; Ehrlich and Ehrlich, 2009): any resource required to sustain a population level must increase at least as fast as the population does, or the population will overshoot the carrying capacity of the resource, and the population will collapse. For example, the world population has tended to increase exponentially but the resources required to sustain that population have increased at best linearly. Over at least the last century, in particular, the global population has tended to grow at least one percent year over year (i.e., has exhibited an exponential growth rate of at least one percent per year), while agricultural output has, on *average*, increased only linearly. Of the nine Benchmark Scenarios, only Benchmark Scenario 9 avoids a population collapse.

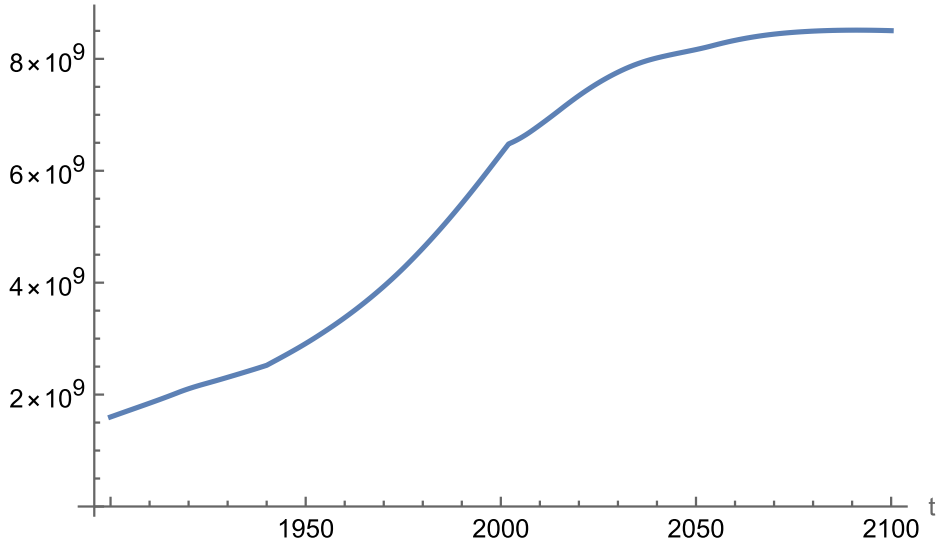


Figure 3. World population (number of persons) vs. time. *World3*, Benchmark Scenario 9. Horizontal axis is calendar year. Note the population is approximately constant starting about Year 2070. Compare with Figure 1 (from Benchmark Scenario 1).

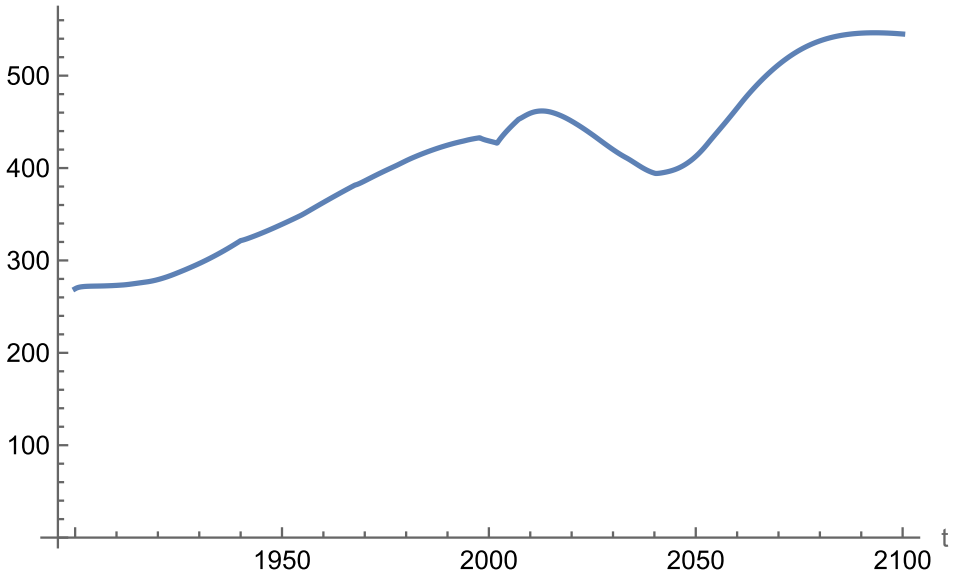


Figure 4. World food production (in vegetable-equivalent kilograms per person-year) by time. *World3*, Benchmark Scenario 9. Horizontal axis is calendar year. Note that food production is constant starting about Year 2080. Compare with Figure 2 (from Benchmark Scenario 1).

3. Method

This section describes the method used in the present study. Section 3.1 describes the platform used in the study. Section 3.2 identifies, and provides rationale for, the *World3* parameters that were varied in the study.

3.1. Platform

The version of *World3* used in this study is the version hosted under the *System Modeler* v12.0.0.0 (Wolfram, 2019) and *Mathematica* v 14.2.1.0 (Wolfram, 2025) framework. The *World3* configuration files used in this study for Benchmark Scenarios 1-9 are bundled with Wolfram (2019). *Modelica* 4.0 (2025) provided the *Modelica* resources required by Wolfram (2019). The *World3* documentation in Wolfram (2019) provides a detailed mapping between *World3*'s "sectors" and their *Modelica* implementation counterparts. Microsoft C++ Visual Studio provided the C++ resources required by Wolfram (2019). All software used in this study was executed under Windows 10 on a Dell Inspiron 545 desktop containing an Intel Q8200 quadprocessor clocked at 2.33 GHz and 8 GB of physical memory.

3.2. Selection of parameters to vary

The objective of the present study is to determine bounds on the *effects*, within *World3*, on *World3*'s population-resource dynamics of loss of insect pollinators of food crops. The study adopted the following desiderata to constrain the list of *World3* parameters to vary. The parameter(s) should:

- Bear some plausible connection to measurands external to *World3*. (This is a constraint on any simulator that aspires to provide at least some information about the world external to that simulator.)
- Be necessary and sufficient to bound *all* the *effects*, within the Benchmark Scenarios, of the loss of insect pollinators of food crops.
- Be consistent with the range-of-value checks implemented in World*3.* (These checks variously protect *World3* (i) from at least some trajectories that lie well outside the scope of *World3*'s calibration and (ii) from operating outside the accuracy limits of *World3* numerical integrators).
- *Not* modify the *World3* software (rationale for this desideratum are discussed in Section 5).

In the world external to *World3* (= the "real world"), the proximate effect of loss of insect pollinators is loss of *land yield* (defined in terms of mass of food crop produced per unit land area per unit time). *World3* contains a model of land yield that is sufficient to satisfy (a).

An analysis of the *World3* land yield software revealed that the parameter **p_land_yield_fact_1** is the *only* parameter in *World3* that can satisfy (a) and (b). **p_land_yield_fact_1** occurs in the defining equation for land-yield variable LY in *World3*. By design **p_land_yield_fact_1** allows the user to define variation in LY caused by any user-designated regime that is consistent with the intended application semantics (see Turner (2011) for a discussion of this term) of the rest of *World3*. *World3* in effect multiplies LY by **p_land_yield_fact_1**, as shown in Eq. 1. Eq. 1, furthermore, is the *only* use of **p_land_yield_fact_1** in *World3* (Meadows et al., 1974, p. 307; Wolfram, 2019):

LY = **p_land_yield_fact_1** * LFERT * LYMC * LYMAP Eq. 1

Where,

LY and **p_land_yield_fact_1** are as noted above

LFERT is a land fertility multiplier

LYMC is a land-yield multiplier from capital (investment)

LYMAP is a land-yield multiplier from air pollution

Eq. 1 implies that, all else being the same, if **p_land_yield_fact_1** = 1.0 (the value assumed in all the Benchmark Scenarios), **p_land_yield_fact_1** has no effect on the value of LY. If **p_land_yield_fact_1** = 0.7 (a 30% reduction from LYF = 1.0), all else being the same, Eq. 1 says that LY is 0.7 times the value it would have if LYF = 1.0. Similarly, all else being the same, if **p_land_yield_fact_1** = 1.3 (a 30% increase in LYF = 1.0), Eq. 1 says that LY is 1.3 times the value it would have if LYF = 1.0.

SystemModeler supplies a function, **SystemModelSimulateSensitivity**, that, given a *Modelica* program and the name of a parameter in that program, returns (among other things) the names of all *Modelica* variables in that program that could be affected by variation in the given parameter. If (as in the case of the present study), the user does not explicitly specify a set of such variables in a SystemModelSimulateSensitivity invocation, SystemModelSimulateSensitivity lists each Modelica variable (i) whose trajectory is directly propagated by numerical integrators in the program of interest, and (ii) whose value could be affected by the parameter of interest. Appendix 1 of the present paper shows the list of variables satisfying (i) and (ii) in Benchmark Scenario 1 that SystemModelSimulateSensitivity determines could be affected by variation in **p_land_yield_fact_1**. (This list (see Appendix 1) is the same for all Benchmark Scenarios. The meaning of those variables in that list can be found in the World3 documentation identified in Section 3.1.)

SystemModeler also provides a powerful sensitivity analysis function, SystemModelPlot, which, given a parameter P, a Modelica_variable V, and a percent range R of variation of P, returns a plot of the sensitivity of V to variation in P over R. In this study, R for **p_land_yield_fact_1** was set to +/- 30% of its Benchmark Scenario default value (= 1.0) for all Benchmark Scenarios), i.e., R is the closed real interval [0.7, 1.3]. There are two compelling reasons for choosing this value of R for **p_land_yield_fact_1**:

- In the Benchmark Scenarios, variation in **p_land_yield_fact_1** outside the range of +/- 30% involves trajectories that lie outside World3's calibration envelope.
- In some Benchmark Scenarios, a range of variation **p_land_yield_fact_1** larger than +/- 30% will cause World3 to exit via accuracy-control code in World3's numerical integrators.

This choice of R for **p_land_yield_fact_1** satisfies (a), (b), and (c).

Because it is a modifiable parameter in the World3 software, modifying the value of **p_land_yield_fact_1** does not change the *World3 software* as such, thereby satisfying (d).

Collectively, the choice of **p_land_yield_fact_1** and R = [0.7, 1.3] satisfy (a) – (d) for the Benchmark Scenarios. The present study therefore defines the effects (as identified by SystemModelSimulateSensitivity and SystemModel Plot) on Benchmark Scenario variables of **p_land_yield_fact_1** with R = [0.7, 1.3] to be *bounds* on the sensitivity of *World3* to loss of insect pollinators of food crops.

For each Benchmark Scenario, on the platform described in Section 3.1, SystemModelPlot was applied to each (Modelica_variable, p_land_yield_fact_1) pair identified by SystemModelSimulateSensitivity, assuming R.

4. Results

SystemModelSimulateSensitivity identified 41 (Modelica_variable, **p_land_yield_fact_1**) pairs per Benchmark Scenario, yielding a total of 369 (Modelica_variable, **p_land_yield_fact_1**) pairs whose sensitivity was then analyzed by **SystemModelPlot**.

Figures 5 and 6 depict examples of the output of 369 sensitivity analyses generated by SystemModelPlot. In each of these Figures, the blue line corresponds to the effect of the default value of **p_land_fact_1** (= 1.0 in all the Benchmark Scenarios) on the indicated *Modelica*_variable. The green line corresponds to the effect of 1.3 times the default value **p_land_fact_1** on the indicated *Modelica*_variable. The orange line corresponds to the effect of 0.7 times the **p_land_fact_1** on the indicated *Modelica* variable.

How can these results serve as hypotheses that can inform "real-world" decision-making? Consider Figures 5 and 6. Both are cast in terms of *World3*-specific (here, *Modelica*-variable-name) nomenclature. We can translate that nomenclature to terms that are more familiar to policy stakeholders. **Population_Dynamics1.Pop_15_44.Integrator.y** represents population in the 15-44 year-old population cohort (Wolfram, 2019). Figure 5 indicates that, in Benchmark Scenario 1, the 15-44 year age group will peak at about 4.2 billion people at about Year 2030 (green line) if **p_land_yield_fact_1** = 1.3, or at about 3.4 billion people at about Year 2050 (orange line) if **p_land_yield_fact_1 =** 0.7. Figure 6 indicates that in Benchmark Scenario 9, there is no population collapse; rather, population in the indicated age cohort stabilizes at about Year 2030 at two rather different values – 2.2 billion at about Year 2020, versus 3.8 billion at about Year 2020, depending on the value of **p_land_yield_fact_1.**

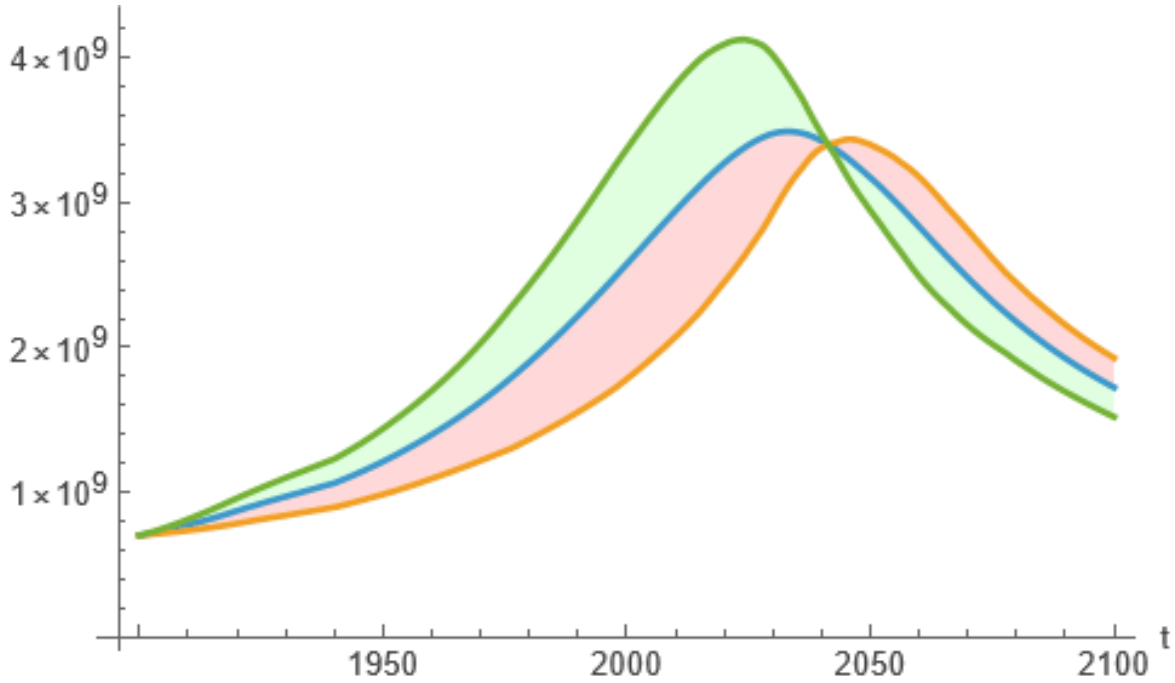


Figure 5. Benchmark Scenario 1. Sensitivity of Population_Dynamics1.Pop_15_44.Integrator.y obtained by varying p_land_yield_fact_1 from 0.7 to 1.3. The horizontal axis is simulated Year.

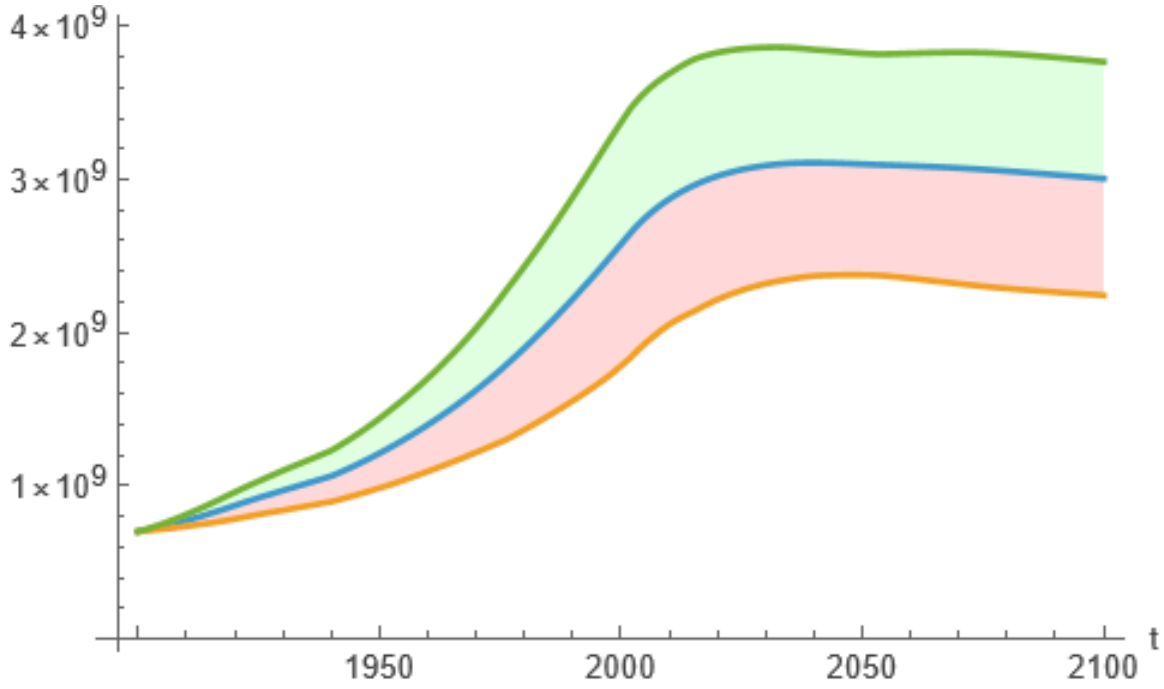


Figure 6. Benchmark Scenario 9. Sensitivity of Population_Dynamics1.Pop_15_44.Integrator.y obtained by varying p_land_yield_fact_1 from 0.7 to 1.3. The horizontal axis is simulated Year.

Now suppose that our primary population-resource policy objective is to avoid a population collapse (an example of which is shown by the green line in Figure 5). Figure 5 implies that, within Benchmark Scenario 1, even a 30% increase in insect pollinators will not avoid the population collapse – it can only offset the beginning of that collapse by at most 20 years. Put another way, the effect insect pollinators on population stability in Benchmark Scenario 1 is "in the noise", compared to the effects of the population overrun of food supplies. Similar population collapses occur, with the variation of **p_land_yield_fact_1** and **R** in each of Benchmark Scenarios 2 – 8 (see Horner (2025) for details.) In contrast, Figure 6 implies that within Benchmark Scenario 9 no population collapse will occur even if there is a 30% loss of land yield due to loss of insect pollinators of food crops. In Benchmark Scenario 9, the population in the age cohort noted stabilizes at about Year 2030 at two very different sizes (3.9 billion vs. 2.4 billion, depending on the value of **p_land_yield_fact_1**) *without engendering a population collapse*, depending on loss of land yield.

Collectively, these results imply that within the Benchmark Scenarios, a 30% loss of land yield caused by loss of insect pollinators of food crops does not affect whether the 15-44 year-old age cohort suffers a population collapse.

Figures 5 and 6, and the "policy-stakeholder"-language translations associated with those Figures can be abstracted to a translation rubric for any **SystemModelPlot** sensitivity analysis of *World3*. In outline, that rubric is:

- Obtain the policy-stakeholder-language narrative from Wolfram (2019) for a given Benchmark Scenario N, N = 1, 2, …, 9 (for example, N = 1 denotes Benchmark Scenario 1).
- From Wolfram (2019) obtain policy-stakeholder-language translations of the *World3* variables in play in a given sensitivity graph G (e.g., Figure 5) produced by **SystemModelPlot.**

- Interpret G in terms of the causal structure of *World3* as depicted in Figure 1-3 (p. 14) of Meadows et al. (1974).

5. Discussion

Which *World3* scenarios should be subsumed under the name "Benchmark" could be debated, but it's clear enough that the community of *World3* users has found the nine nominated as "Benchmark" in this paper to be a convenient reference. Meadows et al. (2004) describe a 10th scenario, which is Benchmark Scenario 9 with the sustainability policies of Benchmark Scenario 9 introduced 20 years earlier. The 10th scenario of Meadows et al. (2004) is not included in the current study. Cellier (2019) includes a 10th and 11th scenario, neither of which is identical to any of Benchmark Scenarios 1-9. As implemented in the *SystemModeler* framework, however, Scenarios 10 and 11 of Cellier (2019) will not compile on the platform described in Section 3.1 of this paper. For this reason, those two scenarios were excluded from further consideration. In any case, the Benchmark Scenarios used in this study are those designated "Scenario N", N = 1, 2, 3, …, 9 in Wolfram (2019).

World3 does not explicitly model insect-pollinator/population-resource dynamics. In the world *external* to *World3*, pollination services can differ across crops and regions, and climatic conditions, and these might result in the heterogeneous effects on land yield (in the world external to *World3*). As an alternative to the parameter-variation-based approach used in the present work, one could explicitly model the relations among insect-pollinator loss, land yield, and the *World3* sectors, by adding an explicit pollinator/land-yield model to *World3*. Such an approach, however, would not yield *World3* as such. The resulting software would therefore have to be calibrated and verified. The effort required to perform that calibration and verification would be at least as large as the effort expended by the *World3* user community to date to test and calibrate *World3* (thousands of person-years). Moreover, it is provably *impossible* for finite agents (such as humans) to verify that a given calibration/test regimen of *World3* is at least as comprehensive as another (Horner and Symons, 2019).

The total wall-clock time to execute all 369 sensitivity analyses documented in Horner (2025) was approximately 135 minutes on the platform described in Section 3.1. The application code used in this study, and a PDF export of the results of running that code, are available at Horner (2025).

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APPENDIX 1

List of *World3* variables identified by SystemModelSimulateSensitivity that could affect variation in parameter p_land_yield_fact_1 in Benchmark Scenario 1. The list of the variables is the same for all Benchmark Scenarios. The meanings of these variables can be found in Meadows et al. (1974) and Wolfram (2019).

{Arable_Land_Dynamics1.Arable_Land.Integrator1.y, p_land_yield_fact_1},

{Arable_Land_Dynamics1.Pot_Arable_Land.Integrator1.y, p_land_yield_fact_1},
{Arable_Land_Dynamics1.Urban_Ind_Land.Integrator1.y, p_land_yield_fact_1},
{Food_Production1.Agr_Inp.Integrator1.y, p_land_yield_fact_1},
{Food_Production1.P_Land_Yield_Fact_2.Smooth1.Integrator1.y, p_land_yield_fact_1},
{Food_Production1.P_Land_Yield_Fact_2.Smooth2.Integrator1.y, p_land_yield_fact_1},
{Food_Production1.P_Land_Yield_Fact_2.Smooth3.Integrator1.y, p_land_yield_fact_1},
{Food_Production1.Perc_Food_Ratio.Integrator1.y, p_land_yield_fact_1},
{Human_Fertility1.Avg_Ind_Out_PC.Smooth_of_Input.Integrator1.y, p_land_yield_fact_1},
{Human_Fertility1.Del_Ind_Out_PC.Smooth1.Integrator1.y, p_land_yield_fact_1},
{Human_Fertility1.Del_Ind_Out_PC.Smooth2.Integrator1.y, p_land_yield_fact_1},
{Human_Fertility1.Del_Ind_Out_PC.Smooth3.Integrator1.y, p_land_yield_fact_1},
{Human_Fertility1.Fert_Cont_Facil_PC.Smooth1.Integrator1.y, p_land_yield_fact_1},

{Human_Fertility1.Fert_Cont_Facil_PC.Smooth2.Integrator1.y, p_land_yield_fact_1},
{Human_Fertility1.Fert_Cont_Facil_PC.Smooth3.Integrator1.y, p_land_yield_fact_1},
{Human_Fertility1.Perc_Life_Expectancy.Smooth1.Integrator1.y, p_land_yield_fact_1},
{Human_Fertility1.Perc_Life_Expectancy.Smooth2.Integrator1.y, p_land_yield_fact_1},
{Human_Fertility1.Perc_Life_Expectancy.Smooth3.Integrator1.y, p_land_yield_fact_1},
{Industrial_Investment1.Industrial_Capital.Integrator1.y, p_land_yield_fact_1},
{Labor_Utilization1.Labor_Util_Fr_Del.Integrator1.y, p_land_yield_fact_1},
{Land_Fertility1.Land_Fertility.Integrator1.y, p_land_yield_fact_1},
{Land_Fertility1.Yield_Tech_LYTD.Integrator1.y, p_land_yield_fact_1},
{Life_Expectancy1.Eff_Hlth_Serv_PC.Smooth_of_Input.Integrator1.y, p_land_yield_fact_1},
{NR_Resource_Utilization1.NR_Resources.Integrator1.y, p_land_yield_fact_1},
{NR_Resource_Utilization1.P_Nr_Res_Use_Fact_2.Smooth1.Integrator1.y, p_land_yield_fact_1},
{NR_Resource_Utilization1.P_Nr_Res_Use_Fact_2.Smooth2.Integrator1.y, p_land_yield_fact_1},
{NR_Resource_Utilization1.P_Nr_Res_Use_Fact_2.Smooth3.Integrator1.y, p_land_yield_fact_1},
{NR_Resource_Utilization1.Res_Tech_NRTD.Integrator1.y, p_land_yield_fact_1},
{Pollution_Dynamics1.PPoll_Appear_Rate.Smooth1.Integrator1.y, p_land_yield_fact_1},
{Pollution_Dynamics1.PPoll_Appear_Rate.Smooth2.Integrator1.y, p_land_yield_fact_1},
{Pollution_Dynamics1.PPoll_Appear_Rate.Smooth3.Integrator1.y, p_land_yield_fact_1},
{Pollution_Dynamics1.PPoll_Tech_PTD.Integrator1.y, p_land_yield_fact_1},
{Pollution_Dynamics1.P_PPoll_Gen_Fact_2.Smooth1.Integrator1.y, p_land_yield_fact_1},
{Pollution_Dynamics1.P_PPoll_Gen_Fact_2.Smooth2.Integrator1.y, p_land_yield_fact_1},
{Pollution_Dynamics1.P_PPoll_Gen_Fact_2.Smooth3.Integrator1.y, p_land_yield_fact_1},
{Pollution_Dynamics1.Pers_Pollution.Integrator1.y, p_land_yield_fact_1},
{Population_Dynamics1.Pop_0_14.Integrator1.y, p_land_yield_fact_1},
{Population_Dynamics1.Pop_15_44.Integrator1.y, p_land_yield_fact_1},
{Population_Dynamics1.Pop_45_64.Integrator1.y, p_land_yield_fact_1},
{Population_Dynamics1.Pop_65plus.Integrator1.y, p_land_yield_fact_1},
{Service_Sector_Investment1.Service_Capital.Integrator1.y, p_land_yield_fact_1}