Food security and food aid; persistent insecurity

Bernhard Rootinck

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Parts of the paper: main paper, its appendix, the model ‘Food security and food aid; persistent insecurity’ + the slides ‘Food security and food aid; persistent insecurity’.

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Abstract

Hunger remains a persistent problem within the world. This problem manifest itself in the way that there is a higher food demand then the food production sector can deliver. The balance between food availability and food requirements is called food security (Oxford, n.d.). This paper evaluates food security using data from Kenya.

In general there are two ways that food is provided in Kenya. Firstly there is the Kenyan food production. However, due to a number of circumstances the production is not able to keep up with the demand. This in turn causes food insecurity.

In turn charities send food aid to supplement the shortage. However this is always too little too late. The food aid send cannot continuously provide enough food for the population.

This paper aims to show that the current system is not efficient. Sending food aid only addresses the symptoms of a food production system that is not able to fulfill its purpose. A more structural solution needs to be developed and implemented into the system. The paper does give two possible policy suggestions but its main focus remains to show that the current system is not sustainable.

1: Introduction

The United Nations have made seventeen sustainability goals (General assembly economic and social counsil, 2023). Goal number two is the elimination of hunger. Unfortunately hunger is a large problem in Africa, with over 150 million people affected (British Red Cross, 2023).

The focus on eliminating hunger comes from the extreme effects it has on the health of the population. Hunger has consequences for physical health. Hunger can lead to brain damage, hearth diseases and will eventually result in death from starvation (TechnoServe, n.d.). These conditions logically impact the mental health of the stricken persons and has consequences for society as a whole.

One country that falls under these conditions is Kenya. Over 27% of the Kenyan population is experiencing hunger on a fourth level scale (IPC, 2023). The IPC expresses hunger in a five point scale, ranging from level one meaning no hunger at all to level five meaning famine.

One of the causes of hunger is that Kenyan farms are not able to produce enough food to sustain the population. Only 25% of the Kenyan population are farmers contributing to food production (US aid, 2023) and most farmers on average only maintain 1,25 acres of land (Birch 2018). In addition the soil in Kenya is of poor quality and the country is stricken by a agricultural unfriendly climate (Verheye, 2000).

This balance between food availability and food requirements is called food security (Oxford, n.d.). The more there is a gap between the amount of food aviable and the amount of food needed the bigger the food insecurity becomes.

To supplement the domestic production shortcomings food aid is being send. However the food aid is not reliable. This is because of the dependence of food aid organizations on donations, donations who mostly only are generated during disasters.

As stated by Stupart & Strelitz (2016) media plays an important role in the response to a famine. Often times there is more happening in the world then the media is able to cover. Therefore only the more serious / impactful events are reported on.

When applied to Kenya this means that a low level of hunger, which would have been more easy to manage, would go unreported. Thus people are not donating to the charity organizations making them unable to react to the beginning of an food crisis. Then, as hunger levels increase towards famine levels, media reporting on the issue increases. This in turn increases donations which the aid organizations then use to supply food. But it remains an fight in which the aid organizations are always a few steps behind.

The combination of these factors causes food security in Kenya to be low which all its consequences. In order to improve this it is important to understand how food security comes to be. Once insight in this has been achieved policies can be designed in order to improve food security.

Further insight into the problem can be found in the reference modes in appendix 1.

2: Model description

The model that has been created gives insight in how food security comes to be. The main process of the model is as follows:

The main driving force of the model is the population. Population drives both the food production and food consumption. The population is accumulates via net birth and dissipates via net death. In this model net birth and net death are fully exogenous. Birth and death are both very complicated. They are determined by a lot of factors who also influence each other (Roser, 2019).

An increase in birth has two consequences. Firstly the total amount of food needed, defined as the amount of food needed to keep the population heathy, increases. Secondly the amount of farmers increases which in turn increases the total production.
These two consequences come together in the food stockpile stock. Food stockpile has one inflow named production rate. When population increases the amount of farmers increases. These farmers in turn produce more food which gets added to the food stockpile via the production rate inflow. Secondly when population increases the amount of food required to keep the population healthy increases. Here the food stockpile outflow consumption rate comes into play. It determines how much food is being used, this being either the total food requirement or, when requirement is higher than the stockpile, the total stockpile.

What the model shows is that the amount of food that the farmers are able to produce does not sufficed to provide the population with enough food to stay healthy. Food security is not guaranteed and as such people go hungry and pass away. This is represented via the deaths from hunger outflow out of the population stock. Here there is an effect variable, the less food security is, relatively the more deaths from hunger there are. However simply having population pass away does not solve the situation. As population decreases and as such total food need decreases the amount of farmers decreases as well. Meaning that there are less farmers to work on the land so there is less production. This creases a feedback loop.

In addition to food coming from domestic production there is also an inflow of food aid. This is set up as follows:
If there is food security the population has enough food to keeps itself healthy as mentioned before and if food security drops there is hunger. To combat this situation there are food aid organizations. These food aid organizations use funds to buy food and send this to Kenya in order to supplement the shortage. Their funds come forth from donations.

When food security is high there is little interest in donating. This comes down to the mentality: 'they have enough food so why would they need donations' (Howe, 2010). Then, as food security lowers, this mentality shifts and the amount of donations increases. This is then compared to the anchor donations per year based on the US aid organization. The donations get added to the amount of donations stock.

On the other side of the amount of donations stock there is the usage of donations outflow. When the total food need matches the amount of food available there is no need to buy additional food. The system structure does not allow the population to eat more than their needed amount to stay healthy. When the total amount of food is higher than the amount of food available there is reason for aid organizations to buy additional food aid and send this to Kenya. The amount of food that is bought is dependent on the availability gap. It tries to close this 1:1. However the administrative process of aid organizations causes an delay. Thus, as food security drops, aid organizations try to compensate but have an delayed response. In In addition aid organizations are limited by their funds.

They can only use what they have and addition donations are limited until the crisis becomes 'serious' enough and increased donations become available.
In summary, although aid organizations have an commendable cause, they are always a few steps behind, same as with the farmers situation described above.

These two factors combined, the farmers never being able to produce enough food and aid organizations always delayed or, when donations run out, unable to help solve the crisis allows hunger to remain an problematic factor in Kenya. The model shows that the system, in its current form, does not have the capacity to solve the behavior.

Notes:

The data that has been used in the model is based on Kenya. Factors regarding the amount of incoming donations are based on the US aid data.

A few assumptions have been made in order to realize the model, these are as follows:

Population	There is no split between male vs female. Kenya has about a 50/50 male vs female split which helps negating this assumption.
Normal birth rate	No differentiation between fertile vs non fertile population. Normal birthrate is 0.028. Has been halved into 0.014 (since the 50/50 population split).
Calories needed per year for healthy living	Uses an average between recommended male and female intake.

3: Validation

Structure confirmation

In order to validate the structure each variable has been documented. The documentation per variable can be found in appendix 2. The documentation details the purpose of the variable, its starting value or its equation, its unit and its real world representation. All parameters are based on data, the sources are also included in the documentation. A few assumptions have been made as mentioned in chapter 2.

Parameter confirmation

All parameters are based on real world counterpart. Its values are based on literature regarding Kenya. Two exceptions: the values of donations per year and price per kg for aid are based on US aid program and world bank data respectively.

Dimensional consistency

All variables in the model are dimensionally consistent, both mathematically and conceptually. Mathematical consistency is proven by the fact that Stella Architect does not give unit errors. Conceptual consistency can be verified with the model documentation (appendix 2).

Direct extreme condition

Each equation has been tested for extreme conditions, both individually and with partial model testing. Min and max functions have been used where needed in order to prevent unreasonable behavior. The upper and lower bounds of table functions are estimated in order to give reasonable results under extreme conditions. See appendix 2 for the documentation.

Indirect extreme condition

Several indirect extreme condition tests have been carried out, see appendix 4. These tests show that the system does not always respond the way it is supposed to. Where decreasing yield and decreasing birth fraction show expected behavior increasing values of farmers, yield per acre or anchor of donations results in an state of equilibrium. The model is sensitive to increased parameter values.

Integration error

The smallest time constant in the model is 0.1 from the time to use donations variable. Therefore, following the power of 2 denominator rule, the minimum dt should be 1/16. During testing there was no difference between 1/16 or 1/32. Therefore 1/16 has been used. No difference observed between Euler and 4th order Runge-Kutta, therefore Euler has been used.

Behavior sensitivity

Below is the summary of the behavior sensitivity tests. Behavioral sensitivity results are shown in appendix 6.

Model sector	Parameter	Range	Sensitivity
Course of population	Normal birth fraction	0.01 - 0.05	Behavioral
	Normal death fraction	0.003 - 0.03	Behavioral
	Anchor fraction of population dying of hunger.	0.01 - 0.08	Numerical
Food production and usage	Farmers fraction	0.01 - 0.05	Numerical
	Acres per farmer	1-4	Behavioral
	Maximum acres available	20 million - 30 million	Numerical
	Yield per acre	1500 - 2500	Behavioral
	Needed calories per year for healthy living	80000-810000	Numerical
	Calories per kg	800-900	Behavioral
Food aid realization	Anchor donations per year	100 million - 150 million	Numerical
	Kg per dollar	0.50 - 1	None
	Time to use donations	0.05 - 3	Numerical

Behavior reproduction tests

The reference modes as seen in appendix 1 have been compared to the results of the simulation. The comparison is in appendix 6. The system does not reproduce reference modes, most likely because there is model structure missing.

4: Analysis

4.1 Feedback loops

When running the model in the initial values the model shows interesting behavior. The base line scenario graphs can be found in appendix 3.

The model has five feedback loops who serve as first order controls and three feedback loops who control the overall behavior of the model.

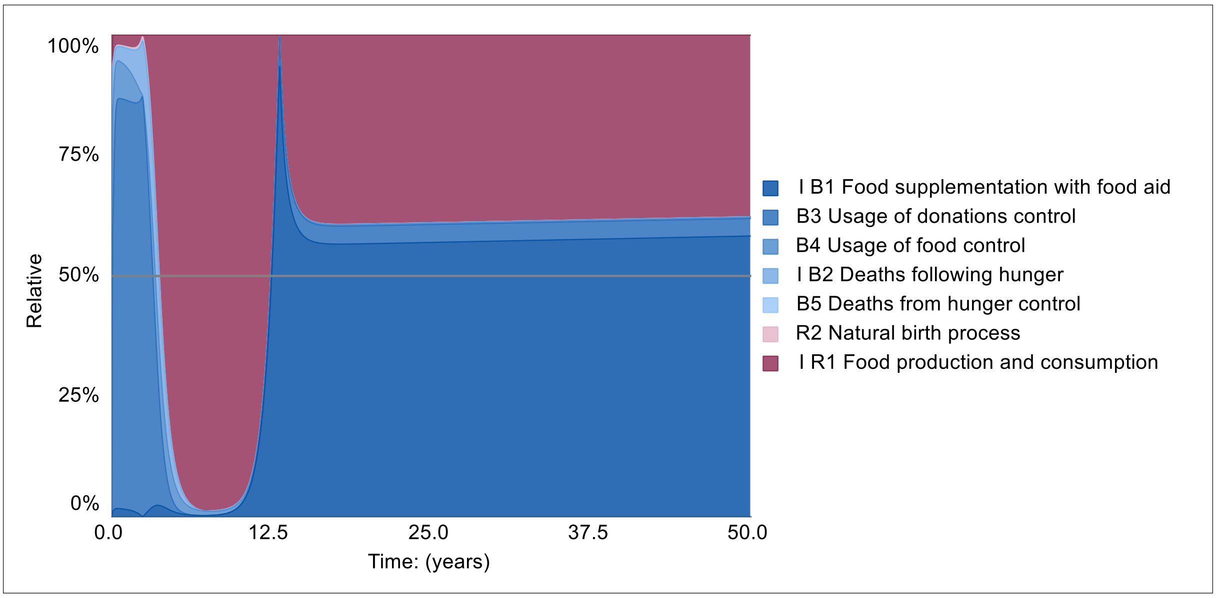
The first order feedback loops are as follows:

Number	Name
B2	Usage of donations control
B3	Usage of food control
B5	Deaths from hunger control
B6	Natural deaths process
R2	Natural birth process

The feedback loops are as follows:

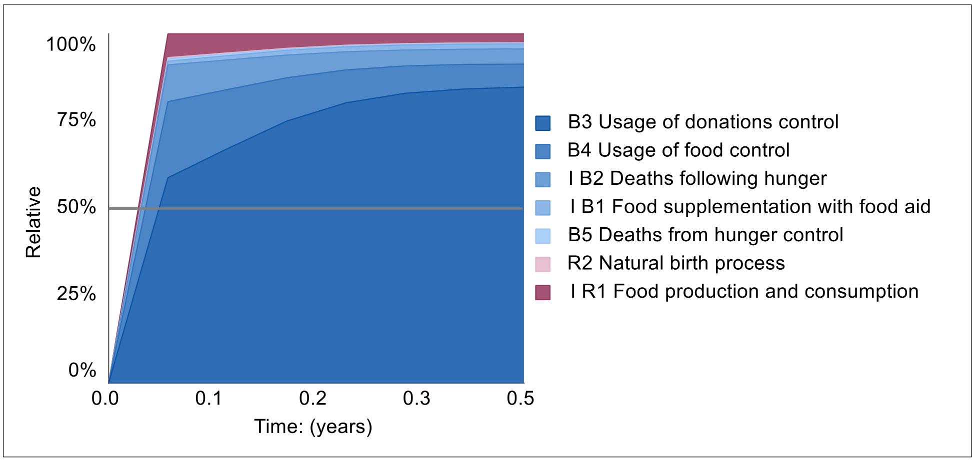
Number	Name
R1	Food production and consumption
B1	Food supplementation with food aid
B4	Deaths following hunger

4.2 Feedback loops dominance over time



Graph 4.1 All loops year 0 - 50.

Graph 4.1 shows the loop dominance of the model during a 50 year run of the model. The graph has been cut op and analyzed below.

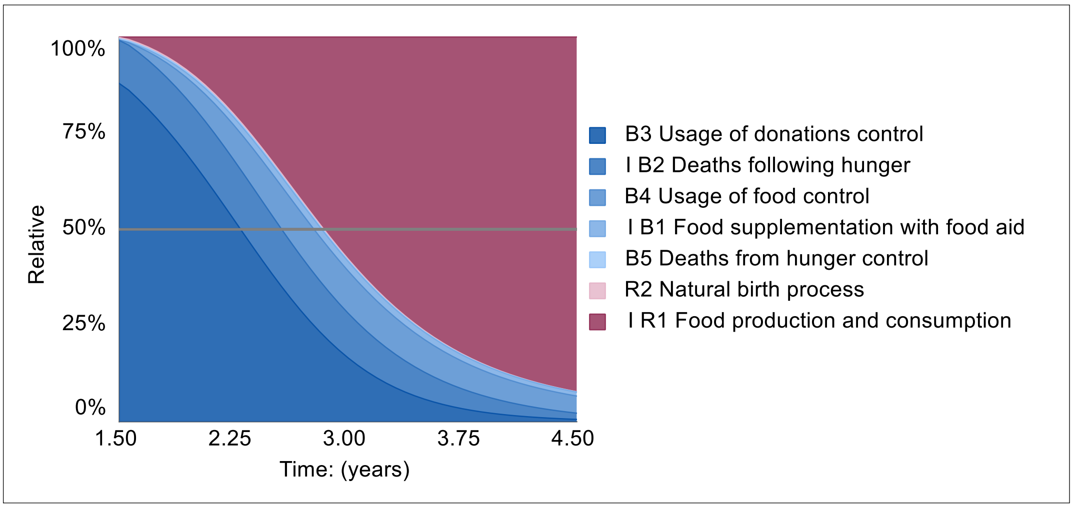


Graph 4.2 All loops year 0 - 0.5

Graph 4.2 shows the behavior from year 0 till year 0.5. It can be seen that in the start the usage of donation control b3 is the most dominant loop in the system, in the end controlling 85% of the behavior. This is because from the very start the population needs 52.5 billion kilos of food whilst the farmers are only able to produce 50 billion kilos. As from the beginning on the donations are needed to supplement it. This immediately puts pressure on the amount of donations stock. Since food security is high there is an incoming amount of donations of 83 million whilst 100 million are needed. Therefore the stock needs to be controlled via b3 making it dominant. Where b3 is dominant it means that b1 food supplementation with food aid is causing an inflow of food from aid to the food stockpile but b3 controls that b1 does not use too many donations.

The food aid is still not enough. Therefore from the very first moment there are hunger deaths. The loop responsible for this b2 is not very visible in this graph and can be found as a standalone in appendix 7.

From year 0.5 until 1.5 little changes. Only the amount of deaths following hunger keeps increasing and therefore gains more dominance in the system. The graph can be found in appendix 7.



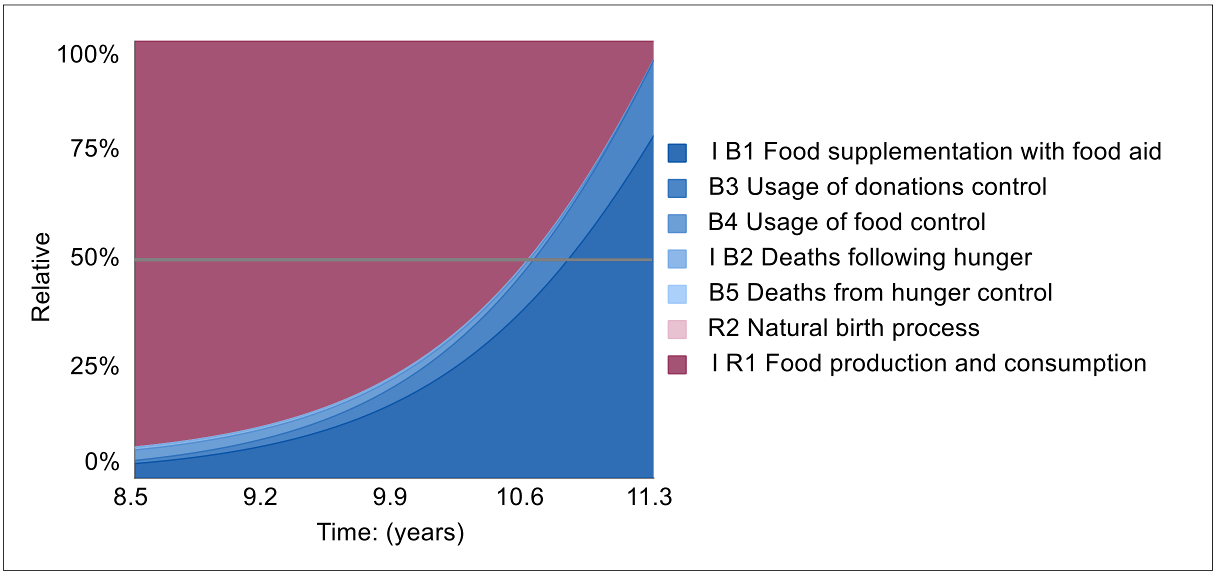
Graph 4.3 All loops year 1.5-4.5

Then at year 1.5 the behavior of the model starts to shift as seen in graph 4.3. The usage of donations control loop starts to lose its power. This is because the initial donations amount starts to run out. No longer can aid organizations freely supplement a food gap but they need to start taking incoming donations into account. The model structure starts to force the food aid to be calculated based on incoming donations instead of available donations.

Because the food gap is no longer being supplemented with food aid the amount of deaths from hunger also increases. It increases until an spike around year 2.5, then decreases again. See deaths following hunger year 1.5-4.5 in appendix 7.

This combination of factors causes the r1 food production and consumption to take over the dominance that b1 usage of donations control has lost. This is logical because r1 food production and consumption and b1 usage of donations control are the only two loops that continuously fight to dominate the system as seen in graph 4.1 above. When the food aid is lessened then the domestic production becomes the main supplier of food and vice versa. The other loops are minus the death from hunger loop are, as mentioned before, mainly first order control loops.

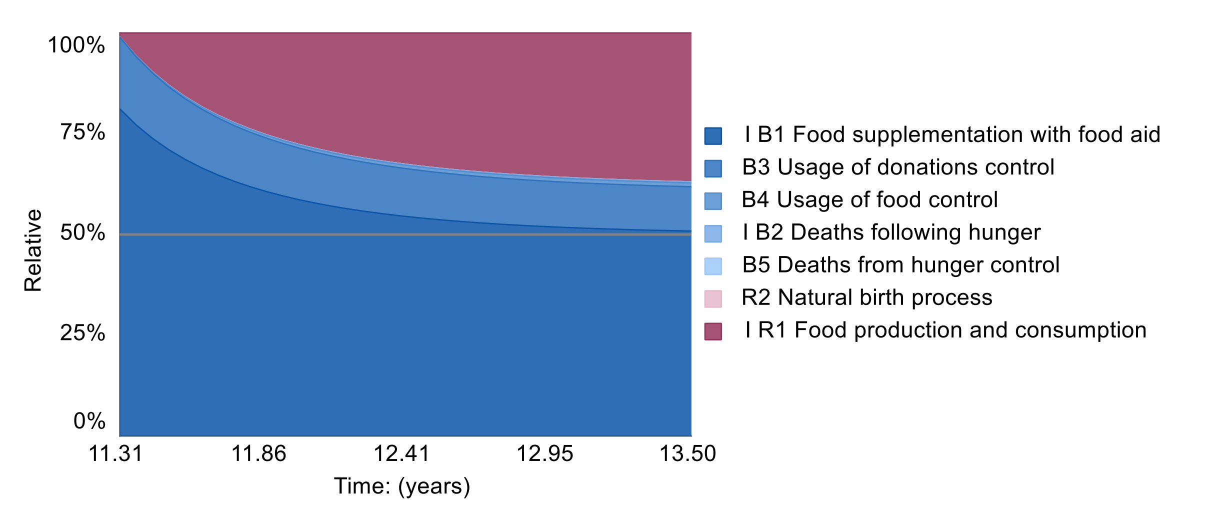
From year 4.5 till year 8.5 little of note happens. See appendix 7 all loops year 4.5-8.5 graph for details.



Graph 4.4 All loops year 8.5-11.3

Starting at year 8.5 there is a large shift in loop dominance. This is because the variable time to use donations becomes active. This allows the loop to temporary gain an large dominance within the system. After the 0.1 year mark that the variable represents has been passed the loop loses dominance again to the r1 food production and consumption loop. At the moment it is not clear what is the origin of the shift. The values surrounding the loop stay consistent, the stock does stays consistent and the values in the rest of the system do not display sudden changes. There is a strong suspicion that it is a result of the min functions in the consumption rate and the usage of donations rate. Further research is needed to explain the phenomenon, see also further research section in chapter five.

It is of note that during this time the amount of deaths following hunger does drop as well. This can be seen in appendix 7 Deaths following hunger year 8.5-11.3.

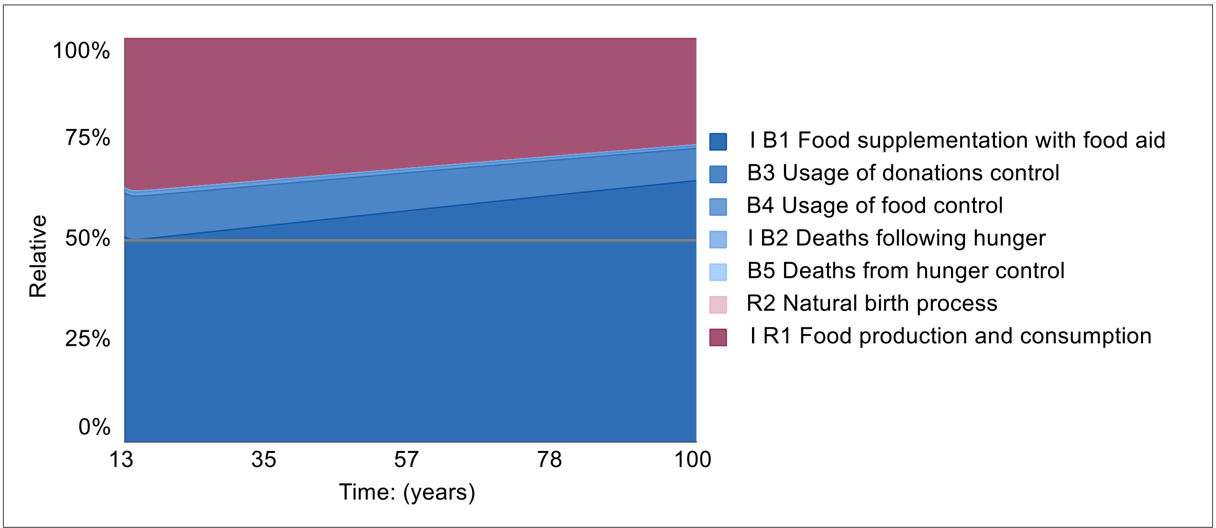


Graph 4.5 All loops year 11.3-13.5

Graph 4.5 shows the loop dominance of the system after the spike seen in graph 4.4. After the variable 0.1 time to use donations has passed the b1 food supplementation with food aid loop loses strength. This is helped by the b3 usage of donations loop. However it does remain the most dominant loop in the system, not dropping below 50.2%. The dominance that the loop loses is largely replaced by r1 food production and consumption.

Also of note is that during this time the amounts of deaths from hunger increases again. See appendix 7 deaths following hunger year 8.5-11.3.

This combination of factors lays the groundwork for the behavior during the rest of the simulation.



Graph 4.6 All loops year 13.5-100

Graph 4.6 shows the behavior of the model after 13 years. Each year the b1 loops gains a little more dominance over the r1 loop. This is an result of the previous behavior. As mentioned in the model description the population is not able to sustain itself with domestic food production and food aid is always too little too late. This graph shows that in loop dominance form. Each year the population decreases a little because the combination of hunger deaths and natural deaths is higher than the natural birth. Thus each year there are a few farmers less meaning each year r1 food production and consumption loses a little of its dominance. This dominance is then replaced by b1 food supplementation with food aid. This behavior continues forever since the population always decreases each year. For a longer simulation run an stacked area graph of a 500 years run has been added to appendix 7.

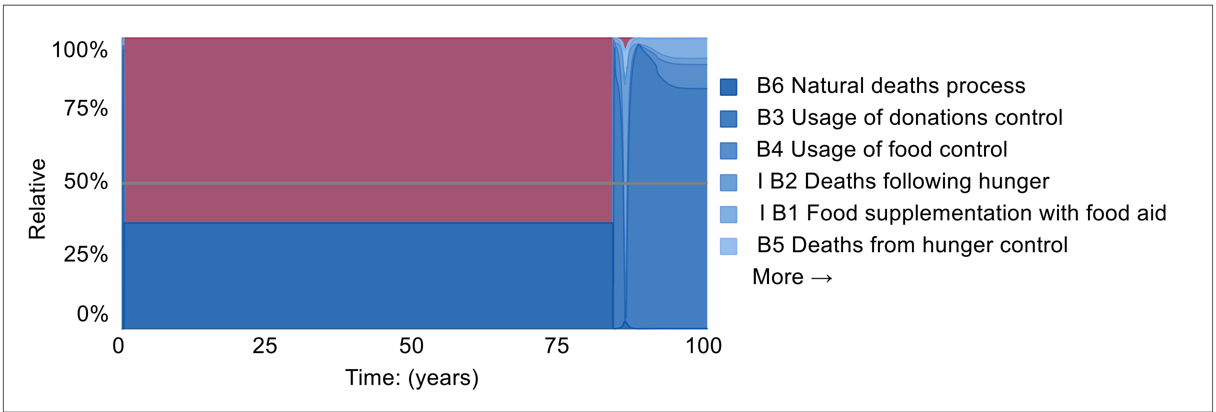
4.3 Policy via tipping points

In order to give meaning to the following policy suggestions it is important to appreciate the magnitude of hunger. Hunger is a prevalent and highly complex problem. It is influenced by both global and local highly interconnected aspects. This model does not provide cut and clear solutions. It is aimed at giving an insight in the balance between domestic food production and food aid and that this system in its current form is not sustainable.

That being stated it is possible to indicate some potential pressure points. By focusing policies on these pressure points their effect can be increased.

Policy point 1: Yield per acre

As seen in the behavior sensitivity tests the system has a large sensitivity for the yield per acre. By expanding this it the food output will be increased. US farms are able to produce on average 11.500 kg per acre (Langemeier & Zhou, 2022). Of course the situation is different in Kenya but as Mathenge (2016) mentions the corn production in Kenya is subpar. Already an increase from 2000 kg to 2500 kg per acre makes a difference.

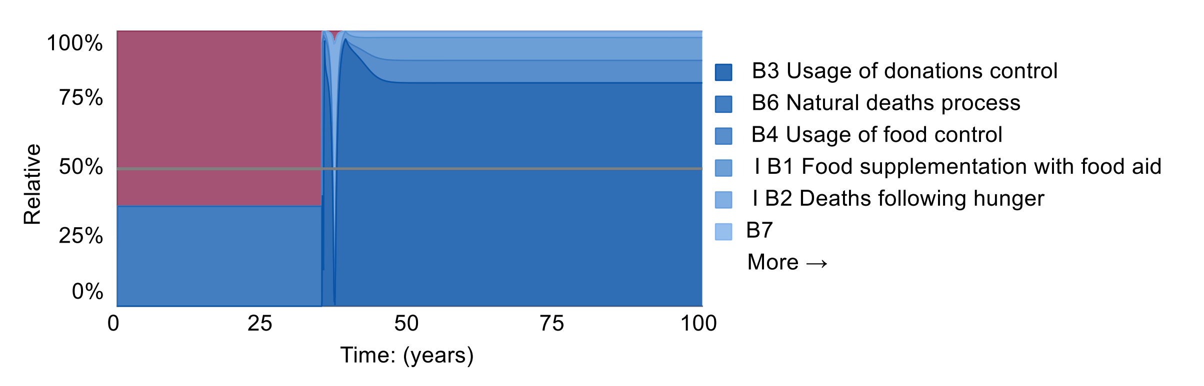


Graph 4.7 All loops year 0-100 with increased yield per acre.

This graph shows the same loop dominance as in the model with the original settings expect for a much later moment when b3 usage of donations takes over from r1 food production and consumption (at timestep 80). This allows the population to grow much larger, see appendix 8 policy point 1 for the graphs. The year at which deaths from hunger spikes is with this policy around year 80 where in the base scenario it was already at the beginning.

Policy point 2: Calories per kg

The system works with large amounts of calories, going into the billions. This makes the system sensitive to even a small change in the calories per kg. Therefore a policy could be to change the used crops. The model currently uses maize as the crop most used in Kenya with 860 calories per kg. Potatoes deliver 930 calories per kg which would allow for more population being fed with the same amount of calories. The moment when the deaths from hunger starts to increase is also delayed with this policy till year 35, see also in the appendix.

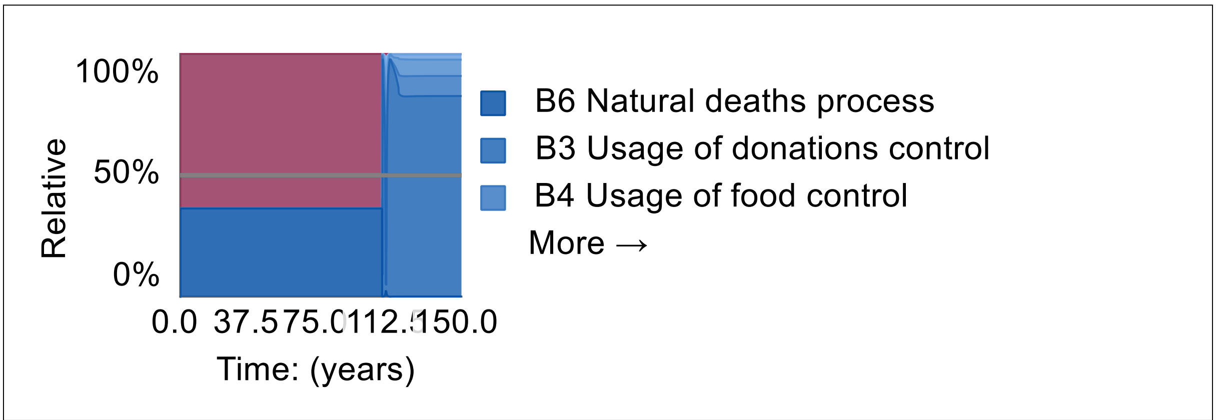


Graph 4.8 All loops year 0-100 with increased calories per kg.

As graph 4.8 shows the loop dominance is very similar as with the base scenario expect the b3 loop takes over from r1 at timestep 30 instead of 12.5. The impact of the policy change on the behavior is in appendix 8 policy point 2.

Combined policy 1 and 2

It is also possible to combine both policies. This would result in graph 4.9 as seen below.



Graph 4.9 All loops year 0-150 with both policies enacted (note that the timescale is 150 instead of 100)

This shows that the policies together manage to postpone the moment at which the domestic production is not able to feed the population any more to year 110 (see graph in appendix 8 combined policy 1 and 2). At that moment the graph system starts to use the donations as in the base scenario. Population comes into an equilibrium but this is only maintained due to a steady amount of deaths from hunger.

Both policy 1, 2 and the combined policy are in the 'policy command center' of the model.

Note: for more practical considerations regarding the policies and their implementation refer to chapter 5.

5: Discussion and conclusions

The impact of the polices

It is important to again state the purpose of the model. It is not made to fully model hunger and does not provide policies that fully solve it. It is to show that the current way of handling it is not the right way of handling it.

To refer this principle back to the policies in 4.3: they are potential ways to buy time. The graphs still show that the policies only delay the (in the current system) inevitable hunger. And that is okay. Hunger is a complex theme with both global and local strongly interconnected elements. It takes time to untangle, get to the core of the problem and to design policies to change that core. The proposed policies are a way to get the time needed whilst minimizing the suffering in the meantime.

Enacting the policies is possible in the current system. In practical terms Kenya needs to improve its agriculture mechanization process. Currently Kenyan farmers largely depend on animals (Groote, Marangu & Gitonga, 2020) and 95% of the farms depend on rain instead of irrigation systems (Hornum & Bolwig, 2020). Improving this requires funding. Funding can be drawn from the aid organizations, if at least they are able to undergo a paradigm change.

As the model states traditionally aid organizations send food aid in order to combat an developing hunger crisis or actual famine. However these funds could also be used in an earlier stage. By funding farms to improve output the hunger crisis is solved before it starts (or as seen in 4.3 much delayed). This is called anticipatory action (United Nations office for humanitarian affairs, n.d.) (Loo, Aguiar & Kopainsky, 2023) and requires long term thinking. Aid organizations must be willing to limit their short term capabilities to help in order to create long term solutions. The Kenyan population will see a dip in aid support on the short term in order to realize the long term advantages which could prove difficult to accept but is needed to change the system.

Also worth mentioning that the extra time being 'bought' with the policies is not solely for more research time. During this time Kenya has an opportunity to grow without the threat of hunger. This allows the population to grow, to focus on thriving instead of surviving and to develop Kenya. Herein lie opportunities which cannot be predicted beforehand.

Recommendations for further research

"Food is national security. Food is economy. It is employment, energy, history. Food is everything" - José Andrés (National Geographic, 2015).

However the way the current system handles hunger is not sustainable. This model is made to help bring that realization into perspective. It gives insight into the current unbalance between domestic food production, food aid and consumption. It can be used as an argument for the need of change and as a groundwork on which to base further system dynamics research into food security.

Due to time constraints during the making of this model it still displays some abrupt behavior. This does not take away that the foundation of this model is strong and that the behavior displayed is not unrealistic. Further research can help iron out these flaws.

But most of all, this model is a testament to the need to change the problem of hunger, to the need of long term thinking and to the power of system dynamics to combine these two into a strong and usable model.

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