Case Study for AEO Using
T21 Malawi Model

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September 2005

I. Introduction

Malawi is a relatively small, landlocked and southern African country with many challenges to reducing poverty, protecting its environment and increasing development prospects. Much of its population lives below the absolute poverty line. As a landlocked state, Malawi faces particular challenges to promoting development and getting access to external markets. One challenge is balancing sustainable agricultural development (to raise rural incomes) while promoting modern industrial development. Malawi's goals include improving the standard of living of its people and reaching the MDGs, in addition to raising measured average income per capita.

The government of Malawi is currently employing Millennium Institute's (MI) Threshold 21 (T21) model to strengthen its capacity to sustain and monitor a viable and broadly supported strategy for national development. Currently, the Ministry of Economic Planning and Development and the Ministry of Finance are building capacity by using and further customizing the T21 model (Mr. Shadrack Malenga from MEPD and Mr. Wavisanga Munyenyembe from MOF). For a previous report on Malawi T21 work, see Appendix A.

UNEP is currently assisting the African Ministerial Conference on the Environment (AMCEN) to prepare the second Africa Environment Outlook (AEO-2) report. It will use T21 Malawi as a case study to support the AEO scenario development process.

Based on AEO scenario requirements, T21 Malawi was upgraded and expanded, with additional data, in order to provide this quantitative case study within time and resource constraints.

II. Current and historical conditions of Malawi

Data was collected from Malawi and several international sources. The T21 Malawi model was first calibrated to generate a historical (1990 – 2004) picture of the country, and in the process the consistency of data was tested. When data were inconsistent from sources, we used data from local sources first, when available.

The current and historical conditions and driving forces for AEO-2 analysis are briefly presented in this section.

1. Demographics

Total population increased from 9.4M in 1990 to 11.7M in 2004, with an average annual increase of 1.5%. The relatively slow increase is partly due to rising AIDS deaths. A closer look at the age-cohort pyramid reveals a strong potential for further population growth in the future. The urban population almost doubled between 1990 and 2002, from 13.3% to 26.0%.

2. Social

The adult literacy rate improved for both genders and the gender gap seems to have narrowed. In 2004, the rate was about 57% for women and 71% for men. The HIV adult prevalence rate has grown rapidly since 1990, reaching about 19%, in 2004. As a result, in 2004 about 800,000 adults died of AIDS and 400,000 were AIDS orphans (defined as below the age of 15 with the mother having died of AIDS). Average life expectancy rose slowly but only to a level of about 42 years, in 2004.

Access to safe drinking water improved slowly in both urban and rural areas, about 85% and 50%, respectively. Adequate sanitation coverage also improved very slowly, about 5% in rural and 12% in urban areas, in 2004.

Infant and under-5 mortalities were high at about 150 and 270, respectively. The total fertility rate was about 5.7 in 2004.

Much of the population lived below the absolute poverty line in 2004, 40% in urban and 80% in rural areas. The Gini coefficient is estimated at 0.51 in urban areas and 0.39 in rural.

Food security improved, but at a low level. In 2004, the national average daily calorie intake was below 1800.

3. Economics

Real GDP in local currency increased about 2.4% per year between 1990 to 2004, reaching about 14.6B in 1994 Malawian Kwachas (MK). The nominal exchange rate for 1994 was 8.7MK to $1 USD. Per capita GDP in 2004 was under $200. Given the PPP value of 3, the real purchasing power per capita was below $600.

Formal employment in industry and services was low, and over half of the urban labor force were in the informal sector. In rural areas, about 75% of the labor force were subsistence farmers.

Public foreign debt in 2004 was close to $4B USD, and public domestic debt was about 40B MK (nominal exchange rate for 2004 is 95 MK to $1 USD). Official foreign grants between 1990 – 2004 varied between $100-200M USD per year. Foreign direct investment was negligible.

The government had been trying to spread the SASAKAWA agriculture technology and increase irrigation, but due to limited financial support, the progress was slow. In 2004, irrigated land increased to about 40,000 hectares, only 1.3% of total crop land.

4. Land

Land is divided into five categories in T21: Agriculture, forest, settlement, fallow, and waste. In 2004, agricultural land, or cropland, increased to about 3M hectares to meet food demand. Of these hectares, it is estimated 25% were degraded.

In 2004, forest land declined to about 2.5M hectares. Annually, the government planted trees in 10,000 to 20,000 hectares but only 20% or so survived.

In 2004, settlement land increased with the population to about 460,000 hectares.

Fallow land includes grazing land for livestock, natural reserves and land usable for growing trees or grass, or that can be converted to agriculture (crop) land. It is estimated that in 2004, there were about 1M hectares of fallow land, 56% of which was degraded.

Waste land includes desert and other severely degraded land that is not usable for planting, without heavy investment. In 2004, such land was about 720,000 hectares.

The portion of degraded land, including degraded agriculture and fallow land, and all settlement and waste land accounts for about 26.5% of the national land area in 2004.

5. Water

Internally produced water (rainfall minus evaporation) totals about 17B tons per year. The annual sustainable water supply is much less, about 1.56B tons, assuming that 10% of surface water can be withdrawn and utilized. In 2004, total water demand was about 1B tons, so generally speaking, Malawi does not yet lack water resources, except during dry seasons. In 2004, domestic water use was about 26%, agricultural water use was 72%, and industry water use was only 2%.

Biochemical oxygen demand (BOD) pollutants are modeled in T21 to represent the surface water pollution conditions in Malawi. BOD pollutants come from three sources: sewage, agriculture runoff, and industry. In 2004, BOD pollutants entering surface water from sewage were about 183,000 tons; agriculture BOD pollutants were about 24,000 tons; and industry BOD pollutants 3,500 tons. Together, these account for 87%, 11%, and 2%, respectively.

6. Air

Malawi has rich coal reserves and good hydropower facilities but it has not found any oil or natural gas. In 2004, the country produced 76,000 tons of coal, more than it needed, and generated 1.1B KWH from hydropower, which met most of its domestic electricity demand.

Malawi relied on oil imports to meet its demand on transportation fuel, fuel for some electric power generation and for some household lighting and cooking. In 2004, oil imports totalled 260M liters.

Fuel wood demand was about 3.7M tons in 2004, which contributed to deforestation and emissions, especially SPM emissions in indoor conditions which are harmful to health.

On the national level and per capita level, Malawi still produces a low level of emissions. In 2004, Fossil fuel CO2 emissions were less than 1M tons while total greenhouse gas emissions in CO2 equivalent, including emissions from deforestation and the NOx and CH4 conversions, reached 17M tons.

In 2004, SPM emissions were about 0.11M tons, and SOx emissions from fossil fuels were about 2.7 thousand tons.

III. The four AEO scenarios

We have discussed the past and the present. What will the future be like for Malawi?

AEO developed the four scenarios below to describe possible futures. These four scenarios were used in the T21 Malawi model to generate pictures of Malawi for the years 2005 – 2025. The four scenarios are:

1. Fortress World: Domestically there is struggle and division between the rich and the poor. The government serves the rich and powerful and oppresses the poor majority. Globally, there is tension between the North and South, and within regions neighboring countries are divided and not cooperating.

2. Market Forces: Market forces start to play a strong role in breaking the Fortress World scenario and in generating quick returns, which result in faster growth in some sectors and more investment in places where there is profit, especially over the short term. Government control and supervision is weak. There is a growing gap between the rich and poor, and there is possibly a faster environmental degradation and resource depletion due to short-term profit-seeking activities.

3. Policy Reform: The government works with the market forces and implements policies in economic development, social planning, and environmental protection, such as improving infrastructure to support private sector and foreign investors, investing in domestic poverty reduction, and supporting national environmental protection. Comprehensive and coordinated government action is taken for sustainable land and water management. However, government capacity (general) may be constrained by limited resources and possibly bureaucracy (such as additional steps for private investors to get permits.)

4. Great Transitions: Reaching the MDGs becomes the driving force of all parties, including the government, private sector, civil society, donors, and the outside world. Progress in

social, economic, and environmental development is balanced and positive. There is harmony:

- between domestic rich and poor, and the gap is shrinking;
- between the government and the private sector, and the government is clean and efficient;
- between North and South where appropriate technologies are transferred to the South at an accelerated pace and the North, also, learns from the South;
- within regions, and countries cooperate on issues of economic development, social justice, and environmental protection;
- between donors and domestic parties, and foreign support and investment for achieving the MDGs is more abundant; and
- culture and values shift away from materialism toward sustainability.

IV. Major assumptions in T21 for the scenarios

Based on the narrative presentation of the four scenarios, a series of assumptions were made in T21. These assumptions are grouped into five categories: economy, society, land, water, and air.

1. Economy

Investment efficiency. Historically, investment efficiency in Malawi has been low, even compared to other developing countries. It will remain low for the Fortress World scenario but will be high for the Market Force and Great Transition scenarios (to the level of an 'average' to 'advanced' developing country). For the Policy Reform scenario, efficiency is in the middle.

Agriculture extension to promote SASAKAWA and irrigation to help the rural poor. This will receive incremental support from the government in the following sequence of scenarios: Fortress World, Market Force, Policy Reform, and Great Transition.

Urban micro-credit programs to help the urban poor. There are no micro-credit programs in the Fortress World and Market Force scenarios, but micro-credit programs are implemented in the Policy Reform scenario, and further strengthened in Great Transition.

Skills training to help the poor and improve productivity. This will receive incremental support from the government in the following sequence of scenarios: Fortress World, Market Force, Policy Reform, and Great Transition.

Official grants from donors. The government will receive low foreign grants in the Fortress World scenario, more in Market Force, still more in Policy Reform, and the most in Great Transition.

Foreign direct investment will increase in the same order as official grants.

2. Social

Effectiveness of HIV prevention programs. HIV will continue to spread in the Fortress World and Market Force scenarios. By Policy Reform, the infection rate will decrease, and under Great Transition will improve the most (with lowest infection rate).

The fertility rate. In 2004, the total fertility rate was high at about 5.63. With development and education, this rate is expected to fall gradually. In Fortress World, the rate will fall to 5.23, in 2025. In Market Force, it will be 4.23, in 2025. In Reform, it will be 3.23, and in Great Transition it will be 2.23, by 2025.

3. Land

Different land policies (or lack of them) will be implemented in each scenario. Policies will cover a wide range of issues including land reform, land tenure, and land management. Policies will affect land degradation and the maintenance of irrigation facilities. Market Forces will accelerate land degradation and perform poorly in maintaining irrigation facility. Fortress World slows land degradation over Market Force but performs equally poor in maintaining irrigation facility. The Policy Reform scenario protects land from degradation and enhances the life of irrigation facilities. Great Transition performs better than Policy Reform.

Forest loss is due to 1) logging for wood fuel and commercial uses, and 2) forest land conversion to other use, such as settlement and farming. In the past, it is estimated about 10,000 hectares are converted each year. This trend continues in Fortress World. In Market Force, this situation gets worse as more forest land is converted. Policy Reform slows this conversion and Great Transition stops it, entirely.

In the past, the Malawian government made a limited, but consistent, effort to plant trees to re-build their forests. Each year, about 10,000 hectares were planted with a survival (success) rate of about 20%. In Fortress World, the effort continues at the same survival rate. In Market Force the effort is more effective, reaching a 40% survival rate. In Policy Reform and Great Transition the success rate jumps to 60% and 80%, respectively.

4. Water

Technology that improves the efficiency of water use is not available in the Fortress World scenario. In Market Force it is available but not widely used. In Policy Reform the technology is spread out faster and wider. In Great Transition it is spread the farthest.

The government has made efforts to promote adequate sanitation in rural and urban areas, but with limited progress. In Fortress World, the sanitation situation does not improve from 2004 levels. With the other scenarios, the coverage of adequate sanitation improves a little for Market Force, more for Policy Reform and the most for Great Transition.

It is assumed that access to safe drinking water consists of two parts: those who use water from treated water, ground water, or bottled water, and the rest who use water from surface water. Water that is treated, ground or bottled is assumed safe and clean. Only a limited percentage of

the population has access to this water. The remaining population uses surface water, including water from rivers, lakes, and reservoirs, which can be easily polluted. The percentage of surface water that is still safe to drink is related to the amount of pollutants (only BOD in the current version of T21 Malawi) in surface water. The higher the average pollutant concentration, the lower the percentage of surface water that is still safe to drink. Pollutants are from sewage, agriculture runoff and industry discharge.

Safe water coverage for the first part is assumed low for Fortress World, a bit higher for Market Force, still higher for Policy Reform, and highest for Great Transition.

The national average of access to safe drinking water is calculated using the coverage of clean water for the first part and the percentage of safe surface water from the second part.

5. Air

The availability of technology that increases the efficient use of energy is assumed to exist at very low levels in the Fortress World scenario. These levels will improve in Market Force, improve more in Policy Reform and improve the most in Great Transition. When energy efficiency technology is high, it takes less energy (fossil fuel, electric, or wood fuel) to generate the same results.

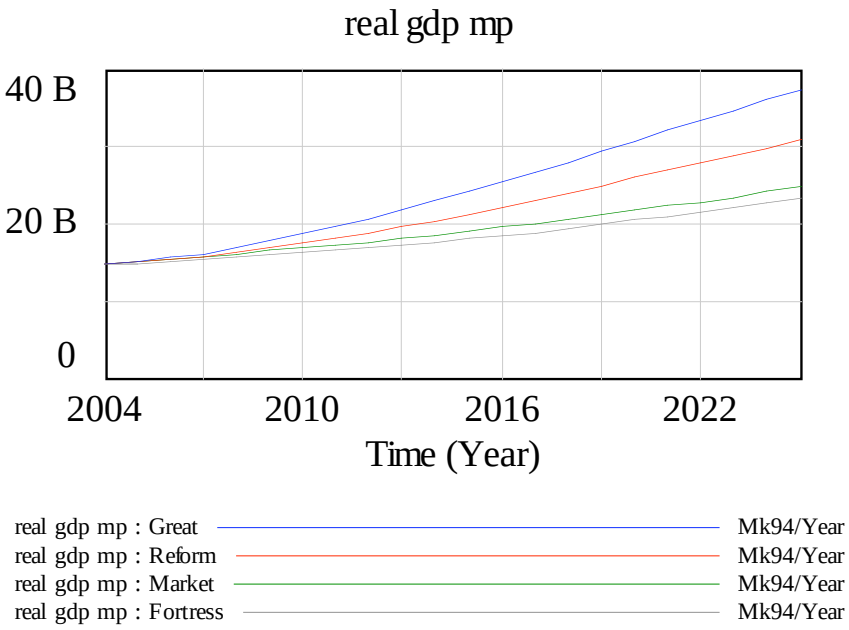
Investments in renewable energy are expected to follow the same path as energy efficiency technology: very low for Fortress World, higher in Market Force, higher in Policy Reform and highest for Great Transition. The generation of higher renewable energy would better support domestic industry and, possibly, generate some power for export.

V. Major results of the four scenarios from T21

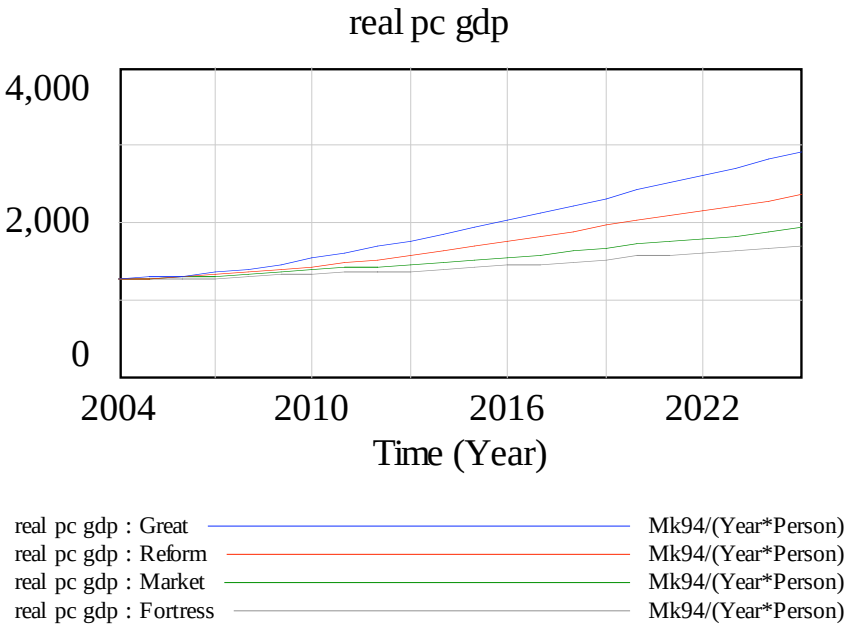
In this section we present major results for all four scenarios, with one indicator in each graph. The indicators are classified into five groups: economy, society, land, water, and air. A brief description or analysis precedes each graph. The numeric values of the indicators can be observed in the model and be copied to an Excel file.

1. Economy

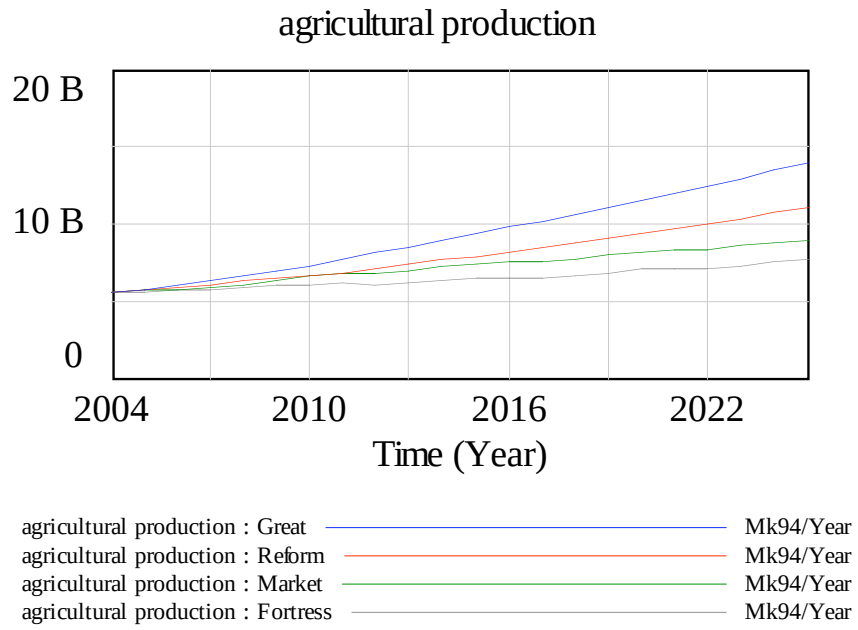
Real GDP is highest in the Great Transition scenario and the lowest in Fortress World. In 2025, the former is 61% higher than the latter. Market Force is not expected to generate added value to the country. In Market Force, many factors will contribute to its failure: the private sector will not be mature enough to compete in the international market; it lacks human, technological, and financial resources; and it lacks infrastructural (physical, legal, and cultural) support from the government and society. Cultural changes toward consumerism, brought by Market Force, could slow GDP growth as more consumption leaves less money for investment.



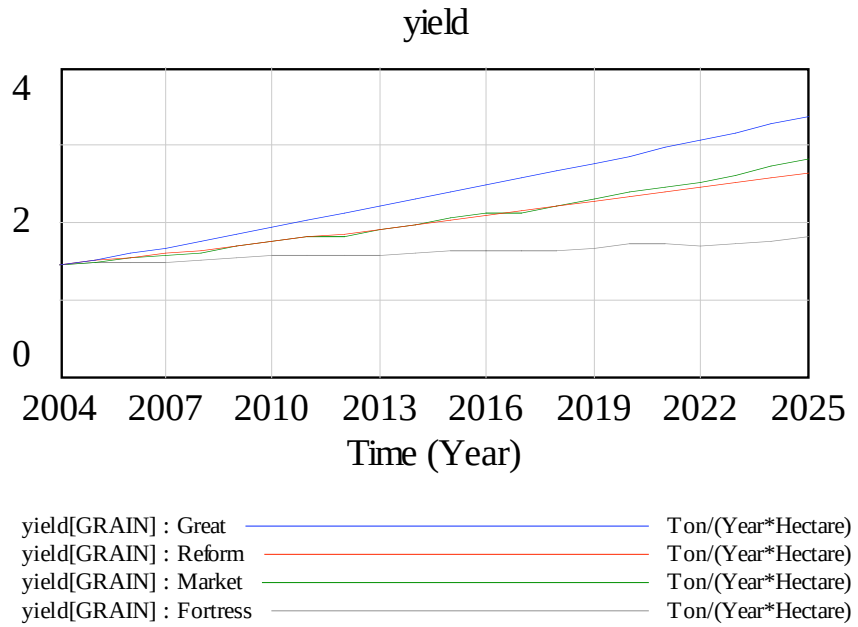
The difference for real per capita GDP is even greater due to population difference: In 2025, Great Transition is 73% higher than Fortress World.



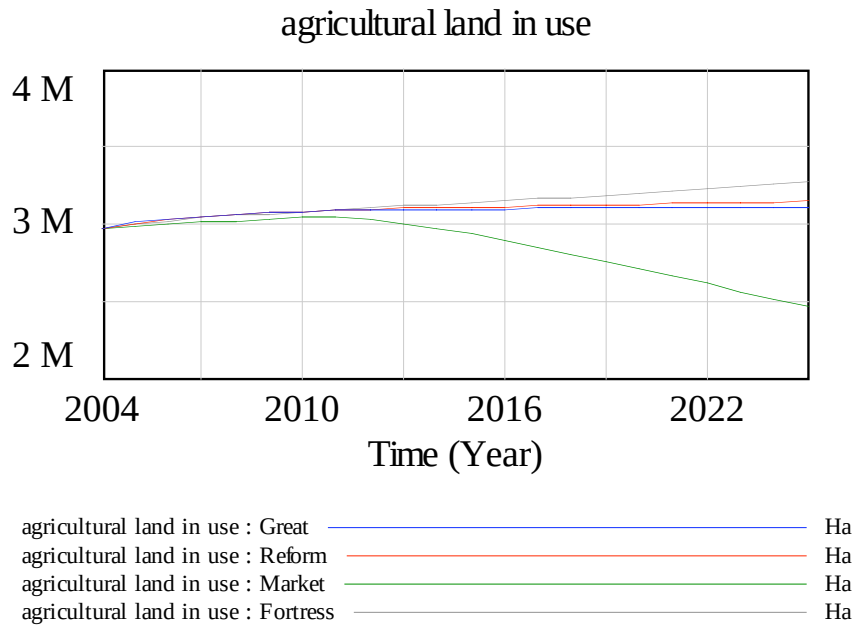
Agricultural production, which is vital for food security, is shown in the following graph. The Market Force scenario does not perform very well.



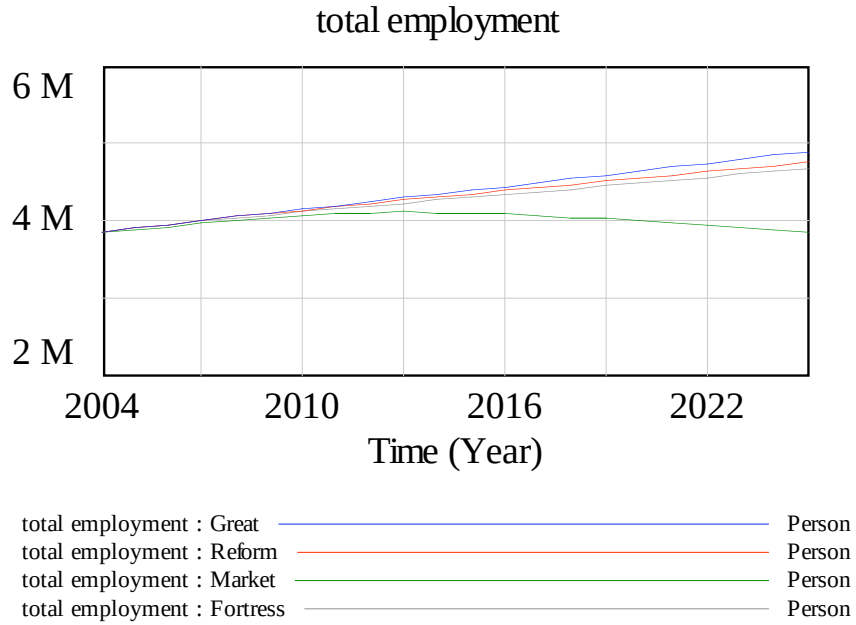
The major components of agriculture production are yield and harvested area. A further look into yield shows that Market Force produces a quite high yield, even higher than Policy Reform.



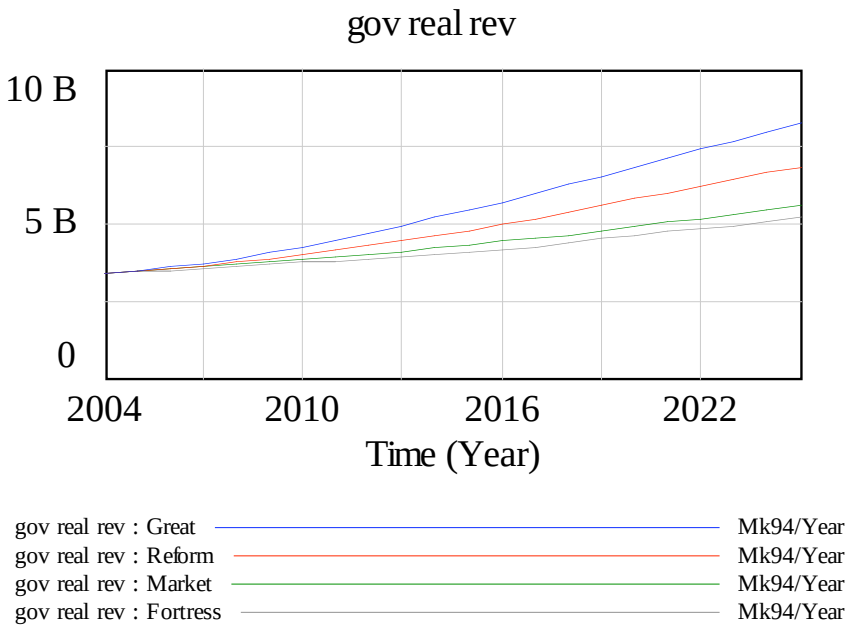
Harvested area, or agriculture land, is shrinking in the Market Force scenario due to short-term profit-seeking farming practices that bring degradation quickly to crop land.



Total employment is lowest in the Market Force scenario, due primarily to shrinking employment in the agriculture sector, due to loss of agriculture land.

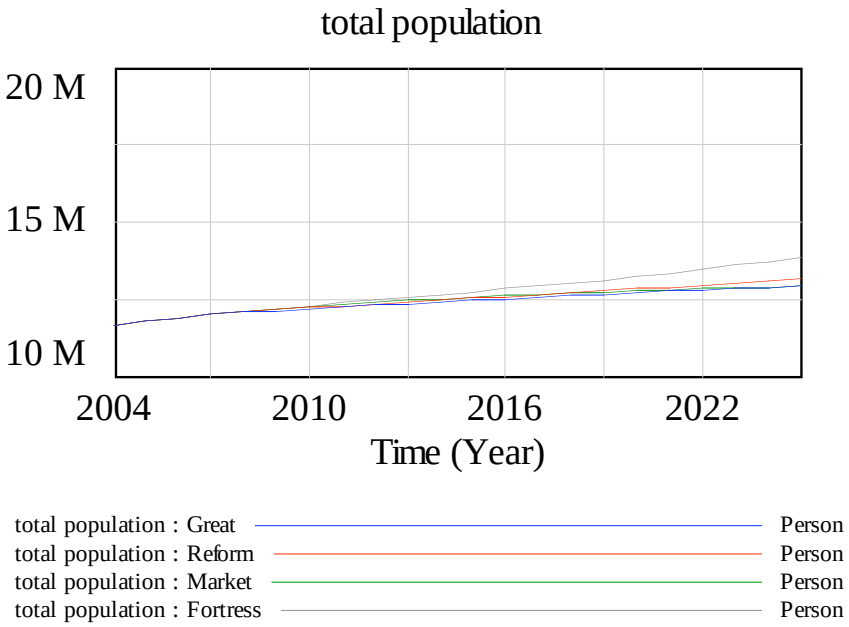


Government real revenues grow in proportion to real GDP growth, as shown in the next graph.



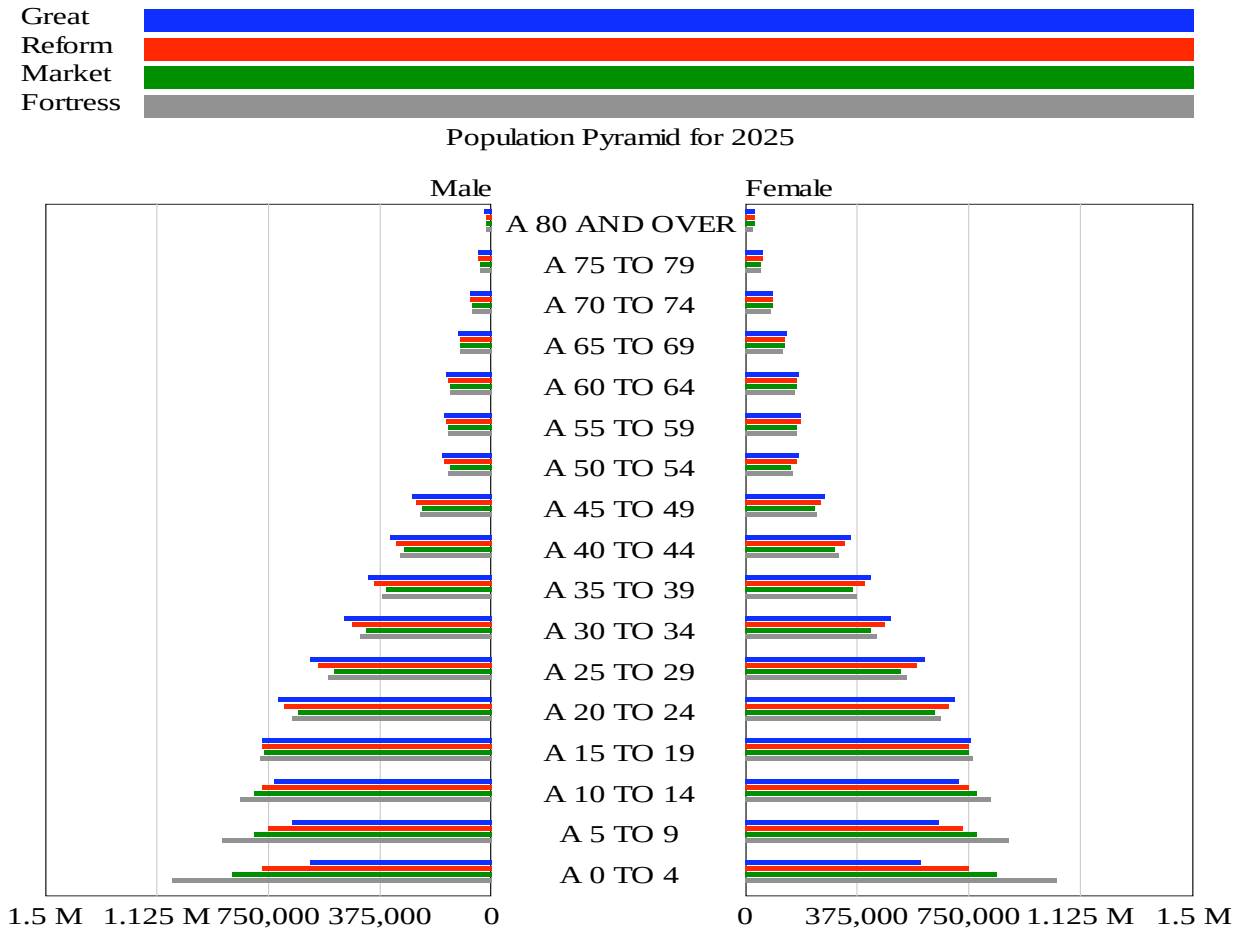
2. Social

Total population will continue to grow in all the scenarios. In Fortress World, it will grow the fastest. The other three scenarios seem to generate similar numbers.

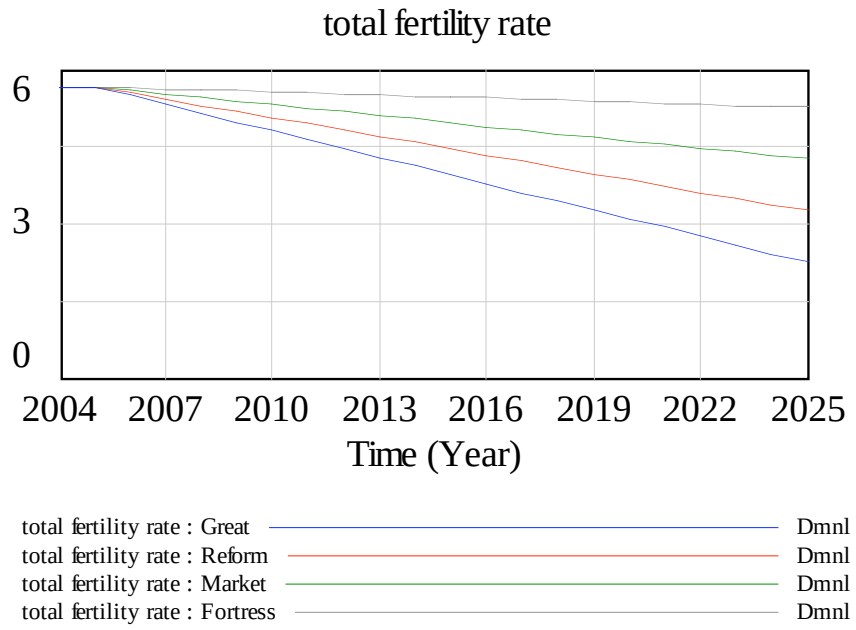


The next graph shows the population according to age structure. Great Transition has more middle-aged people, due to a longer life expectancy and fewer AIDS deaths, but shows fewer children due to a lower fertility rate. With such an age structure, Great Transition has a small

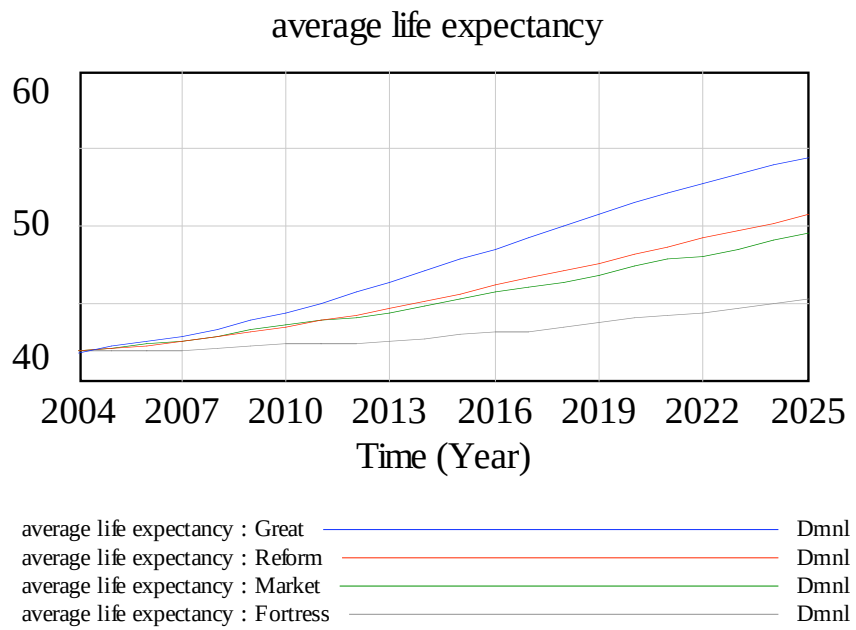
potential for further population growth beyond 2025. The situations for Market Force and Fortress World are the opposite.



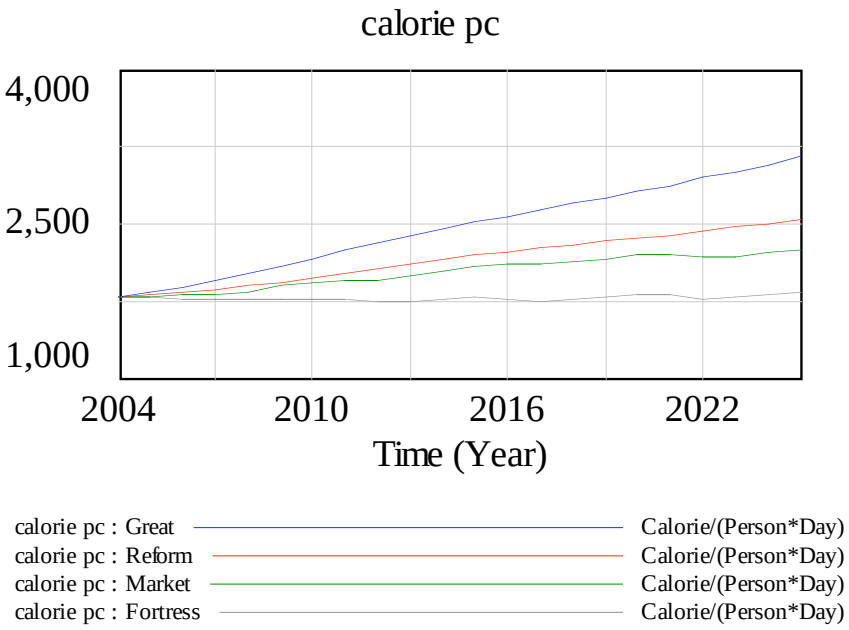
Total fertility rate is shown in the next graph.



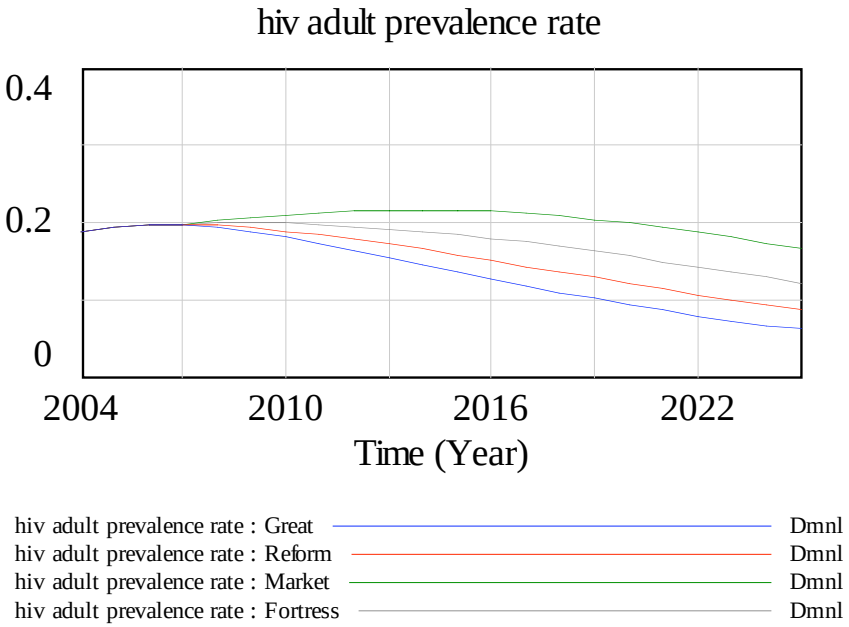
Average life expectancy will grow to about 54 in 2025 for Great Transition, but will only be 45 in Fortress World.



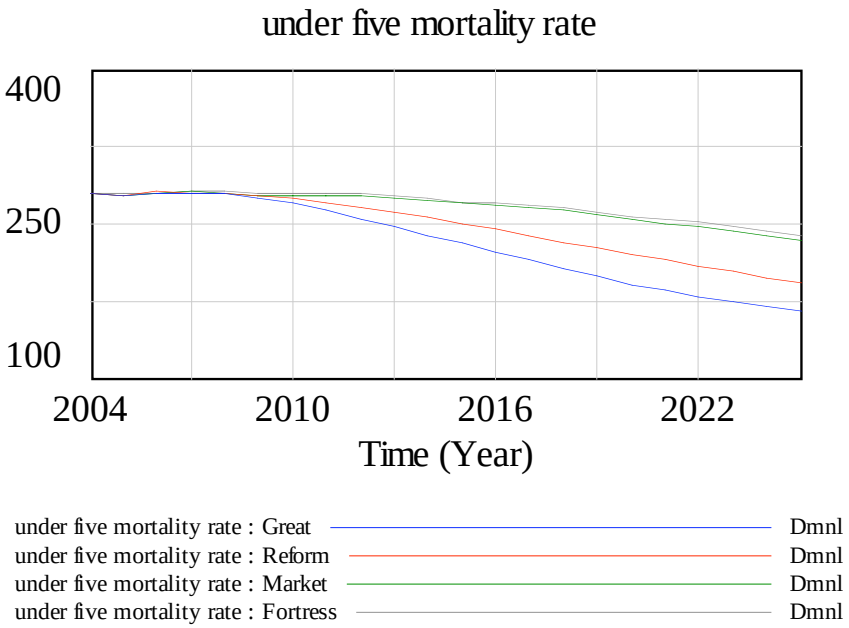
Nutritional status, measured by per capita daily caloric intake, is seen in the next graph.

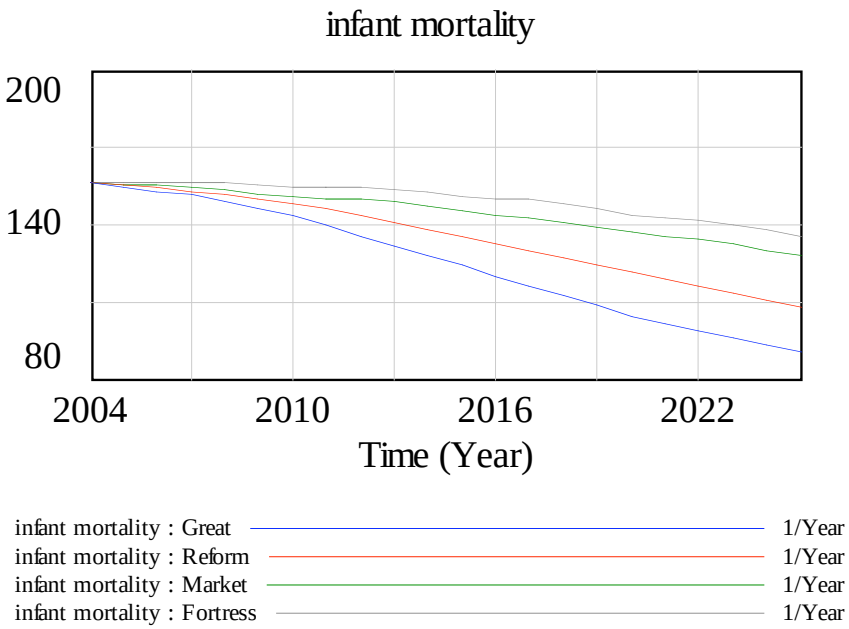


The adult HIV prevalence rate is in the next graph. Market Force has the highest (worst) rate.

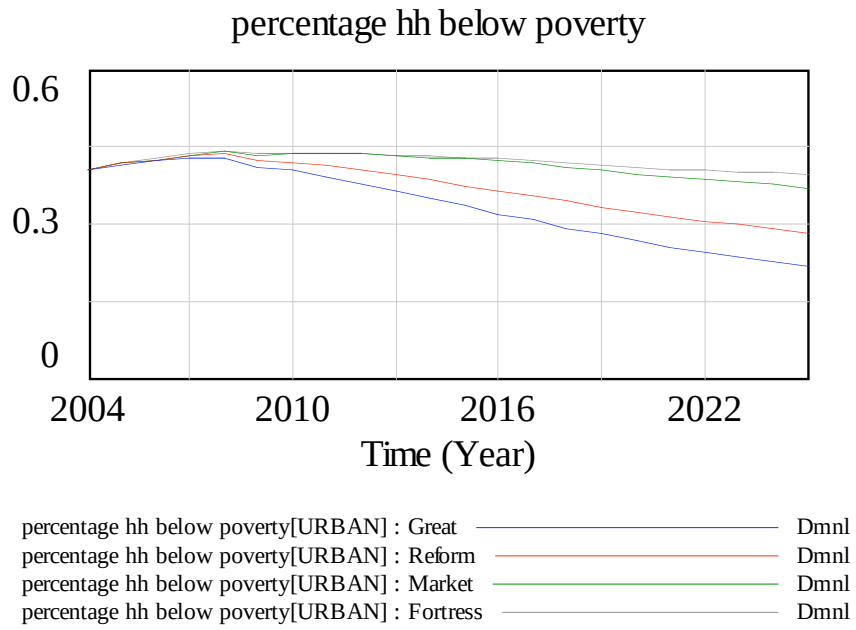


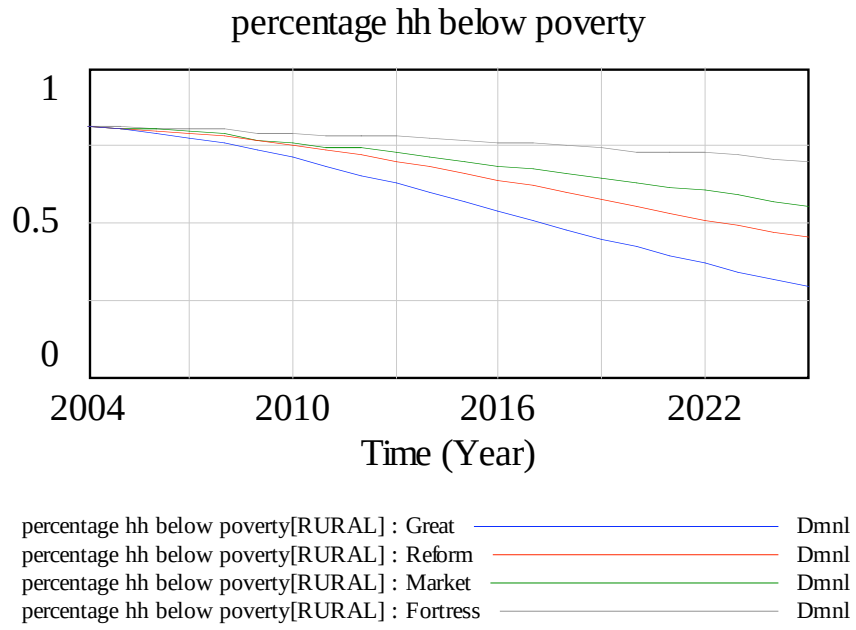
The ‘under age five’ mortality rate and infant mortality rate are influenced by many factors: income, access to safe drinking water, nutrition, access to basic health care, adult HIV infection rate, and adult literacy. These trends are shown in the next two graphs.





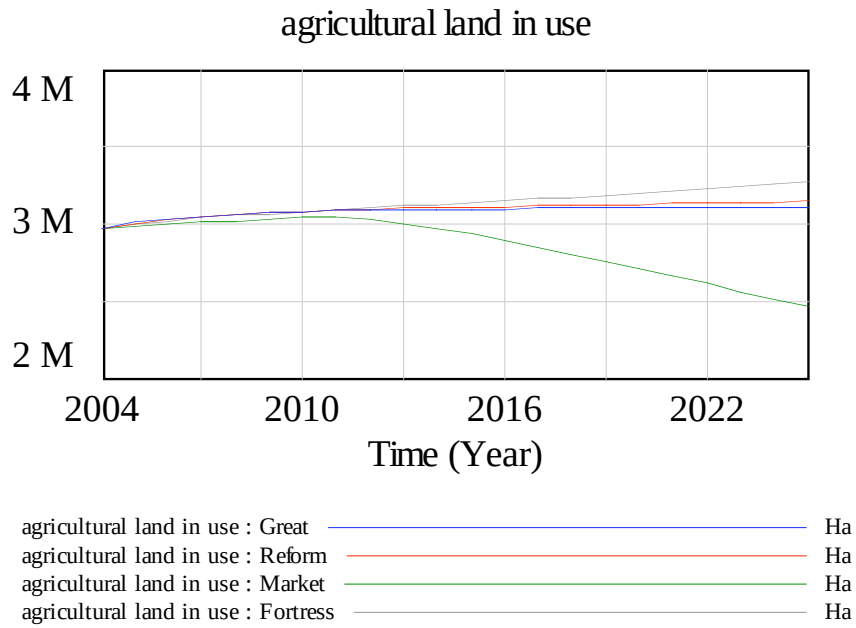
The percentage of households (hh on graph) below the poverty line in urban and rural areas is shown below. The poverty line is $1 USD day/per person in PPP. It is assumed the PPP value in Malawi is 3, from 2004 – 2025. The rise in urban poverty from 2004 – 2007 is the result of a rapid increase in the urban population with stagnant income during the same period.



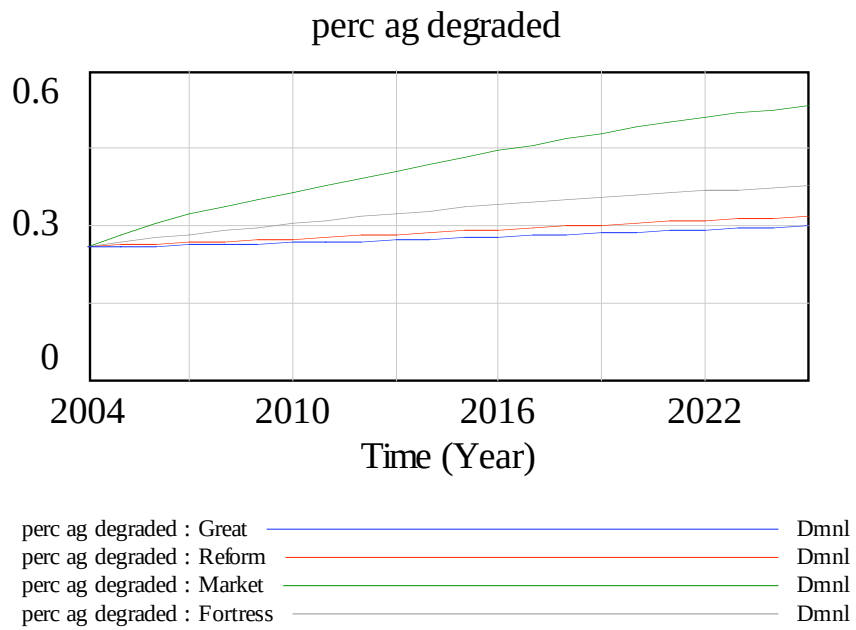


3. Land

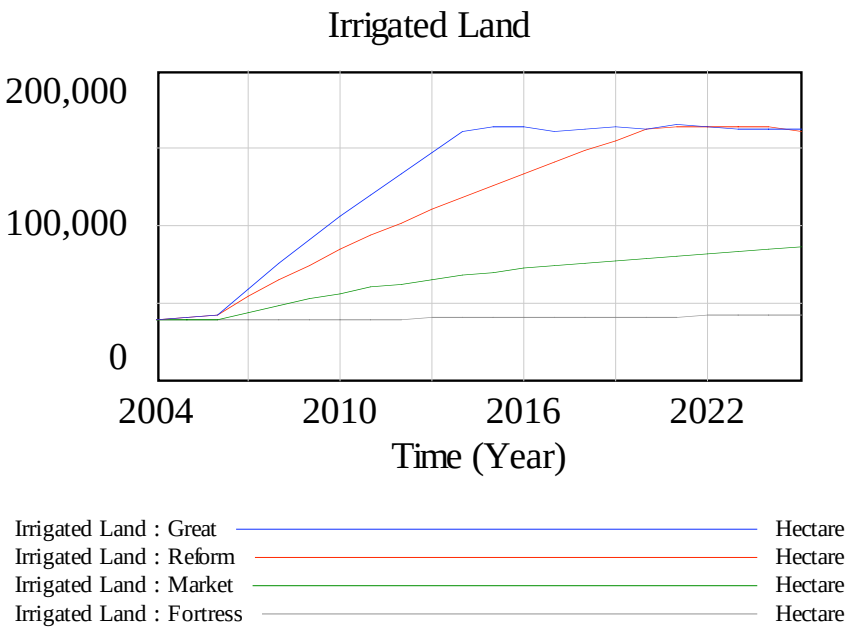
Agricultural land in the Market Force scenario is decreasing due to severe degradation as more and more crop land is converted to highly and extremely degraded land. This is the result of intensified agricultural practices driven by profit goals.



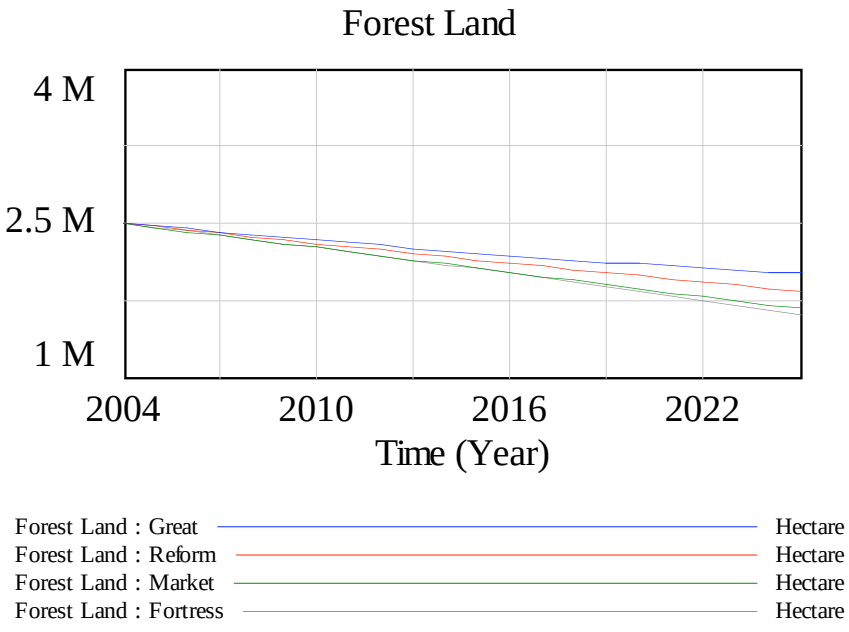
In the above graph, the availability of higher agricultural land in Fortress World is the result of greater pressure from the population for food. This increase is not sustainable, as can be seen from the next graph. Market Force has the highest degraded percentage, followed by Fortress World.



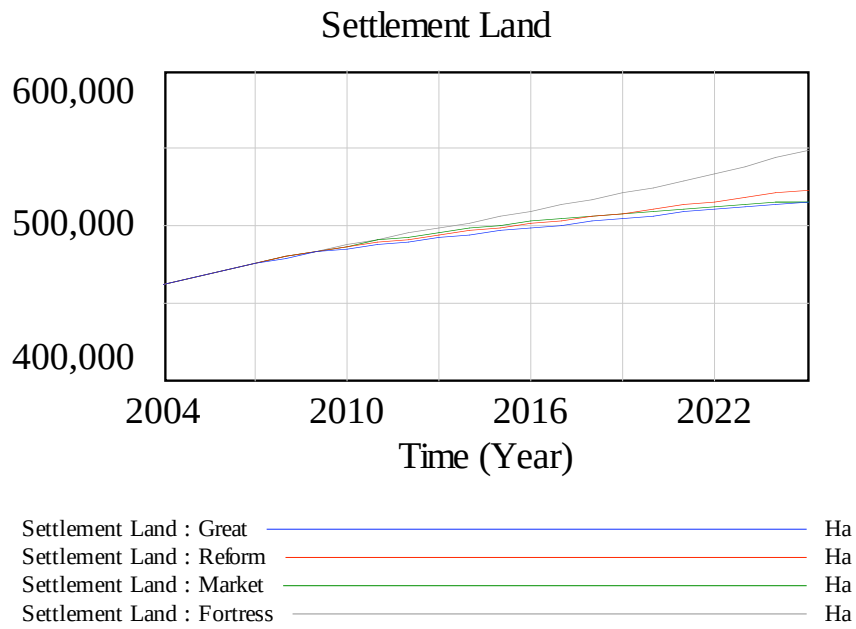
Irrigated land increases quickly in Policy Reform and Great Transition, but after reaching the irrigation potential of 160,000 hectors (from Aquastat of FAO), further expansion is limited.



Forest land changes with human planting (positive) and forest loss (negative). Great Transition has the highest human planting survival rate and the lowest forest loss, while Fortress World shows the opposite. The result is that Great Transition shows the largest supply of forest land, and Fortress World shows the smallest.

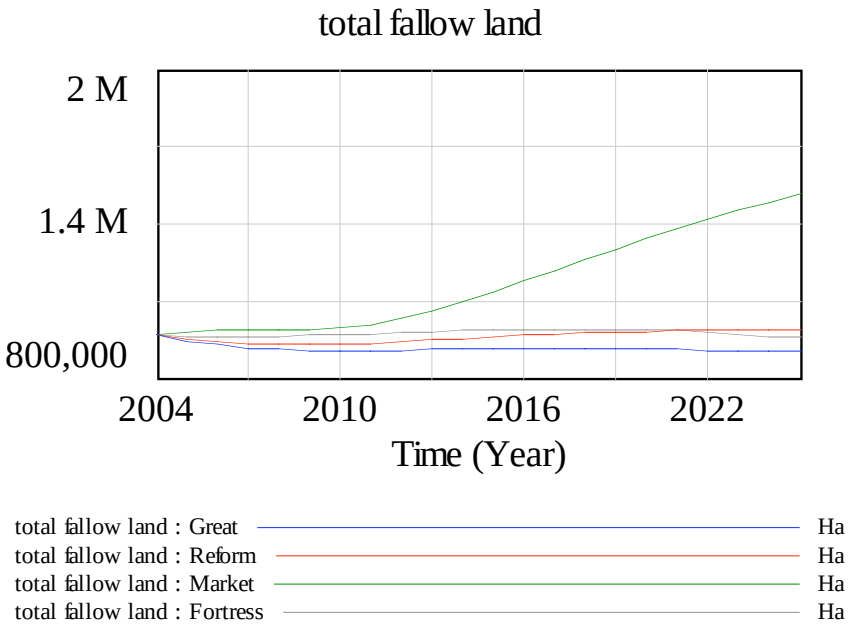


Settlement land is driven by population size in the next graph.

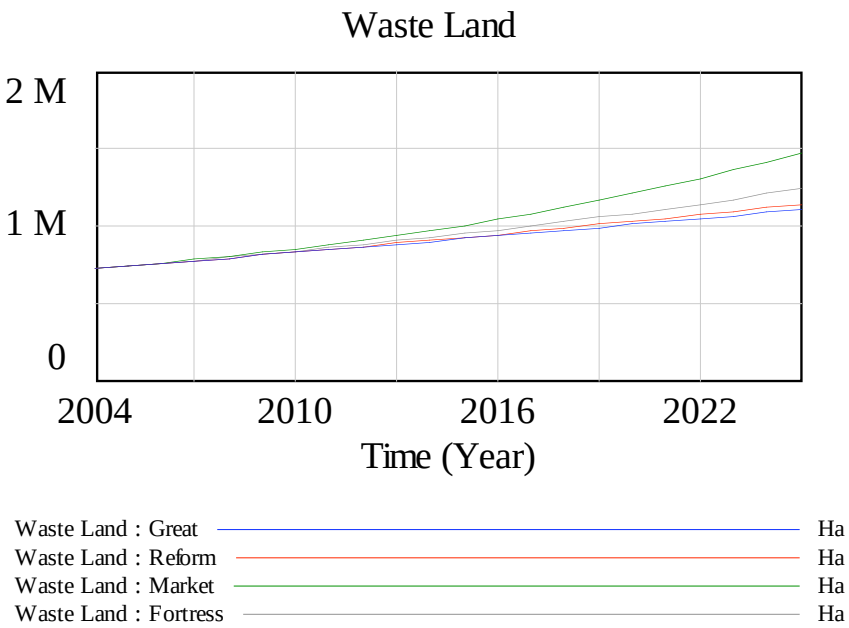


Fallow land is divided into two parts: cultivable and degraded. Cultivable fallow land can be converted to crop land when food demand grows or it can be used for planting trees. When crop land is degraded to the extent that it is no longer good for farming, it becomes degraded fallow land. When trees are first cleared, the deforested land becomes cultivable fallow land. Degraded fallow land can be further degraded to become waste land.

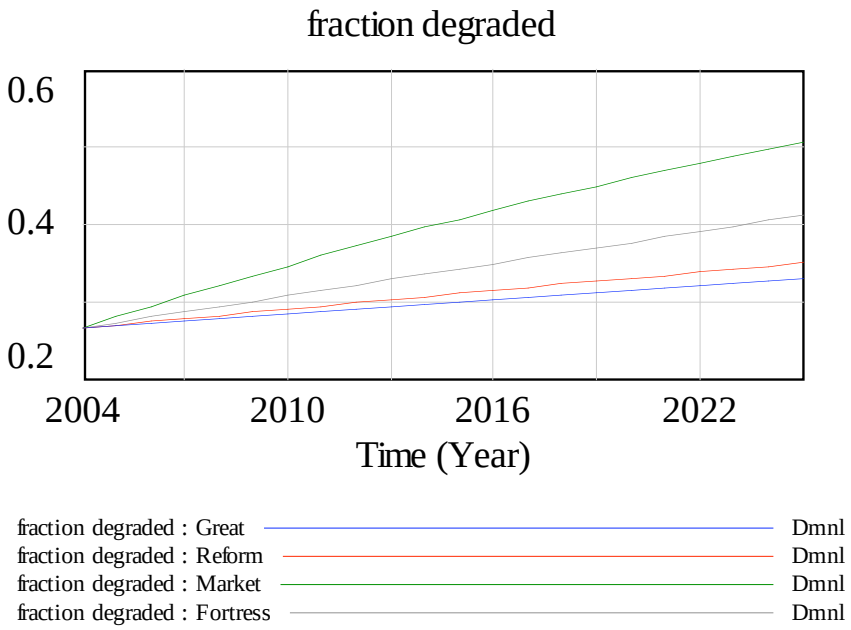
In the next graph, Market Force has the highest level of fallow land. The major cause is the degradation of crop land that converts part of the crop land to degraded fallow land.



Waste land is also high in Market Force, as more degraded fallow land is further degraded to waste land.

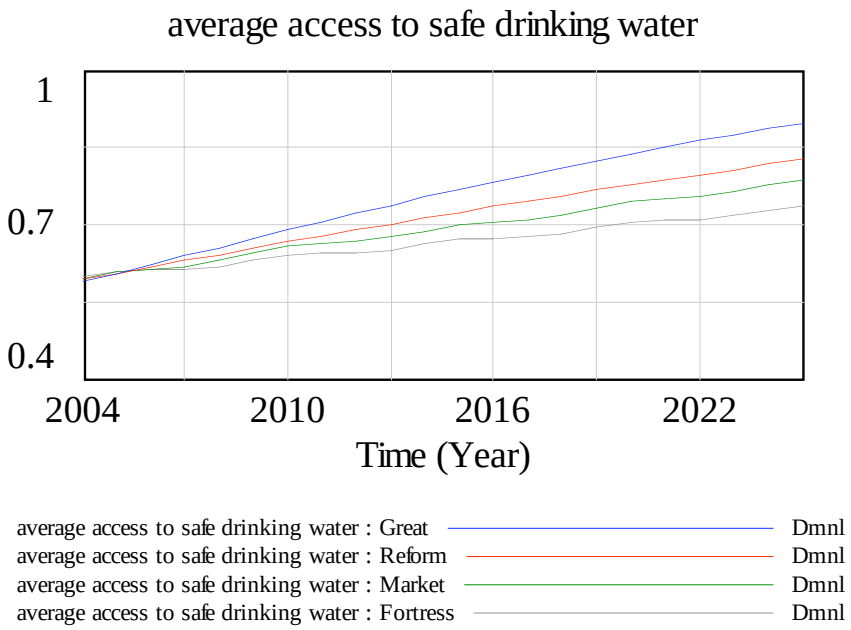


The total percentage of degraded land, including waste land, settlement land and the degraded parts in fallow and crop land, is shown in the next graph. In the Market Force scenario, the fraction of degraded land reaches 50% in 2025, which is a huge environmental cost for this scenario.

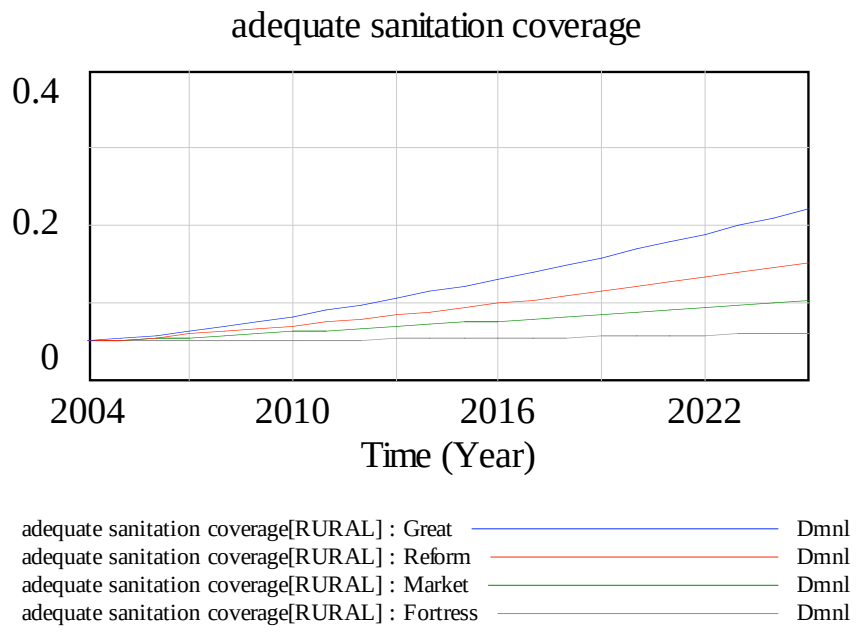


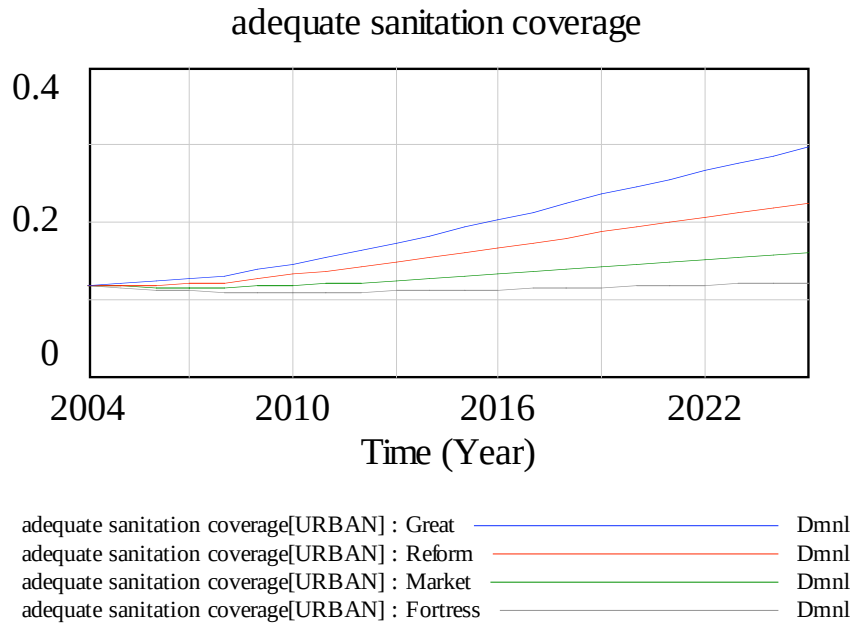
4. Water

Access to safe drinking water is not only an important indicator of quality of life, but also important for reducing under five mortality and infant mortality, and to prolong life expectancy. Average access to safe drinking water is the next graph.



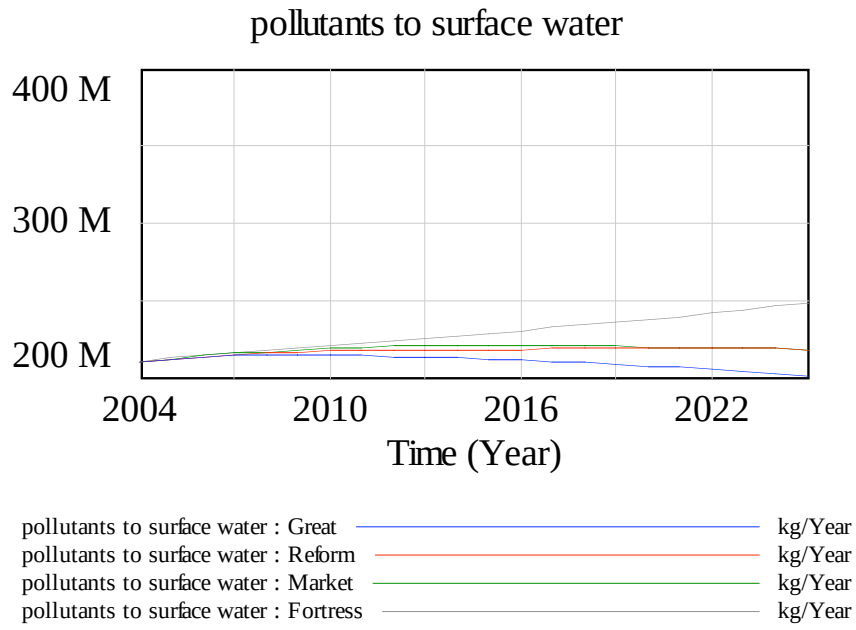
Greater access to safe drinking water is partly the result of a greater coverage of adequate sanitation, which means less sewage is released to surface water. Adequate sanitation for rural and urban areas is shown in the next two graphs.



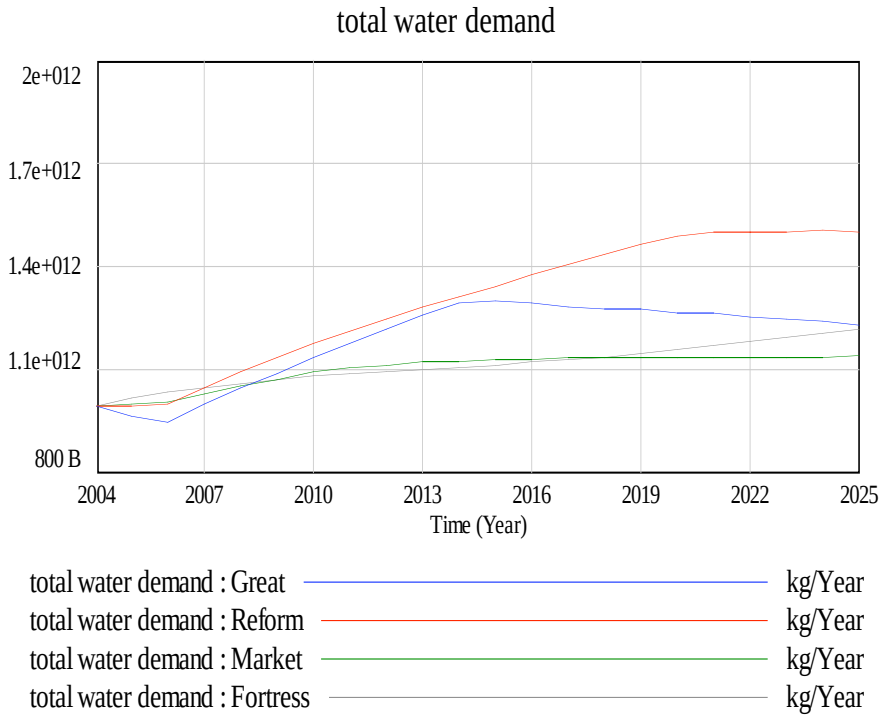


Total pollutants from sewage, agriculture, and industry to surface water are shown in the next graph. Great Transition generates the lowest while Fortress World generates the highest. Market Force and Policy Reform generate seemingly similar amounts, but have different components.

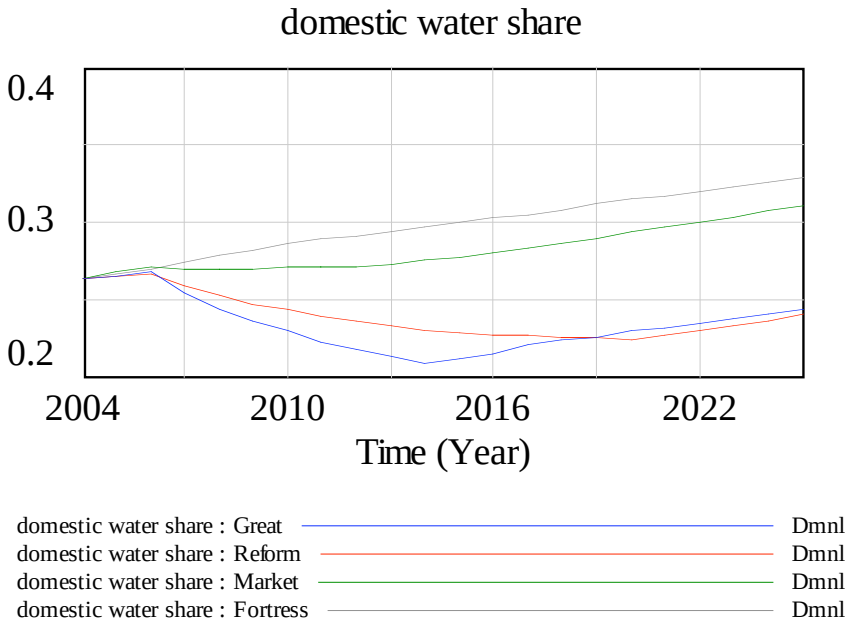
Market Force has more pollutants from sewage than Policy Reform, as it has lower coverage of adequate sanitation; but Market Force has less pollutants from agriculture, as it has much less agriculture land. These two results make the total pollutants equal.

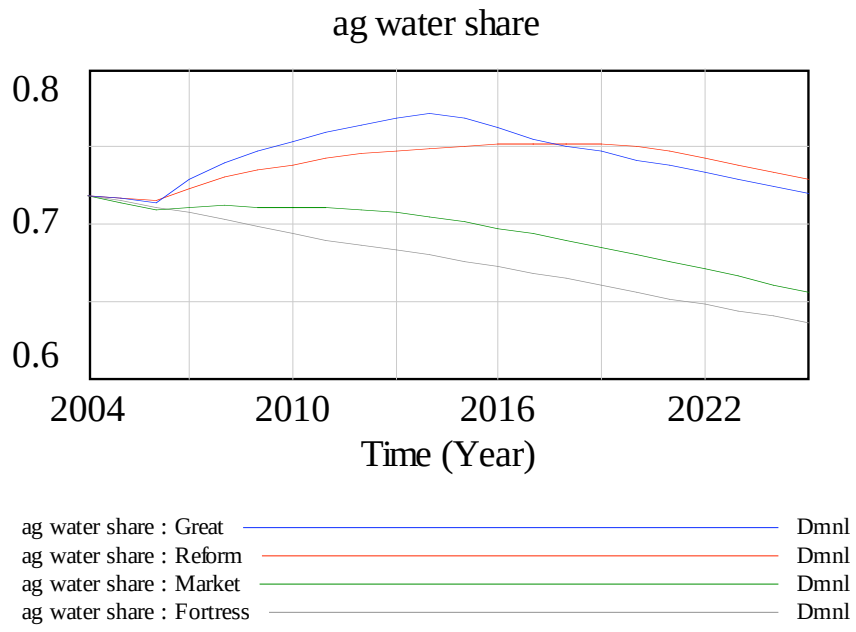


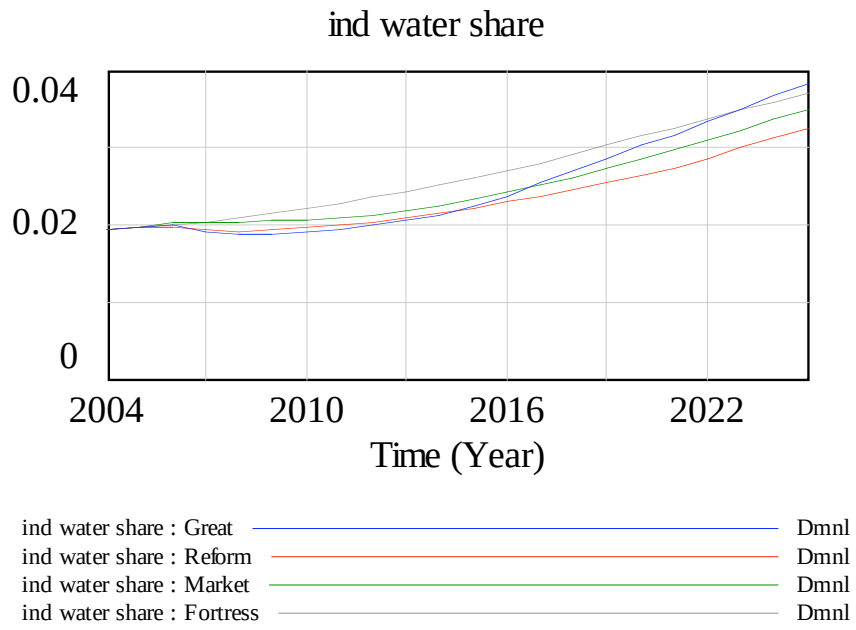
Total water demand is primarily related to the level of water use technology and the size of irrigated land. Although Great Transition has more irrigated land, higher per capita GDP (hence higher per capita water demand), and higher industry water demand (due to higher production), water demand in 2025 is only slightly higher than Fortress World and Market Force, due to its higher water use technology.



Shares for water use for domestic, agriculture, and industry are shown in the next three graphs. For Malawi, water will be generally available, even for the Policy Reform scenario that has the highest water demand towards 2025 (see above graph). When water is no longer available to meet demand, it is usually domestic and industry users that can pay for, and have easier access to, more water while agriculture users suffer.

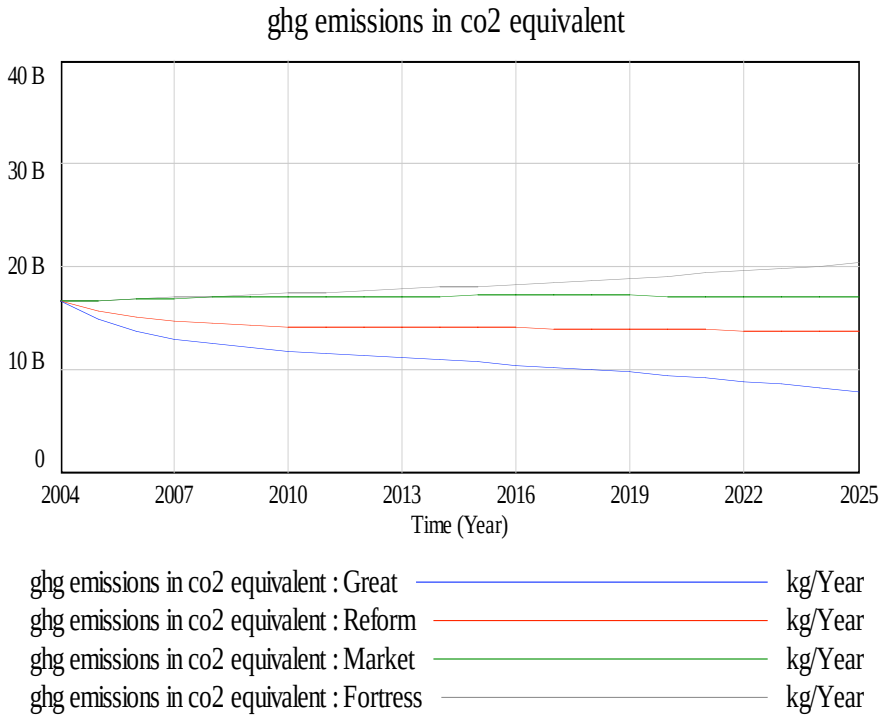




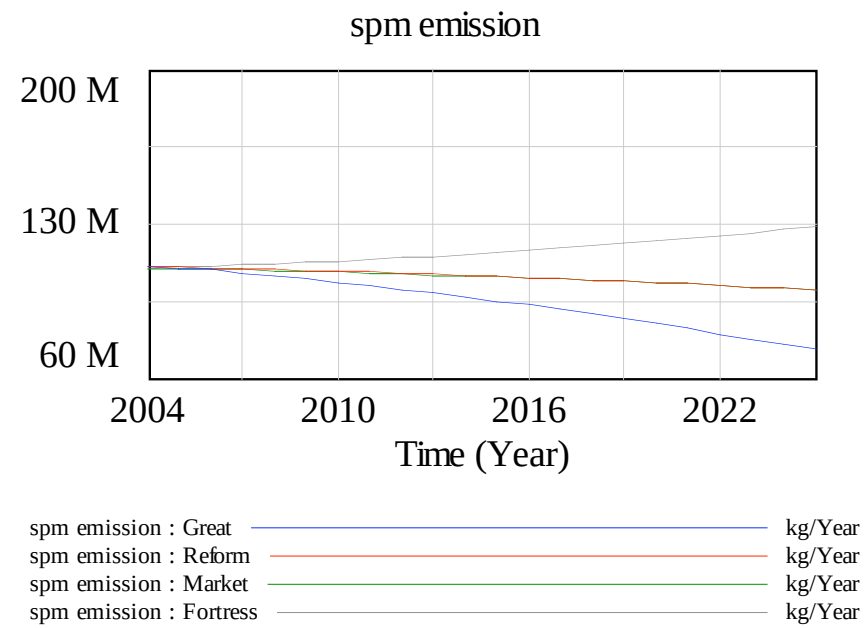


5. Air

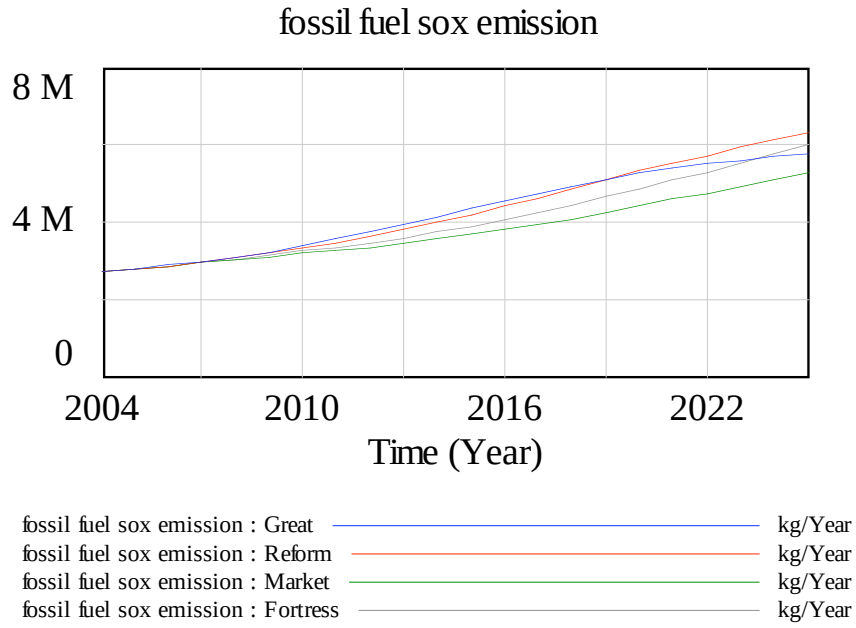
Greenhouse gas emissions in CO2 equivalent for the four scenarios are shown in the next graph. By 2025, annual emissions will be 8 to 20 billion kg (or million tons.) Most of the emissions will be from deforestation, not fossil fuels, in all the scenarios including Great Transition.



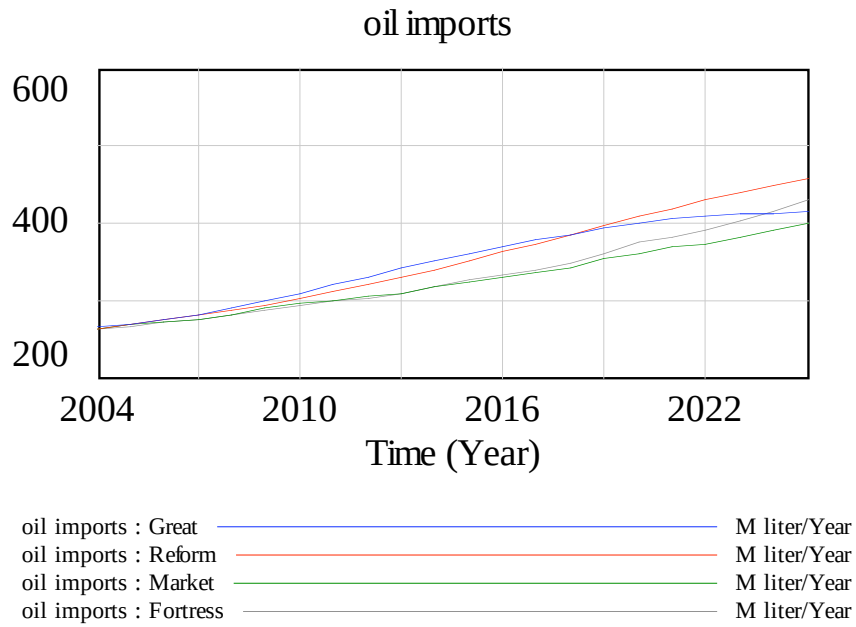
SPM emissions are shown in the next graph. Policy Reform and Market Forces overlap. More wood fuel is used in Market Force while more fossil fuels are used in Policy Reform since its GDP develops faster.



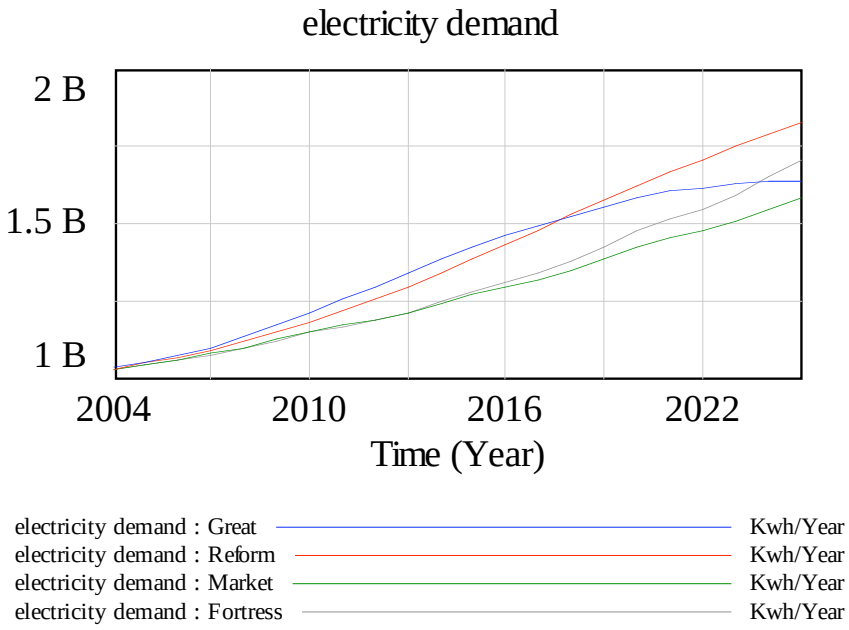
SOx is not a greenhouse gas, but is toxic. Emissions from fossil fuels are shown in the next graph.



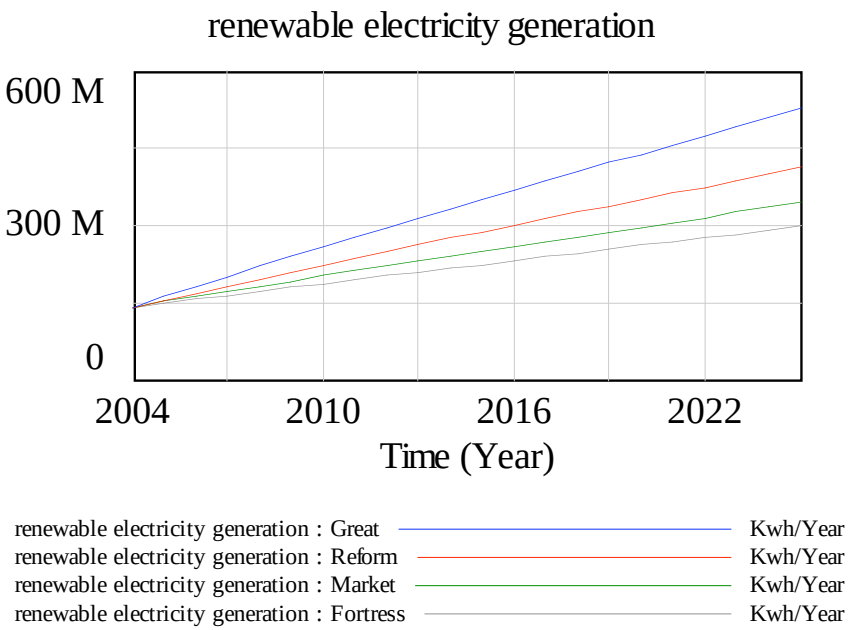
Oil import demand is related to GDP growth and energy efficiency technology. With Great Transition, energy efficiency technology is progressing fast, and even though its GDP growth is the fastest, its oil demand towards the year 2025 is even lower than Fortress World.



Electricity demand is similar to oil demand seen above, and is shown in the next graph.



Renewable power generation from wind is shown in the next graph. It will supplement hydro-power to meet the national demand for electricity.



IV. Conclusion

This report provides a brief summary of the T21 Malawi simulation results for the AEO case study. The latest T21 Malawi has been upgraded and expanded to address land, water, and air issues to their maximum extent possible and within the time and resource constraints available to MI. In its current form, T21 Malawi can be used to provide quantitative support to the AEO report. Further discussion and exploration of the structures and parameters used in the model are expected between UNEP experts and MI modelers. These discussions will lead to further modifications of the model and make it more adaptable to the challenges faced in the AEO. We hope that this is the beginning of a process that will continue and lead to more sustainable development in Africa.

There are many limitations to both the T21 model presented here and the analysis presented in this report. Environmental issues in land, water, and air are closely linked with each other and to many other factors in economic, social, and demographic areas. Although the author has spent many years working and directing environment-related national development modeling, there is still much to be learned. Also, more resources (including data, expertise, and time) are needed than what is currently available.

The author does not regard the numbers provided in this report as conclusive forecasts, but rather issues for debate and further research and modeling.

This report is accompanied by the model package that can be installed and run on a PC. The model not only allows users to re-generate the four scenarios, but gives the flexibility to use any combination on any issues to generate more scenarios. The model also gives users the option of using an 'extreme event' or disaster, which is not covered in this report.

V. ACKNOWLEGEDMENT

UNEP acknowledges the contribution made by the individuals and institutions that have made the production of the AEO-2 T21 Malawi scenarios model possible. Special thanks are extended to:

Millennium Institute

AEO Collaborating Centres

Agence Internationale pour le Développement de l'Information Environnementale (ADIE), Gabon

Centre for Environment and Development for the Arab Region and Europe (CEDARE), Egypt

Indian Ocean Commission (IOC), Mauritius

National Environment Management Authority (NEMA), Uganda

Network for Environment and Sustainable Development in Africa (NESDA), Cote d'Ivoire

Southern African Research and Documentation Centre (SARDC), Zimbabwe

Funding support

The Governments of Belgium, Luxembourg, Norway, Ireland, The Netherlands and the UNEP Environment Fund are providing funding for the Africa Environment Outlook process including the establishment of the Africa Environment Information Network and capacity building in integrated environmental assessment and reporting.

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