Supplementary Materials to

Enabling Resilient Food Systems: Simulating the Impact on Local Farmers' Livelihoods in Greater Adelaide, Australia

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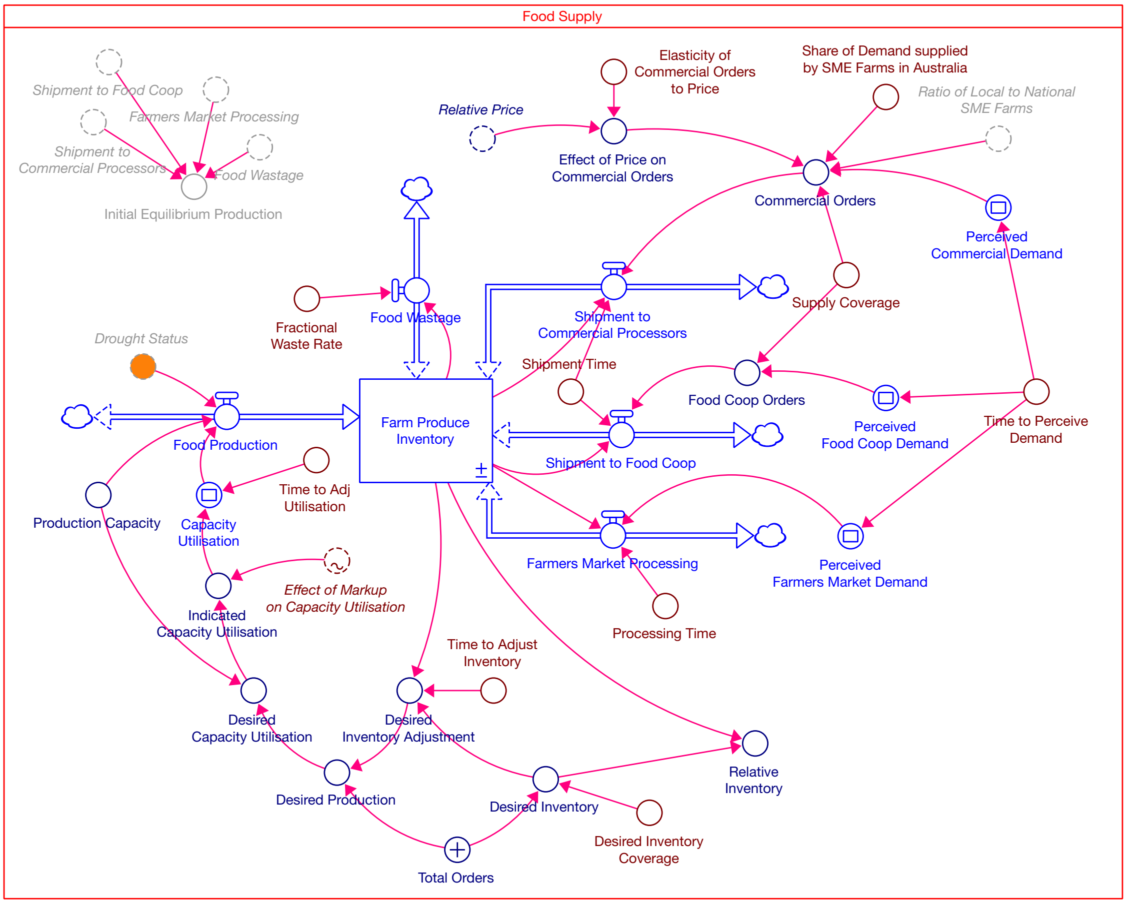


Capacity_Utilisation = SMTH1(Indicated_Capacity_Utilisation, Time_to_Adj_Utilisation, 1) {DELAY CONVERTER}
UNITS: dmnl
DOCUMENT: This delay converter represents the capacity utilisation of farms at any one point in time. According to Sterman (2000) capacity utilisation cannot be adjusted immediately, as it takes time for farmers to perceive how much to adjust utilisation as well as to implement changes to utilisation, such as scaling down labour or purchasing more inputs.

Commercial_Orders = Perceived_Commercial_Demand*Supply_Coverage*Share_of_Demand_supplied_by_SME_Farms_in_Australia*Ratio_of_Local_to_National_SME_Farms*Effect_of_Price_on_Commercial_Orders
UNITS: Tons/Years
DOCUMENT: This variable represents the ordering rate from commercial food processors and/or wholesalers. The commercial orders is determined by the perceived commercial demand for food produce in total (for national consumption as well as exports) multiplied by the share of the demand supplied by local SME farms in Greater Adelaide. Moreover, the aforementioned indicated ordering rate is affected by the effect of price, making it dynamic to changes in price levels.

Desired_Capacity_Utilisation = Desired_Production/Production_Capacity
UNITS: dmnl
DOCUMENT: The Desired Capacity Utilisation is the ratio between the Desired Production and the Production Capacity. In other words, it serves as the demand/supply ratio or the demand pressure on production.
When the Desired Capacity Utilisation is more than 1, it indicates that the production capacity is less than the desired production level, which indicates a schedule pressure. When the Desired Capacity Utilisation is less than 1, it indicates that the production capacity is more than the desired production level, which indicates that production can be scaled down.

Desired_Inventory = Total_Orders*Desired_Inventory_Coverage
UNITS: Tons
DOCUMENT: This variable represents the Desired Inventory level at any one point in time. It is simply the product of the Total Orders and the Desired Inventory Coverage.

Desired_Inventory_Adjustment = (Desired_Inventory-Farm_Produce_Inventory)/Time_to_Adjust_Inventory
UNITS: Tons/Years
DOCUMENT: The Desired Inventory Adjustment represents how much of the gap between the Farm Produce Inventory and Desired Inventory farmers hope to close per year. It has the goal of adjusting the food production in order to accumulate the inventory to its desired level.

Desired_Inventory_Coverage = 1.5
UNITS: year
DOCUMENT: The Desired Inventory Coverage represents how many years worth of orders the inventory is able to cover. It is assumed that the desired coverage is 1.5 years worth of orders.

Desired_Production = Total_Orders+Desired_Inventory_Adjustment
UNITS: Tons/Years
DOCUMENT: The Desired Production per year is determined by desired inventory adjustment added to the number of orders received per year. If farmers produce at the Desired Production level, they will be producing at equilibrium; meaning that they will be able to maintain the Inventory at the desired level.

Effect_of_Price_on_Commercial_Orders = Relative_Price^Elasticity_of_Commercial_Orders_to_Price
UNITS: dmnl
DOCUMENT: This variable represents the amount of change in Commercial Orders from food processors to changes in Price with reference to the elasticity. This is calculated by taking the elasticity of commercial orders (demand) as an exponent of the relative price.

Elasticity_of_Commercial_Orders_to_Price = -1.2
UNITS: dmnl
DOCUMENT: This parameter determines the sensitivity of Demand from Commercial Food Processors to changes in Relative Price. In this model, it is assumed that demand is relatively elastic to price, meaning that demand responds more than proportionally to changes in price. Since the local producers are all but a small fraction of total producers in Australia, Commercial Processors are likely to switch to substitute some of their orders with producers from elsewhere in the country. Hence, it is assigned a value of 1.2. The negative coefficient indicates an inverse relationship between the two variables. This parameter can be adjusted to reflect a more accurate elasticity with proper data collection.

Farm_Produce_Inventory(t) = Farm_Produce_Inventory(t - dt) + (Food_Production - Food_Wastage - Shipment_to_Commercial_Processors - Shipment_to_Food_Coop - Farmers_Market_Processing) * dt
INIT Farm_Produce_Inventory = Desired_Inventory
UNITS: Tons
DOCUMENT: This stock represents the amount of Food Produce that is stored in the Inventory at any one point in time. It is accumulated by the rate of Food Production and depleted by four outflows: (1) shipment rate to commercial food processors and/or wholesalers, (2) shipment rate to food cooperatives, (3) processing rate for selling at farmers marker, and (4) food wastage rate. The initial value of stock is simply the Desired Inventory level. For simplification, this stock does not differentiate between types of foodstuff produced such as maze, cereal, vegetables, or meat. It is an aggregate unit of foodstuff measured in tons.

Food_Production = (1-Drought_Status)*Production_Capacity*Capacity_Utilisation + Drought_Status*Production_Capacity
UNITS: Tons/Year
DOCUMENT: This inflow represents the Food Production rate per year, and it accumulates the Farm Produce Inventory. When the Drought Status is 0 (indicating that there is usual weather conditions), the rate is determined by the product of the production capacity and the capacity utilisation. However, when the Drought Status is 1 (indicating extreme weather condition), then the food production rate is simply the production capacity. The assumption here is that in extreme weather conditions (shocks to the system), farmers do not have the ability to make decisions about capacity utilisation given that the production capacity itself is severely impacted. Hence, under such conditions, they will simply produce what they can rather than what they want.

Food_Wastage = Farm_Produce_Inventory*Fractional_Waste_Rate
UNITS: Tons/Year
DOCUMENT: This outflow represents the rate at which farm produce is wasted each year. Food wastage occurs due to improper post-harvest handling and/or storage, causing a post-harvest loss (Ayenew & Kopainsky, 2014). Food Wastage rate is determined by the product of the Inventory and the fractional food waste rate.

Shipment_to_Commercial_Processors = MIN(Commercial_Orders, Farm_Produce_Inventory/Shipment_Time)
UNITS: Tons/Year
DOCUMENT: This outflow represents the Commercial Processing Shipment rate; the amount of food that farmers sell to commercial processors and/or wholesalers. This rate is determined by the commercial orders. However, if there is insufficient produce in the inventory to satisfy the orders, the MIN function takes whatever that is left in the inventory for shipping over the shipment time.

Shipment_to_Food_Coop = MIN(Food_Coop_Orders, Farm_Produce_Inventory/Shipment_Time)
UNITS: Tons/Year
DOCUMENT: This outflow represents the Food Cooperative Shipment rate; the amount of food that farmers sell to the relevant parties in cooperative arrangements. This rate is determined by the orders food cooperatives. However, if there is insufficient produce in the inventory to satisfy the orders, the MIN function takes whatever that is left in the inventory for shipping over the shipment time. For simplification, it is assumed that there will always be enough food cooperative arrangements (i.e. food hubs, direct farm to cafe/restaurant etc. which cuts out the middlemen) within Greater Adelaide to meet the demand.

Farmers_Market_Processing = MIN(Perceived_Farmers_Market_Demand, Farm_Produce_Inventory/Processing_Time)
UNITS: Tons/Year
DOCUMENT: This outflow represents the Farmers Market Processing rate; the amount of food that farmers send for processing each year before selling it directly to consumers at farmers market. This rate is determined by the perceived demand for food produce at farmers market. However, if there is insufficient produce in the inventory to supply the farmers market, the MIN function takes whatever that is left in the inventory for supplying over the processing time. Importantly, it is assumed that farmers seek to meet demand hindered only by supply (inventory level). In reality, there needs to be enough distribution channels (i.e. farmers markets) within Greater Adelaide to meet the demand. For simplicity, this model assumes that there will always be enough farmers markets set up to meet the demand.

Food_Coop_Orders = Perceived_Food_Coop_Demand*Supply_Coverage
UNITS: Tons/Years
DOCUMENT: This variable represents the ordering rate from food cooperative arrangements. It is the perceived market demand for locally produced food through food cooperatives multiplied by the supply coverage. For simplification, it is assumed that there will always be enough food cooperative arrangements within Greater Adelaide to meet the demand. Food cooperatives include food hubs, direct farm to cafe/restaurant, social enterprises, and any other community initiative that cuts out the middlemen and values the farmer's well-being and livelihood.

Fractional_Waste_Rate = 0.05
UNITS: dmnl/year
DOCUMENT: This parameter represents the fractional waste rate per year. It is assumed that 5% of the food produce in the inventory is wasted each year.

Indicated_Capacity_Utilisation = MAX(0.5, MIN(1.5, Desired_Capacity_Utilisation*Effect_of_Markup_on_Capacity_Utilisation))
UNITS: dmnl
DOCUMENT: The Indicated Capacity Utilisation calculates the Effect of Markup on the Desired Capacity Utilisation. It represents the decision rule in deciding how much to eventually adjust the capacity utilisation to. The MIN function sets the maximum limit of capacity utilisation to 1.5, meaning that it is impossible for farmers to scale up production more than 1.5 time through short-term adjustments for extracting more than the capacity level. The MAX function sets the minimum capacity utilisation 0.5, meaning that farmers only scale down production to half the normal level rather than shutting down production altogether.

Initial_Equilibrium_Production = INIT(Food_Wastage+Farmers_Market_Processing+Shipment_to_Food_Coop+Shipment_to_Commercial_Processors)
UNITS: Tons/Years
DOCUMENT: The Initial Equilibrium Production is the sum of all the initial outflows of the Farm Produce Inventory. It indicates how much is produced at the first instance in order to maintain the inventory level at equilibrium.

Perceived_Commercial_Demand = SMTH1(Reference_Commercial_Demand, Time_to_Perceive_Demand) {DELAY CONVERTER}
UNITS: Tons/Years
DOCUMENT: This delay converter represents the Commercial Demand as perceived by the relevant buyers from commercial food processing or retail. Since market actors are not expected to have perfect information about demand at all times, it represents the process of updating their perception of the market demand over an adjustment time.

Perceived_Farmers_Market_Demand = SMTH1(Farmers_Market_Demand, Time_to_Perceive_Demand) {DELAY CONVERTER}
UNITS: Tons/Years
DOCUMENT: This delay converter represents the Farmers Market Demand as perceived by the farmer. Since farmers are not expected to have perfect information about demand at all times, it represents the process of updating their perception of the market demand over an adjustment time.

Perceived_Food_Coop_Demand = SMTH1(Food_Coop_Demand, Time_to_Perceive_Demand) {DELAY CONVERTER}
UNITS: Tons/Years
DOCUMENT: This delay converter represents the Food Coop Demand as perceived by the relevant buyers from food cooperatives. Since market actors are not expected to have perfect information about demand at all times, it represents the process of updating their perception of the market demand over an adjustment time.

Processing_Time = 1
UNITS: Year
DOCUMENT: This parameter represents the time taken to process farm produce for selling at farmers market. It is assumed that it takes about 1 year to process the produce.

Production_Capacity = Total_Farmland_Area*Yield_per_hectare
UNITS: Tons/Years
DOCUMENT: The Production Capacity represents how much food SME farms can normally produce in a year. It is the product of the total farmland area and the yield per hectare of farmland.

Relative_Inventory = Farm_Produce_Inventory/Desired_Inventory
UNITS: dmnl
DOCUMENT: The Relative Inventory represents the ratio between the actual Farm Produce Inventory and the Desired Inventory. This serves as a supply/demand ratio, which then has a dynamic effect on the price of food. When the relative inventory is more than 1, it means that there is more food in the inventory (supply) than the desired level (demand). When the relative inventory is less than 1, it means that there is less food in the inventory than desired, indicating a shortage. This model structure is adapted from agricultural commodity cycle models by Ayenew & Kopainsky (2014) and Sterman (2000).

Share_of_Demand_supplied_by_SME_Farms_in_Australia = 0.49
UNITS: dmnl
DOCUMENT: This parameter represents the share of total commercial demand that is supplied by the total SME Farms in Australia. Based on data from ABARES (2021b), SME farms account for 49% of total value of agricultural output.

Shipment_Time = 1
UNITS: Year
DOCUMENT: This parameter represents the time taken to ship the farm produce to buyers. It is assumed that it takes about 1 year to ship the produce.

Supply_Coverage = 1.5
UNITS: dmnl
DOCUMENT: This parameter represents the supply coverage of the supply chain that is factored into the ordering rate. It is assumed that buyers of farm produce would order 1.5 times the perceived market demand to cover their respective supply lines.

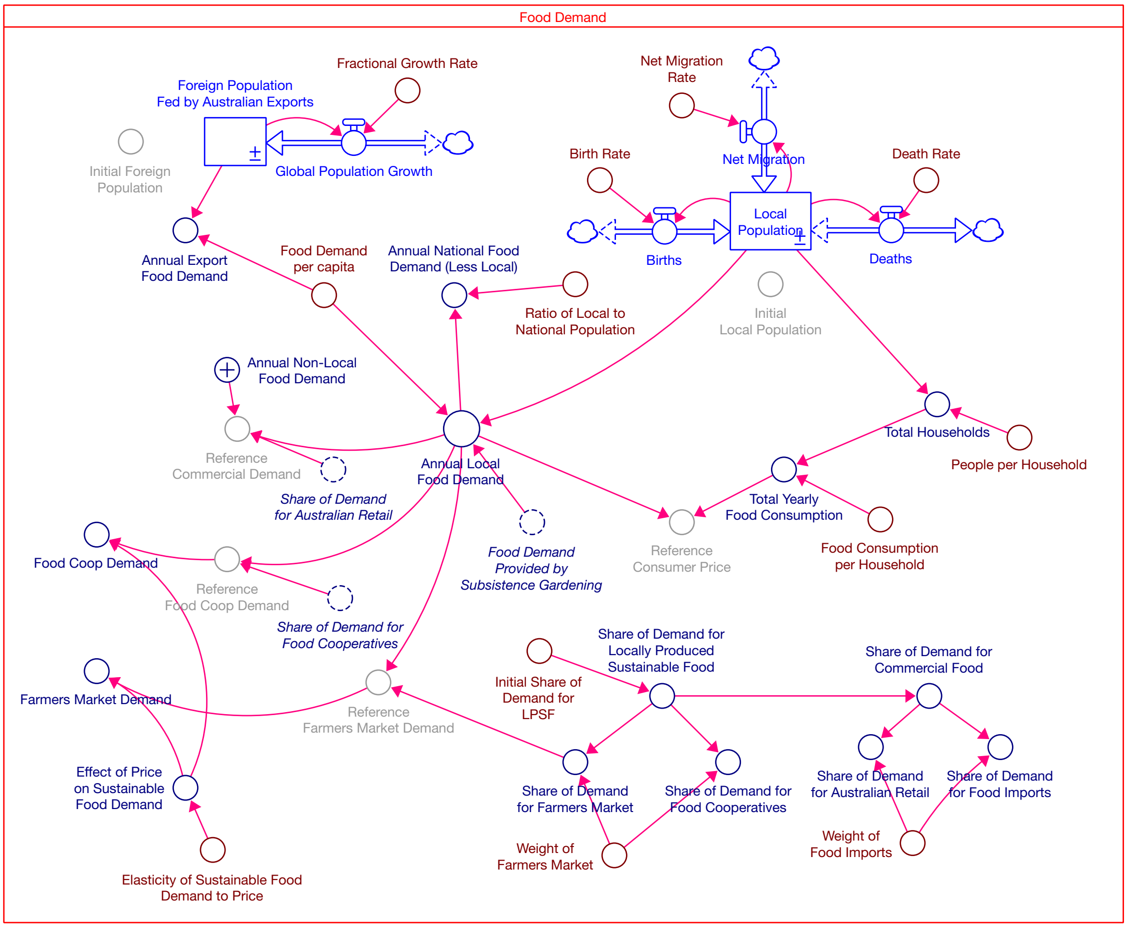
Time_to_Adj_Utilisation = 1
UNITS: Year
DOCUMENT: This parameter represents the time taken to adjust capacity utilisation. According to Sterman (2000) capacity utilisation cannot be adjusted immediately, as it takes time for farmers to perceive how much to adjust utilisation as well as to implement changes to utilisation, such as scaling down labour or purchasing more inputs. It is assumed that farmers take about 1 year to adjust their capacity utilisation.

Time_to_Adjust_Inventory = 1
UNITS: Year
DOCUMENT: This parameter represents the desired time taken to close the gap between the inventory and desired inventory level. It is assumed that farmers will want to adjust their inventory within 1 year.

Time_to_Perceive_Demand = 3
UNITS: Years
DOCUMENT: This parameter represents the time taken to perceive market demand since individuals do not have perfect information and rely on past perceptions of demand. It is assumed that buyers (commercial orders and food coop orders) and/or farmers (for selling at farmers market) take about 3 years to update their perceptions about the level market demand.

Total_Orders = Commercial_Orders + Food_Coop_Orders + Perceived_Farmers_Market_Demand {SUMMING CONVERTER}
UNITS: Tons/Years
DOCUMENT: This summing converter calculates the total number of orders that SME farmers receive per year. It is the sum of the Commercial Orders, Food Coop Orders and the Perceived Farmers Market Demand. Since Farmers are the direct sellers in Farmers Market, they do not receive orders but bring enough supply to the markets based on their perceptions of the demand.

Food Demand Sector



Annual_Export_Food_Demand = Foreign_Population_Fed_by_Australian_Exports*Food_Demand_per_capita
UNITS: Tons/Years
DOCUMENT: This variable represents the amount of food demand per year for exports. It is the product of the foreign population and the food demand per capita. The demand per capita is assumed to be the same for the foreign population as well.

Annual_Local_Food_Demand = (Local_Population*Food_Demand_per_capita) - Food_Demand_Provided_by_Subsistence_Gardening
UNITS: Tons/Years
DOCUMENT: This variable represents the amount of food demand per year from the local population in Greater Adelaide. It is the product of the local population and the food demand per capita. Moreover, the food demand provided by subsistence gardening is subtracted from this result to indicate the annual local food demand for consumption (food for purchase).

"Annual_National_Food_Demand_(Less_Local)" = (Annual_Local_Food_Demand/Ratio_of_Local_to_National_Population) - Annual_Local_Food_Demand
UNITS: Tons/Years
DOCUMENT: This variable represents the amount of food demanded by Australians outside of Greater Adelaide per year. The division of the annual local food demand with the ratio of local to national population, gives us an estimate of the total Australian food demand. Subtracting the annual local food demand from the national demand, we have an estimate of house much food is demanded by Australians outside of Greater Adelaide.

"Annual_Non-Local_Food_Demand" = "Annual_National_Food_Demand_(Less_Local)" + Annual_Export_Food_Demand {SUMMING CONVERTER}
UNITS: Tons/Years
DOCUMENT: This summing converter indicates the Annual demand of food from the non-local population. It is the sum of the Annual national food demand and the demand of exported food per year.

Birth_Rate = 12/1000
UNITS: dmnl/year
DOCUMENT: This constant parameter represents the crude fractional birth rate (the number of births per thousand) of the local population in Greater Adelaide each year. The crude birth rate is estimated from data provided by The World Bank (2021a).

Death_Rate = 8/1000
UNITS: dmnl/year
DOCUMENT: This parameter indicates the crude death rate (number of deaths per thousand) of the local population in Greater Adelaide each year. The reference value was obtained from data provided by the Australian Bureau of Statistics (2021b) for South Australia.

Effect_of_Price_on_Sustainable_Food_Demand = Relative_Price^Elasticity_of_Sustainable_Food_Demand_to_Price
UNITS: dmnl
DOCUMENT: This variable represents the amount of change in Demand for Locally Produced Sustainable Food (includes demand for Farmers' Market and demand for Food Cooperatives) to changes in Price with reference to the elasticity. This is calculated by taking the elasticity of demand as an exponent of the relative price.

Elasticity_of_Sustainable_Food_Demand_to_Price = -0.6
UNITS: dmnl
DOCUMENT: This parameter determines the sensitivity of Demand for locally produced sustainable food to changes in Relative Price. In this model, it is assumed that demand is relatively inelastic to price, meaning that demand responds less than proportionally to changes in price. Since consumers of locally produced sustainable food tend to be more socially connected to the food system, it reasons that they are more tolerant to price increases, and therefore do not radically alter their demand. Hence, it is assigned a value of 0.6. The negative coefficient indicates an inverse relationship between the two variables. This parameter can be adjusted to reflect a more accurate elasticity with proper data collection.

Farmers_Market_Demand = Reference_Farmers_Market_Demand*Effect_of_Price_on_Sustainable_Food_Demand
UNITS: Tons/Years
DOCUMENT: This variable represents the Demand for food sold at Farmers Market at any one point in time, which dynamically reacts to changes in price. It is calculated by multiplying the Reference Farmers Market Demand by the Effect of Price on Sustainable Food Demand.

Food_Consumption_per_Household = 10000
UNITS: AUD19/household/year
DOCUMENT: This parameter indicates the amount spent for food consumption in a household in one year. It is measured in Australian Dollars fixed at its 2019 value (AUD19) per household per year. The reference value was estimated from the ABS Household Expenditure Survey as reported by id informed decisions (2021).

Food_Coop_Demand = Reference_Food_Coop_Demand*Effect_of_Price_on_Sustainable_Food_Demand
UNITS: Tons/Years
DOCUMENT: This variable represents the Demand for food sold at Food Cooperatives at any one point in time, which dynamically reacts to changes in price. It is calculated by multiplying the Reference Food Coop Demand by the Effect of Price on Sustainable Food Demand.

Food_Demand_per_capita = 1500/1000000*365
UNITS: tons/people/year
DOCUMENT: This parameter represents the food demand per capita (i.e. food consumption), which is 0.548 tons per person per year). This value was derived from the average daily apparent consumption of 1548 grams per person (Australian Bureau of Statistics, 2020) divided by 1 ton and multiplied by 365 days.

Foreign_Population_Fed_by_Australian_Exports(t) = Foreign_Population_Fed_by_Australian_Exports(t - dt) + (Global_Population_Growth) * dt
INIT Foreign_Population_Fed_by_Australian_Exports = Initial_Foreign_Population
UNITS: People
DOCUMENT: This stock represents the total foreign population size fed by Australian food exports at any one point in time. It is accumulated by the inflow, global population growth. The initial value of stock is simply the Initial Foreign Population.

INFLOWS:
Global_Population_Growth = Foreign_Population_Fed_by_Australian_Exports*Fractional_Growth_Rate
UNITS: People/Year
DOCUMENT: This inflow represents the global population growth rate. It is simply the product of the foreign population by the annual fractional growth rate. The assumption here is that the foreign population grows with the same growth rate of the global population.

Fractional_Growth_Rate = 1.1/100
UNITS: dmnl/year
DOCUMENT: This constant parameter represents the fractional growth rate of the global population each year. The growth rate is estimated from data provided by The World Bank (2021b).

Initial_Foreign_Population = 33.9*1E6
UNITS: People
DOCUMENT: This parameter indicates the initial number of foreign populations outside of Australia that is fed by food produced in the country in the year 2010. The data was derived from Bellotti (2017), where the number for year 2017 was calibrated based on the fractional growth rate.

Initial_Local_Population = 1253097
UNITS: People
DOCUMENT: This parameter indicates the initial number of people living in Greater Adelaide in year 2010. The data was obtained from Census data available at the Australian Bureau of Statistics (2021c).

Initial_Share_of_Demand_for_LPSF = 0.05
UNITS: dmnl
DOCUMENT: This parameter represents the initial share of local food demand in Greater Adelaide that goes towards Locally Produced Sustainable Food. It is assumed that the initial share is 5% of the total annual local food demand, since the social connectedness of the food system is low at first.

Local_Population(t) = Local_Population(t - dt) + (Births + Net_Migration - Deaths) * dt
INIT Local_Population = Initial_Local_Population
UNITS: People
DOCUMENT: This stock represents the total population size of Greater Adelaide at any one point in time. It is accumulated by three flows: the number of births per year (inflow), the number of deaths per year (outflow) and the net migration rate (biflow). The initial value of stock is simply the Initial Local Population.

INFLOWS:
Births = Local_Population*Birth_Rate
UNITS: People/Year
DOCUMENT: This inflow represents the number of births per year in Greater Adelaide. It is simply the product of the local population by the annual crude birth rate.

Net_Migration = Net_Migration_Rate*Local_Population
UNITS: People/Year
DOCUMENT: This biflow represents the number of net migrations in Greater Adelaide per year. It is simply the product of the local population by the annual net migration rate.

OUTFLOWS:
Deaths = Death_Rate*Local_Population
UNITS: People/Year
DOCUMENT: This outflow represents the number of deaths in Greater Adelaide per year. It is simply the product of the local population by the crude fractional death rate.

Net_Migration_Rate = 4/1000
UNITS: Dmnl/year
DOCUMENT: This parameter represents the difference between the number of immigrants and the number of emigrants throughout the year per thousand of population. The rate was derived by averaging out the data for Australia found in Macrotrends (n.d.).

People_per_Household = 2.5
UNITS: people/household
DOCUMENT: This constant parameter indicates the average number of people living in a household. The data was obtained from Census data available at the Australian Bureau of Statistics (2021c).

Ratio_of_Local_to_National_Population = 0.05
UNITS: dmnl
DOCUMENT: This variable represents the proportion of people living in Greater Adelaide as compared to the whole population of Australia. This is shown as a percentage of the total population. Numbers were obtained from the Australian Bureau of Statistics (2021c).

Reference_Commercial_Demand = Share_of_Demand_for_Australian_Retail*Annual_Local_Food_Demand + "Annual_Non-Local_Food_Demand"
UNITS: Tons/Years
DOCUMENT: This variable indicates the reference demand for food consumed from commercial retailers in all of Australia at any one point in time. It is calculated by multiplying the Annual Local Food Demand and the Share of Demand for Australian Retail, as well as adding in the Annual Non-Local Food Demand. Unlike Farmers Market and Food Coop demand, Commercial Demand need not be sustainable nor locally produced. Hence, commercial demand has to take into account the non-local demand as well.

Reference_Consumer_Price = INIT(Total_Yearly_Food_Consumption)/INIT(Annual_Local_Food_Demand)
UNITS: AUD19/Tons
DOCUMENT: This constant parameter represents the Reference Consumer Price paid on average for a unit of foodstuff. This is calculated by taking the initial total yearly food consumption over the initial annual local food demand. Given the level of aggregation in our model, we do not take into account the variability of price of food for different types of foodstuffs. This reference value is a simplified representation for the average price of food across board.

Reference_Farmers_Market_Demand = Share_of_Demand_for_Farmers_Market*Annual_Local_Food_Demand
UNITS: Tons/Years
DOCUMENT: This variable indicates the reference demand for food sold at farmers market in Greater Adelaide at any one point in time. It is calculated by multiplying the Annual Local Food Demand and the Share of Demand for Farmer's Market.

Reference_Food_Coop_Demand = Annual_Local_Food_Demand*Share_of_Demand_for_Food_Cooperatives
UNITS: Tons/Years
DOCUMENT: This variable indicates the reference demand for food consumed from food cooperatives in Greater Adelaide at any one point in time. It is calculated by multiplying the Annual Local Food Demand and the Share of Demand for Food Cooperatives.

Share_of_Demand_for_Australian_Retail = (1-Weight_of_Food_Imports)*Share_of_Demand_for_Commercial_Food
UNITS: dmnl
DOCUMENT: This variable represents the share of demand for commercial foodstuff which are being consumed from Australian retailers at any one point in time. It is dynamically calculated by the product of the share of demand for commercial food and the weight of Australian retail in that share (1-weight of food imports).

Share_of_Demand_for_Commercial_Food = (1-Share_of_Demand_for_Locally_Produced_Sustainable_Food)
UNITS: dmnl
DOCUMENT: This parameter represents the share of local food demand in Greater Adelaide that goes towards Commercial Food at any one point in time. Here, Commercial Food means purchasing food from retailers likes supermarkets or other sources where the supply of food is usually from commercial wholesalers. This share is dynamically calculated by subtracting the share of demand for local produce from 1, assuming that both these shares add up to 100%.

Share_of_Demand_for_Farmers_Market = Weight_of_Farmers_Market*Share_of_Demand_for_Locally_Produced_Sustainable_Food
UNITS: dmnl
DOCUMENT: This variable represents the share of demand for foodstuff that are sold at Farmers Markets at any one point in time. It is dynamically calculated by the product of the share of demand for locally produced sustainable food and the weight of farmers market in that share.

Share_of_Demand_for_Food_Cooperatives = (1-Weight_of_Farmers_Market)* Share_of_Demand_for_Locally_Produced_Sustainable_Food
UNITS: dmnl
DOCUMENT: This variable represents the share of demand for foodstuff which are being consumed from food cooperatives at any one point in time. It is dynamically calculated by the product of the share of demand for locally produced sustainable food and the weight of food cooperatives in that share (1-weight of farmers market).

Share_of_Demand_for_Food_Imports = Weight_of_Food_Imports*Share_of_Demand_for_Commercial_Food
UNITS: dmnl
DOCUMENT: This variable represents the share of demand for commercial foodstuff which are being consumed from Food Imports at any one point in time. It is dynamically calculated by the product of the share of demand for commercial food and the weight of Food Imports in that share.

Share_of_Demand_for_Locally_Produced_Sustainable_Food = Initial_Share_of_Demand_for_LPSF *Effect_of_SCFS_on_Share_of_Demand_for_Locally_Produced_Sustainable_Food
UNITS: dmnl
DOCUMENT: This parameter represents the share of local food demand in Greater Adelaide that goes towards Locally Produced Sustainable Food at any one point in time. Here, LPSF is assumed to be sourced from Farmers Market and Food Cooperatives where social enterprises have made arrangements with local farmers for their food supply. It is calculated by multiplying the effect of the level of food system social connectedness on the initial share.

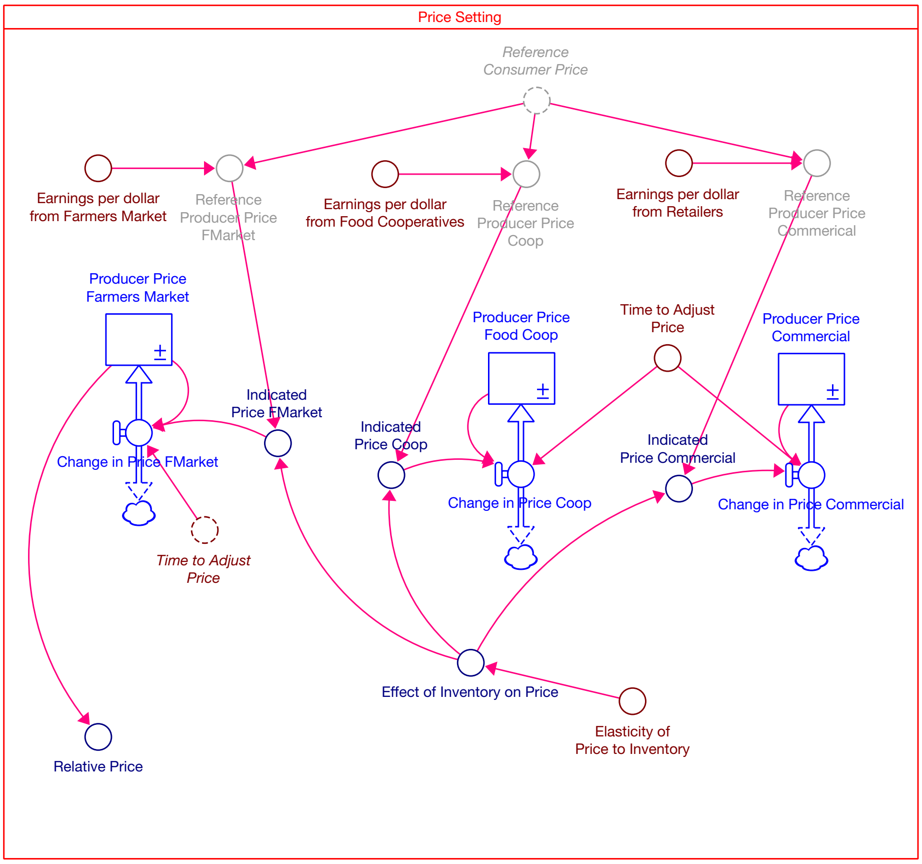
Total_Households = Local_Population/People_per_Household
UNITS: household
DOCUMENT: This variable represents the total number of households in Greater Adelaide at any one point in time. It is calculated by taking the total local population divided by the average number of people per household.

Total_Yearly_Food_Consumption = Total_Households*Food_Consumption_per_Household
UNITS: AUD19/Year
DOCUMENT: This variable calculates the total food consumption in dollars by the population per year. It is calculated by taking the product of total household and total food consumption in dollars per year per household.

Weight_of_Farmers_Market = 0.3
UNITS: dmnl
DOCUMENT: This parameter represents the weight of Farmers Market as a source of demand for locally produced food. It is assumed that the weight is 30% for farmers market, meaning that it has a much smaller weight as compared to food cooperatives (70%). This is so because we expect much more food cooperative arrangements to be set up as compared to setting up farmers market stalls.

Weight_of_Food_Imports = 0.15
UNITS: dmnl
DOCUMENT: This parameter represents the weight of Food Imports as a source of demand for commercial food. It is assumed that the weight is 15% for food imports, meaning that it has a much smaller weight as compared to commercial food produced by large-scale farms as well as SME farms in Australia outside of Greater Adelaide (85%).

Price Setting Sector



Earnings_per_dollar_from_Farmers_Market = 0.5
UNITS: dmnl
DOCUMENT: This parameter represents the fraction of consumer price from Farmer's market that goes to the farmer. According to Parfitt et al. (2012), farmers in Australia can earn up to 50 cents of a dollar spent by consumers in social enterprises that is committed to social equity. However, since farmers are the direct seller in Farmer's market, we can expect a higher profit margin. Yet, we have set this to 0.5 in order to account for other costs associated with food processing, transport, stall rental etc, which are omitted in the cost of production per ton of food.

Earnings_per_dollar_from_Food_Cooperatives = 0.3
UNITS: dmnl
DOCUMENT: This parameter represents the fraction of consumer price from Farmer's market that goes to the farmer. According to Parfitt et al. (2012), farmers in Australia can earn up to 50 cents of a dollar spent by consumers in social enterprises that is committed to social equity. However, we have set this value to 0.3 as a more conservative estimate, since we have conceptualised food cooperatives to include any form of cooperative between final seller and the farmer directly, cutting out the middle man.

Earnings_per_dollar_from_Retailers = 0.1
UNITS: dmnl
DOCUMENT: This parameter represents the fraction of consumer retail price that actually goes to the farmer. According to Parfitt et al. (2012), farmers in Australia only earn 10 cents of a dollar spent by consumers from commercial retailers such as supermarkets.

Effect_of_Inventory_on_Price = Relative_Inventory^Elasticity_of_Price_to_Inventory
UNITS: dmnl
DOCUMENT: This variable represents the amount of change in Price to changes in Relative Inventory (Supply) with reference to the elasticity. This is calculated by taking the elasticity of Price as an exponent of the relative inventory.

Elasticity_of_Price_to_Inventory = -1
UNITS: dmnl
DOCUMENT: This parameter determines the sensitivity of Price to changes in Relative Inventory. In this model, it is assumed that price is unit elastic to relative inventory, meaning that price changes proportionally to a change in relative inventory. Hence, it is assigned a value of 1. The negative coefficient indicates an inverse relationship, whereby an increase in relative inventory (more supply) leads to a decrease in price. This parameter can be adjusted to reflect a more accurate elasticity with proper data collection.

Indicated_Price_Commercial = Reference_Producer_Price_Commerical*Effect_of_Inventory_on_Price
UNITS: AUD19/Tons
DOCUMENT: The indicated Price Commercial represents the immediate dynamic pricing that takes into account the demand and supply dynamics. It multiplies the effect of inventory (supply/demand ratio) on the reference price.

Indicated_Price_Coop = Reference_Producer_Price_Coop*Effect_of_Inventory_on_Price
UNITS: AUD19/Tons
DOCUMENT: The indicated Price Coop represents the immediate dynamic pricing that takes into account the demand and supply dynamics. It multiplies the effect of inventory (supply/demand ratio) on the reference price.

Indicated_Price_FMarket = Reference_Producer_Price_FMarket*Effect_of_Inventory_on_Price
UNITS: AUD19/Tons
DOCUMENT: The indicated Price FMarket represents the immediate dynamic pricing that takes into account the demand and supply dynamics. It multiplies the effect of inventory (supply/demand ratio) on the reference price.

Producer_Price_Commercial(t) = Producer_Price_Commercial(t - dt) + (Change_in_Price_Commercial) * dt
INIT Producer_Price_Commercial = Reference_Producer_Price_Commerical
UNITS: AUD19/Tons
DOCUMENT: The Producer Price Commercial is an information stock, which accumulates the bi-flow Change in Price Commercial. It represents the final Price at which the farmer sells their produce to commercial wholesalers and food processors. The initial value of the stock is simply the Reference Producer Price Commercial.

INFLOWS:
Change_in_Price_Commercial = (Indicated_Price_Commercial-Producer_Price_Commercial)/Time_to_Adjust_Price
UNITS: AUD19/Tons/Year
DOCUMENT: This bi-flow adjusts the Commercial Price by attempting to close the gap between the indicated and actual price over a certain adjustment time. It has an explicit goal of equilibrating the price with the indicated price.

Producer_Price_Farmers_Market(t) = Producer_Price_Farmers_Market(t - dt) + (Change_in_Price_FMarket) * dt
INIT Producer_Price_Farmers_Market = Reference_Producer_Price_FMarket
UNITS: AUD19/Tons
DOCUMENT: The Producer Price at the Farmers' Market is an information stock, which accumulates the bi-flow Change in Price FMarket. It represents the final Price at which the farmer sells their produce to consumers at the Farmers' Market. The initial value of the stock is simply the Reference Producer Price FMarket.

INFLOWS:
Change_in_Price_FMarket = (Indicated_Price_FMarket-Producer_Price_Farmers_Market)/Time_to_Adjust_Price
UNITS: AUD19/Tons/Year
DOCUMENT: This bi-flow adjusts the Price at the Farmers Market by attempting to close the gap between the indicated and actual price over a certain adjustment time. It has an explicit goal of equilibrating the price with the indicated price.

Producer_Price_Food_Coop(t) = Producer_Price_Food_Coop(t - dt) + (Change_in_Price_Coop) * dt
INIT Producer_Price_Food_Coop = Reference_Producer_Price_Coop
UNITS: AUD19/Tons
DOCUMENT: The Producer Price at the Food Cooperative is an information stock, which accumulates the bi-flow Change in Price Coop. It represents the final Price at which the farmer sells their produce to buyers secured through cooperative arrangements. The initial value of the stock is simply the Reference Producer Price Coop.

INFLOWS:
Change_in_Price_Coop = (Indicated_Price_Coop-Producer_Price_Food_Coop)/Time_to_Adjust_Price
UNITS: AUD19/Tons/Year
DOCUMENT: This bi-flow adjusts the Price at Food Cooperative by attempting to close the gap between the indicated and actual price over a certain adjustment time. It has an explicit goal of equilibrating the price with the indicated price.

Reference_Producer_Price_Commerical = Reference_Consumer_Price*Earnings_per_dollar_from_Retailers
UNITS: AUD19/Tons
DOCUMENT: This parameter represents the reference Producer Price at the Commercial Processors or Wholesalers (who eventually sell it to retailers). It is calculated by multiplying the reference consumer price with the fraction that which goes to the farmer.

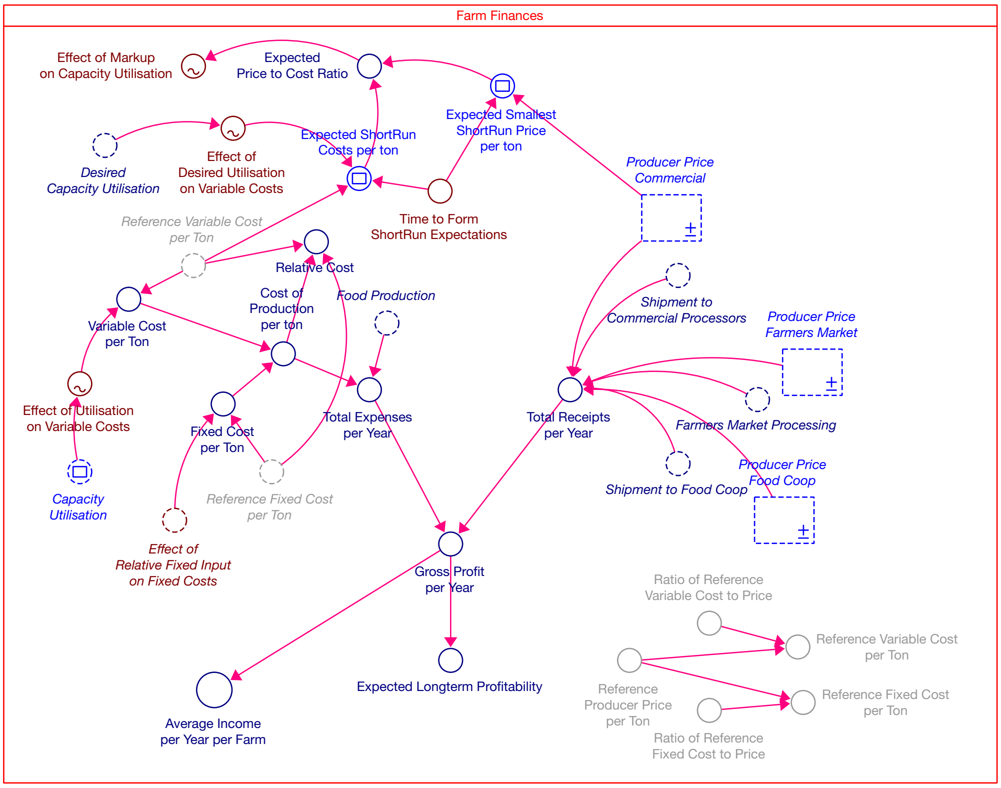
Reference_Producer_Price_Coop = Reference_Consumer_Price*Earnings_per_dollar_from_Food_Cooperatives
UNITS: AUD19/Tons
DOCUMENT: This parameter represents the reference Producer Price at the Food Cooperatives. It is calculated by multiplying the reference consumer price with the fraction that which goes to the farmer.

Reference_Producer_Price_FMarket = Reference_Consumer_Price*Earnings_per_dollar_from_Farmers_Market
UNITS: AUD19/Tons
DOCUMENT: This parameter represents the reference Producer Price at the Farmers' Market. It is calculated by multiplying the reference consumer price with the fraction that which goes to the farmer.

Relative_Price = Producer_Price_Farmers_Market/INIT(Producer_Price_Farmers_Market)
UNITS: dmnl
DOCUMENT: The variable shows the ratio of price to the base year, which indicates how much the variable has changed compared to the base year. Since all three prices have different absolute numbers but the same effect of inventory (supply/demand) on Price, the relative price serves as an excellent candidate for the modelling the effect of changes in price on demand.

Time_to_Adjust_Price = 1
UNITS: Year
DOCUMENT: This parameter represents the time taken to close the gap between the indicated price and the actual price at which the produce is sold at. It is assumed that it takes about 1 year to adjust the price since the supply/demand ratio is not immediately perceived by farmers nor buyers.

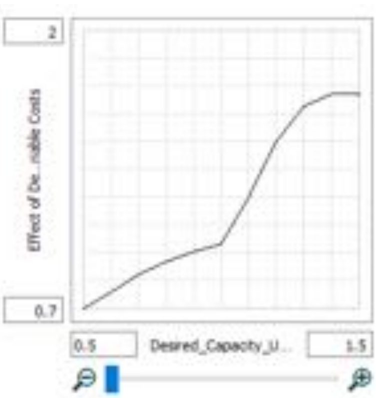
Farm Finances Sector



Average_Income_per_Year_per_Farm = Gross_Profit_per_Year/"#_of_Local_SME_Farms"
UNITS: AUD19/year/farm
DOCUMENT: This variable indicates the average income of each farm per year. This is calculated by taking the gross profit per year over the number of local SME farms in Greater Adelaide. It should be noted that this is the average gross income from food production alone. The net income, which would account for tax, financing and interest payments as well as reinvestments, are not considered in this model given its variability to individual farm situations.

Cost_of_Production_per_ton = Variable_Cost_per_Ton+Fixed_Cost_per_Ton
UNITS: AUD19/Tons
DOCUMENT: This variable represents the total cost of food production per ton. It is simply the sum of the variable cost and fixed cost per ton of food produced.

Effect_of_Desired_Utilisation_on_Variable_Costs = GRAPH(Desired_Capacity_Utilisation)
Points(11): (0.500, 0.700), (0.600, 0.776), (0.700, 0.859), (0.800, 0.918), (0.900, 0.965), (1.000, 1.000), (1.100, 1.216), (1.200, 1.477), (1.300, 1.643), (1.400, 1.700), ...

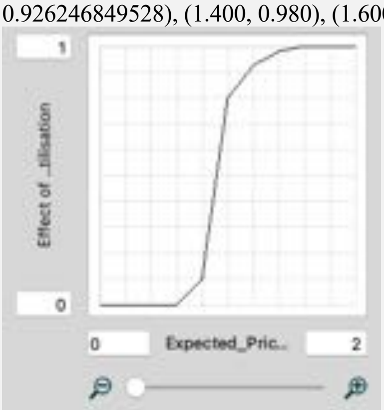


UNITS: dmnl

DOCUMENT: This variable represents the effects of capacity utilisation on variable cost. Unlike the effect of relative input on cost, the effect of utilisation on cost is expected to be nonlinear.

When utilisation is 1, the variable cost is 1 (normal levels). When utilisation decreases below the normal towards 0.5, variable cost decreases towards 0.7. The assumption here is that reducing utilisation does not mean that cost will reduce proportionally. There are some variable cost involved that will not be reduced, for instance electricity bills for maintaining the farm, labour costs etc. When the utilisation increases above 1 to a maximum of 1.5, costs increases with a much steeper slope towards 1.7. The steeper increase and higher cost is based on the assumption that increases utilisation means paying more for some variable costs, like for instance labour cost that needs to take into account a higher over time wage.

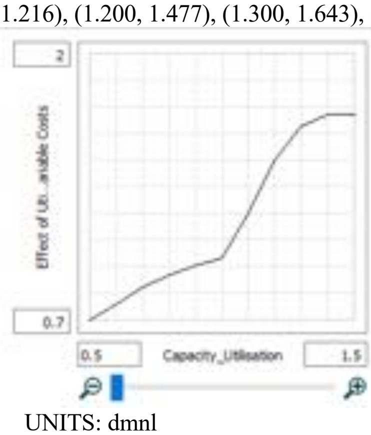
Effect_of_Markup_on_Capacity_Utilisation = GRAPH(Expected_Price_to_Cost_Ratio)
Points(11): (0.000, 0.000), (0.200, 0.000), (0.400, 0.000), (0.600, 0.000), (0.800, 0.100), (1.000, 0.800), (1.200, 0.926246849528), (1.400, 0.980), (1.600, 1.000), (1.800, 1.000), ...



UNITS: dmnl

DOCUMENT: This variable represents the effect of the markup ratio (expected profit margin) on farmers' decision on capacity utilisation. When the markup ratio is 1 (i.e. cost = price), there is no expected profit margin and it is assumed that farmer's will likely adjust their capacity utilisation downward to 80% of the desired level. When the markup ratio is 0.8 (meaning that they will producing at a loss) some optimistic farmers may still produce, and thus the effect is about 10% of the desired utilisation. When there ratio is above 1.5, where the profit margin is sufficiently large enough, the effect on capacity utilisation will be the full desired utilisation level. Between 1 and 1.6 of the price to cost ratio, the effect on capacity utilisation increases increasingly to 1. This formulation is referenced from Sterman's (2020) commodity cycle model.

Effect_of_Utilisation_on_Variable_Costs = GRAPH(Capacity_Utilisation)
Points(11): (0.500, 0.700), (0.600, 0.776), (0.700, 0.859), (0.800, 0.918), (0.900, 0.965), (1.000, 1.000), (1.100, 1.216), (1.200, 1.477), (1.300, 1.643), (1.400, 1.700), ...



UNITS: dmnl

DOCUMENT: This variable represents the effects of capacity utilisation on variable cost. Unlike the effect of relative input on cost, the effect of utilisation on cost is expected to be nonlinear.

When utilisation is 1, the variable cost is 1 (normal levels). When utilisation decreases below the normal towards 0.5, variable cost decreases towards 0.7. The assumption here is that reducing utilisation does not mean that cost will reduce proportionally. There are some variable cost involved that will not be reduced, for instance electricity bills for maintaining the farm, labour costs etc. When the utilisation increases above 1 to a maximum of 1.5, costs increases with a much steeper slope towards 1.7. The steeper increase and higher cost is based on the assumption that increases utilisation means paying more for some variable costs, like for instance labour cost that needs to take into account a higher over time wage.

Expected_Longterm_Profitability = TREND(Gross_Profit_per_Year, 5)
UNITS: dmnl/year
DOCUMENT: The TREND function calculates the fractional change in the average income per farm per year with an averaging time of 5 years. In turn, this represents the 5-year average growth rate of the SME farm industry gross profit, and therefore acts as an indicator for the longterm expected profitability of the industry – an important parameter for making investment decisions.

Expected_Price_to_Cost_Ratio =
Expected_Smallest_ShortRun_Price_per_ton/Expected_ShortRun_Costs_per_ton
UNITS: dmnl
DOCUMENT: This variable calculates the ration of the price to cost. When the ratio is more than 1, then it means that there is a markup in the price; meaning that there is a profit margin. If the ratio is less than 1, it means that it costs more to produce an additional unit of food than the price it can garner, meaning it is not profitable.

Expected_ShortRun_Costs_per_ton =
SMTH1(Reference_Variable_Cost_per_Ton*Effect_of_Desired_Utilisation_on_Variable_Costs,
Time_to_Form_ShortRun_Expectations) {DELAY CONVERTER}
UNITS: AUD19/Tons
DOCUMENT: This delay converter represents farmers' expectation of the variable cost of producing an additional unit of food. Since variable costs vary from year to year, farmers expectations will be based on past cost that is updated over an adjustment time. This expectation only takes into account the variable cost since it is used for assessing the marginal cost of production, and hence omits the fixed costs (Sterman, 2000). For this assessment of short-run costs, then, the effect of desired capacity utilisation is multiplied on the reference variable cost.

Expected_Smallest_ShortRun_Price_per_ton = SMTH1(Producer_Price_Commercial,
Time_to_Form_ShortRun_Expectations, 731) {DELAY CONVERTER}
UNITS: AUD19/Tons
DOCUMENT: This delay converter represents farmers' expectation of the smallest price at which they can sell a unit of food produced. Since prices vary year to year, farmers expectations will be based on past prices that is updated over an adjustment time.

Fixed_Cost_per_Ton = Reference_Fixed_Cost_per_Ton*Effect_of_Relative_Fixed_Input_on_Fixed_Costs
UNITS: AUD19/Tons
DOCUMENT: This variable dynamically calculates the Fixed Cost of production per ton of food at any one point in time. It does so by multiplying the effect of relative fixed input on the reference fixed cost.

Gross_Profit_per_Year = Total_Receipts_per_Year-Total_Expenses_per_Year
UNITS: AUD19/Year
DOCUMENT: This variable indicates the gross profit earned by the farm sector each year. It subtracts the yearly total expenses from the yearly total receipts, giving the yearly gross profit.

Ratio_of_Reference_Fixed_Cost_to_Price = 0.25
UNITS: dmnl
DOCUMENT: This parameter provides the ratio of fixed cost per ton of food produced to the price per ton of food produced. The value was estimated from the broadacre farm performance in South Australia as reported by ABARES (2020). The estimation was done by taking the difference between the farm income and the farm business profit as a fraction of the total cash receipts.

Ratio_of_Reference_Variable_Cost_to_Price = 0.65
UNITS: dmnl
DOCUMENT: This parameter provides the ratio of variable cost per ton of food produced to the price per ton of food produced. The value was estimated from the broadacre farm performance in South Australia as reported by ABARES (2020). The estimation was done by taking the total cash cost as a fraction of the total cash receipts.

Reference_Fixed_Cost_per_Ton =
Reference_Producer_Price_Commerical*Ratio_of_Reference_Fixed_Cost_to_Price
UNITS: AUD19/Tons
DOCUMENT: Given the ratio of reference fixed cost to price, this parameter calculates the reference fixed cost of producing a ton of food. This reference cost is an estimated average cost of producing any kind of food type based on the reference price; this is a necessary simplification given the aggregation in the model.

Reference_Producer_Price_per_Ton = 731
UNITS: AUD19/Tons
DOCUMENT: Given the aggregation of the model, there is no basis for estimating the reference cost of production. Instead, here, we have used the smallest producer price in the model to estimate the reference cost of production. The assumption is that at the very maximum, the cost of production will be at the smallest wholesale price, lest the farmer will be producing at a loss from the get the go.

Reference_Variable_Cost_per_Ton = Reference_Producer_Price_Commerical*Ratio_of_Reference_Variable_Cost_to_Price
UNITS: AUD19/Tons
DOCUMENT: Given the ratio of reference variable cost to price, this parameter calculates the reference variable cost of producing a ton of food. This reference cost is an estimated average cost of producing any kind of food type based on the reference price; this is a necessary simplification given the aggregation in the model.

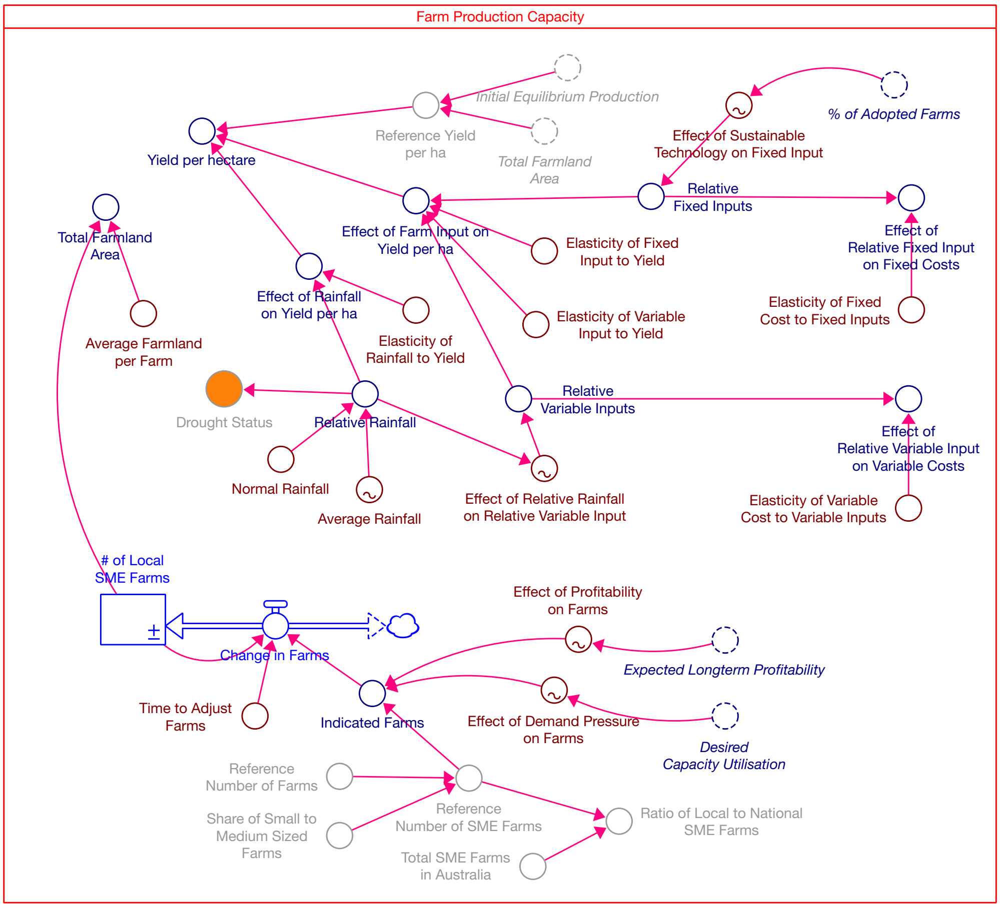
Time_to_Form_ShortRun_Expectations = 2
UNITS: Year
DOCUMENT: This parameter represents the adjustment time for forming short-term expectations of the price they think they will receive for a unit of food production as well as the cost of producing that unit. It is assumed that their expectations will be based on the price and cost from 2 years ago.

Total_Expenses_per_Year = Food_Production*Cost_of_Production_per_ton
UNITS: AUD19/Year
DOCUMENT: This variable represents the total expenses incurred from food production per year – for all small and medium farms in Greater Adelaide. It is simply the product of the number of tons of food produced per year and the cost of production per ton.

Total_Receipts_per_Year = Shipment_to_Commercial_Processors*Producer_Price_Commercial + Shipment_to_Food_Coop*Producer_Price_Food_Coop + Farmers_Market_Processing*Producer_Price_Farmers_Market
UNITS: AUD19/Year
DOCUMENT: This variable shows the total revenue per year for the SME farm industry in Greater Adeliade. It is the sum of the revenues received from the supply of food produced to commercial processors, food cooperatives, and farmer's market, multiplied by the respective prices.

Variable_Cost_per_Ton = Reference_Variable_Cost_per_Ton*Effect_of_Utilisation_on_Variable_Costs*Effect_of_Relative_Variable_Input_on_Variable_Costs
UNITS: AUD19/Tons
DOCUMENT: This variable dynamically calculates the Variable Cost of production per ton of food at any one point in time. It does so by multiplying the effect of capacity utilisation and the effect of relative variable input on the reference variable cost.

Farm Production Capacity Sector

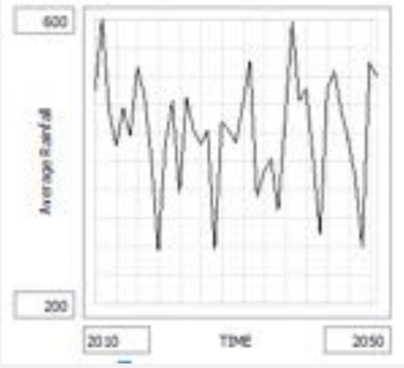


"#_of_Local_SME_Farms"(t) = "#_of_Local_SME_Farms"(t - dt) + (Change_in_Farms) * dt
INIT "#_of_Local_SME_Farms" = Reference_Number_of_SME_Farms
UNITS: farm
DOCUMENT: The Number of Local SME Farms is a stock, which accumulates the bi-flow Change in Farms. It represents the number of operational small and medium scale farms in Greater Adelaide. The initial value of the stock is simply the Reference Number of SME Farms.

INFLOWS:
Change_in_Farms = ((Indicated_Farms-"#_of_Local_SME_Farms")/Time_to_Adjust_Farms)
UNITS: farm/Year
DOCUMENT: This bi-flow increases or decreases the number of operational farms every year by attempting to close the gap between the indicated and actual number of farms over a certain adjustment time. It has an explicit goal of equilibrating the number of local SME farms with the indicated number.

Average_Farmland_per_Farm = 100
UNITS: ha/farm
DOCUMENT: This parameter indicates the area of arable land used for food production per farm. Derived from data provided by the Australian Bureau of Statistics (2021a), on average each farm uses about 100 hectares of land for agricultural production.

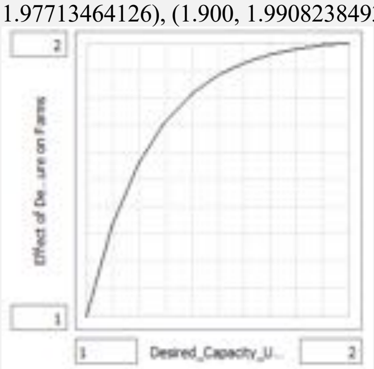
Average_Rainfall = GRAPH(TIME)
Points(41): (2010.00, 500.0), (2011.00, 600.0), (2012.00, 471.0), (2013.00, 422.0), (2014.00, 473.0), (2015.00, 436.0), (2016.00, 532.0), (2017.00, 494.0), (2018.00, 405.0), (2019.00, 275.0), ...



UNITS: mm
DOCUMENT: This variable represents the average rainfall data in South Australia. It serves as an exogenous variable that simulates drought situations. Data points from 2010 to 2020 were taken from historical data provided by the Australian Bureau of Meteorology (2021). Data points beyond 2020 were drawn by hand based on anticipated behaviour – showing similar variability to the past, but with more recurrent drought situations meant to serve as shocks to the food system. Implicit in this assumption is that with Climate Change, we can expect more unpredictability in weather patterns and more recurrent drought situations.

Drought_Status = IF Relative_Rainfall<0.7 THEN 1 ELSE 0
UNITS: dmnl
DOCUMENT: This parameter is a Drought Status indicator. A value of 1 indicates a drought situation, whereas a value of 0 does not. To qualify as a drought, the relative rainfall has to be below 0.7, or below 70% of the normal rainfall.

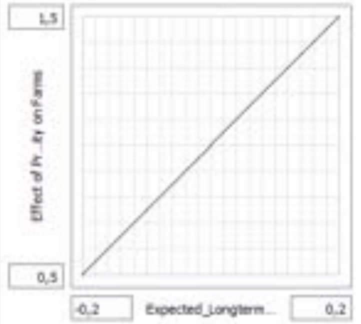
Effect_of_Demand_Pressure_on_Farms = GRAPH(Desired_Capacity_Utilisation)
Points(11): (1.000, 1.000), (1.100, 1.33583091167), (1.200, 1.56094510384), (1.300, 1.7118436595), (1.400, 1.81299398628), (1.500, 1.88079707798), (1.600, 1.92624684953), (1.700, 1.95671274249), (1.800, 1.97713464126), (1.900, 1.99082384938), ...



UNITS: dmnl
DOCUMENT: This variable represents the effect desired capacity utilisation on indicated number of farms. Desired capacity utilisation is the ratio of the production capacity to the desired production based on demand. In that sense, it can also be seen as the demand/supply ratio, indicating the demand pressure.
When the demand pressure is high (desired capacity utilisation more than 1), it stands to reason that it will exert pressure on investment decisions on top of the profitability of investment based on the industry growth rates. If prospective farmers sense that there is more demand than supply in the market, they will attempt to enter the market to close the gap. Hence as the demand pressure increases from 1 to 2, the indicated number of farms increases decreasingly towards a maximum of 2. It increases decreasingly as double the farms is assumed to be the market saturation point. When the demand pressure is low (desired capacity utilisation is less than 1), the effect remains at 1. It means that no farmers are expected the leave the industry so long as they perceive the long run growth rate to be profitable.

Effect_of_Farm_Input_on_Yield_per_ha =
Relative_Variable_Inputs^Elasticity_of_Variable_Input_to_Yield*Relative_Fixed_Inputs^Elasticity_of_Fixed_Input_to_Yield
UNITS: dmnl
DOCUMENT: This variable represents the amount of change in yield per hectare to changes in agricultural inputs with reference to the elasticity. This is calculated by taking the elasticity of inputs as an exponent of the relative fixed input and variable input respectively. Fixed input and variable input have a multiplicative effect on yield.

Effect_of_Profitability_on_Farms = GRAPH(Expected_Longterm_Profitability)
Points(21): (-0.2000, 0.500), (-0.1800, 0.550), (-0.1600, 0.600), (-0.1400, 0.650), (-0.1200, 0.700), (-0.1000, 0.750), (-0.0800, 0.800), (-0.0600, 0.850), (-0.0400, 0.900), (-0.0200, 0.950), ... {GF EXTRAPOLATED}

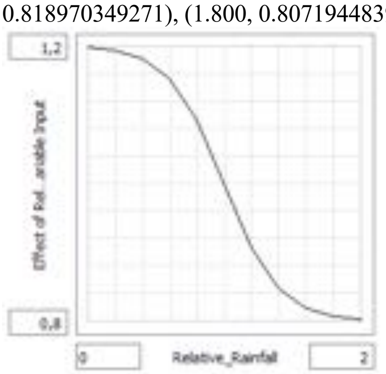


UNITS: dmnl
DOCUMENT: This variable represents the effect expected long-term profitability on indicated number of farms. It is the investment decision-rule for either prospective farmers deciding to enter the industry, or existing farmers deciding to leave the industry. In general, the relationship between profitability and number of farms is assumed to be linear. The more profitable, the more farms, and the less profitable the less farms.

Effect_of_Rainfall_on_Yield_per_ha = Relative_Rainfall^Elasticity_of_Rainfall_to_Yield
UNITS: dmnl
DOCUMENT: This variable represents the amount of change in yield per hectare to changes in rainfall with reference to its elasticity. This is calculated by taking the elasticity of rainfall as an exponent of the relative rainfall.

Effect_of_Relative_Fixed_Input_on_Fixed_Costs =
Relative_Fixed_Inputs^Elasticity_of_Fixed_Cost_to_Fixed_Inputs
UNITS: dmnl
DOCUMENT: This variable represents the amount of change in Fixed Costs per ton of food to changes in Fixed Inputs with reference to the elasticity. This is calculated by taking the elasticity of inputs as an exponent of the relative fixed inputs.

Effect_of_Relative_Rainfall_on_Relative_Variable_Input = GRAPH(Relative_Rainfall)
Points(11): (0.000, 1.19732285963), (0.200, 1.19280551602), (0.400, 1.18102965073), (0.600, 1.15231883119), (0.800, 1.09242343145), (1.000, 1.0000), (1.200, 0.907576568548), (1.400, 0.847681168809), (1.600, 0.818970349271), (1.800, 0.807194483985), ...

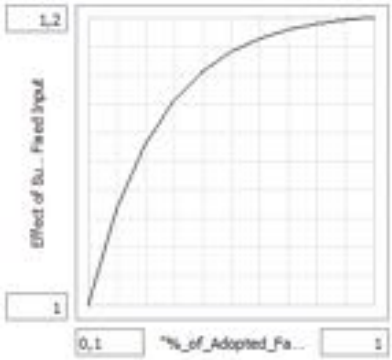


UNITS: dmnl
DOCUMENT: This variable represents the effect of relative rainfall on the relative variable input. It is assumed that as rainfall changes, farmers will adjust their input usage, specifically water usage, accordingly.
When the relative rainfall is 1 (normal level), the effect on the relative input remains at 1. When the relative rainfall decreases towards 0, the effect on relative variable input increases decreasingly towards a maximum of

1.2. Here, it is assumed that farmers will attempt to make up for the lack of precipitation by using more water for irrigation. When the relative rainfall increases towards 2, the effect on variable inputs decreases decreasingly towards a maximum of 0.8. Here, it is assumed that with more precipitation, farmers will reduce their water usage. Since water usage is only one component of variable input, that it affects the total variable input by 20% at most in both directions.

Effect_of_Relative_Variable_Input_on_Variable_Costs =
Relative_Variable_Inputs^Elasticity_of_Variable_Cost_to_Variable_Inputs
UNITS: dmnl
DOCUMENT: This variable represents the amount of change in Variable Costs per ton of food to changes in Variable Inputs with reference to the elasticity. This is calculated by taking the elasticity of variable cost as an exponent of the relative fixed inputs.

Effect_of_Sustainable_Technology_on_Fixed_Input = GRAPH("%_of_Adopted_Farms")
Points(11): (0.1000, 1.0000), (0.1900, 1.06716618233), (0.2800, 1.11218902077), (0.3700, 1.1423687319), (0.4600, 1.16259879726), (0.5500, 1.1761594156), (0.6400, 1.18524936991), (0.7300, 1.1913425485), (0.8200, 1.19542692825), (0.9100, 1.19816476988), ...



UNITS: dmnl

DOCUMENT: This variable represents the effect of the adoption of sustainable technology on fixed inputs. There has been many advances in sustainable farming technology and practices, including the use of Artificial Intelligence, autonomous farming machinery, and precision agriculture – all of which produces favourable production/yield and environmental outcomes (Goedde et al., 2020; Tomchek, 2020). In this model, adoption of sustainable technology increases the fixed assets of farmers, which then has a corollary impact on the yield per hectare. As the percentage of farms which have adopted sustainable technology increases from its initial level of 0.1 towards 1, the effect on fixed inputs increases decreasingly from 1 to a maximum effect of 1.2. Since the initial number of farms assumed to already have sustainable practices and technology, the effect of this initial value has already been accounted for in the reference yield per ha, and thus initial fixed inputs. Increases in the adopted farms thereafter, is expected to increase the relative fixed input above 1. However, fixed inputs is not expected to increase beyond the maximum, assumed to be 1.2. This assumption is based on the fact that farmers do not just constantly add on to their fixed assets, but retire the outdated/depreciated assets. Hence adoption of sustainable technology should also be seen as replacement rather than simple addition.

Elasticity_of_Fixed_Cost_to_Fixed_Inputs = 1
UNITS: dmnl
DOCUMENT: This parameter determines the sensitivity of Fixed Cost to changes in Relative Fixed Inputs. In this model, it is assumed that cost is unit elastic to relative inputs, meaning that cost changes proportionally to changes in inputs. Hence, it is assigned a value of 1. The positive coefficient indicates an positive relationship, whereby an increase in relative input leads to a proportional increase in cost. This parameter can be adjusted to reflect a more accurate elasticity with proper data collection.

Elasticity_of_Fixed_Input_to_Yield = 0.5
UNITS: dmnl
DOCUMENT: This parameter determines the sensitivity of Yield to changes in Relative Fixed Input. In this model, it is assumed that yield is relatively inelastic to relative inputs, meaning that it responds less than proportionally to changes in input. It stands to reason that as inputs increases above the normal, the yield increases with diminishing returns as it approaches its carrying capacity. Hence, it is assigned a value of 0.5 to estimate a moderate response from increases in agricultural inputs. The positive coefficient indicates a positive relationship. This parameter can be adjusted to reflect a more accurate elasticity with proper data collection.

Elasticity_of_Rainfall_to_Yield = 1
UNITS: dmnl
DOCUMENT: This parameter determines the sensitivity of Yield to changes in Relative Rainfall. In this model, it is assumed that yield is unit elastic to relative rainfall, meaning that it responds proportionally to changes in rainfall. Hence, it is assigned a value of 1. The positive coefficient indicates a positive relationship, whereby a decrease in relative rainfall leads to a proportional decrease in yield. It should be noted that this is a necessary simplification since rainfall is used to simulate extreme weather conditions; in reality, drought situations frequently follow from a concurrent high temperature, and thus the elasticity is set at a higher than expected value at 1.

Elasticity_of_Variable_Cost_to_Variable_Inputs = 1
UNITS: dmnl
DOCUMENT: This parameter determines the sensitivity of Variable Cost to changes in Relative Variable Inputs. In this model, it is assumed that cost is unit elastic to relative inputs, meaning that cost changes proportionally to changes in inputs. Hence, it is assigned a value of 1. The positive coefficient indicates an positive relationship, whereby an increase in relative input leads to a proportional increase in cost. This parameter can be adjusted to reflect a more accurate elasticity with proper data collection.

Elasticity_of_Variable_Input_to_Yield = 0.5
UNITS: dmnl
DOCUMENT: This parameter determines the sensitivity of Yield to changes in Relative Variable Input. In this model, it is assumed that yield is relatively inelastic to relative inputs, meaning that it responds less than proportionally to changes in input. It stands to reason that as inputs increases above the normal, the yield increases with diminishing returns as it approaches its carrying capacity. Hence, it is assigned a value of 0.5 to estimate a moderate response from increases in agricultural inputs. The positive coefficient indicates an positive relationship. This parameter can be adjusted to reflect a more accurate elasticity with proper data collection.

Indicated_Farms =
Reference_Number_of_SME_Farms*Effect_of_Profitability_on_Farms*Effect_of_Demand_Pressure_on_Farms
UNITS: farm
DOCUMENT: The indicated Farms represents the number of farms after accounting for the farmers intending to enter or exit the industry. It multiplies the effect of expected longterm profitability and the effect of demand pressure on the reference number of farms.

Normal_Rainfall = 450
UNITS: mm
DOCUMENT: The Normal Rainfall is the mean rainfall in Australia, discerned from historical data provided by the Australian Bureau of Meteorology (2021).

Ratio_of_Local_to_National_SME_Farms =
Reference_Number_of_SME_Farms/Total_SME_Farms_in_Australia
UNITS: dmnl
DOCUMENT: This constant parameter represents the proportion of the local SME farms to the total SME farms in Australia.

Reference_Number_of_Farms = 842
UNITS: farm
DOCUMENT: This parameter represents the total number of farms in Greater Adelaide area. The reference value, 842, is obtained from data provided by ABARES (2021).

Reference_Number_of_SME_Farms = Reference_Number_of_Farms*Share_of_Small_to_Medium_Sized_Farms
UNITS: farm
DOCUMENT: The reference number of farms that are small and medium enterprises (SME) in Greater Adelaide is 758. This constant parameter is derived from the product of the reference number of farms in Greater Adelaide and the share of small to medium sized farms.

Reference_Yield_per_ha = INIT(Initial_Equilibrium_Production)/INIT(Total_Farmland_Area)
UNITS: tons/ha/year
DOCUMENT: The reference yield per hectare of land is set to 3.81 tons per hectare per year. This constant parameter is derived from the initial equilibrium production per year (how much food must be produced in the initial year to maintain the initial inventory) divided by the initial total farmland area, thereby giving us an average yield (food produced) per hectare of farmland.

Relative_Fixed_Inputs = 1*Effect_of_Sustainable_Technology_on_Fixed_Input
UNITS: dmnl
DOCUMENT: This parameter represents the relative fixed inputs or assets; a ratio of the fixed inputs at any one point in time to the normal input level. This represents capital assets such as farm buildings, machinery, irrigation channels and other agricultural infrastructure. A value of more than 1 indicates more input than normal; whereas a value of less than 1 indicates less input than normal. The relative variable input is mainly affected by the effect of sustainable technology adoption.

Relative_Rainfall = Average_Rainfall/Normal_Rainfall
UNITS: dmnl
DOCUMENT: This parameter calculates the relative rainfall; a ratio of the average rainfall at any one point in time to the normal rainfall. A value of more than 1 indicates more rainfall than normal; whereas a value of less than 1 indicates less rainfall than normal.

Relative_Variable_Inputs = 1*Effect_of_Relative_Rainfall_on_Relative_Variable_Input
UNITS: dmnl
DOCUMENT: This parameter represents the relative variable inputs; a ratio of the variable inputs at any one point in time to the normal input level. It represents factors of production such as fertiliser, contract labour, water usage, fuel usage etc. A value of more than 1 indicates more input than normal; whereas a value of less than 1 indicates less input than normal. The relative variable input is mainly affected by a multiplicative effect from changes in rainfall.

Share_of_Small_to_Medium_Sized_Farms = 0.9
UNITS: dmnl
DOCUMENT: This parameter indicates the share of small to medium sized farms to the total number of farms in Greater Adelaide, which is 0.9 (ABARES, 2021a). This means that 90% of farms are small and medium enterprises (SME).

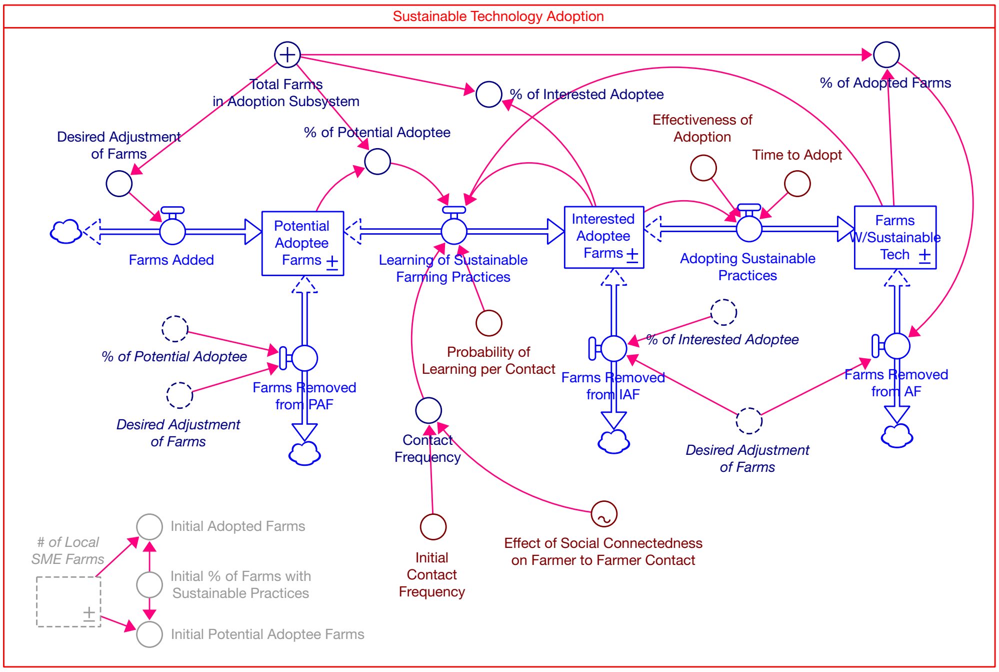
Time_to_Adjust_Farms = 3
UNITS: Year
DOCUMENT: This parameter represents the time taken to close the gap between the indicated number of farms and the actual number of farms. It is assumed that it takes about 3 years to exit or set up a farm.

Total_Farmland_Area = Average_Farmland_per_Farm*"#_of_Local_SME_Farms"*1 + Average_Farmland_per_Farm*INIT("#_of_Local_SME_Farms")*0
UNITS: ha
DOCUMENT: This variable shows the total farmland area for food production in Greater Adelaide at any one point in time. This is the product of average farmland per farm and the number of local SME farms. This variable is measured in hectares.

Total_SME_Farms_in_Australia = 89400*0.9
UNITS: farm
DOCUMENT: The Total SME Farms in Australia is a reference value derived from the total number of agricultural businesses in Australia, 89400 (ABARES, 2021b), multiplied with the assumption that SME farms constitute 90% of the total farms – similar to the proportion in Greater Adelaide.

Yield_per_hectare = Reference_Yield_per_ha*Effect_of_Farm_Input_on_Yield_per_ha*Effect_of_Rainfall_on_Yield_per_ha
UNITS: tons/ha/year
DOCUMENT: This variable dynamically calculates the yield per hectare of farmland by multiplying the effects of farm input and effect on rainfall on the reference yield. The yield represents, on average, how much food (in tons) can be produced by a hectare of land per year.

Sustainable Technology Adoption Sector



"%_of_Adopted_Farms" = "Farms_W/Sustainable_Tech"/Total_Farms_in_Adoption_Subsystem
UNITS: dmnl
DOCUMENT: The variable calculates the percentage of the adopted farms in the adoption subsystem - the fraction of farms that have implemented and use sustainable technology.

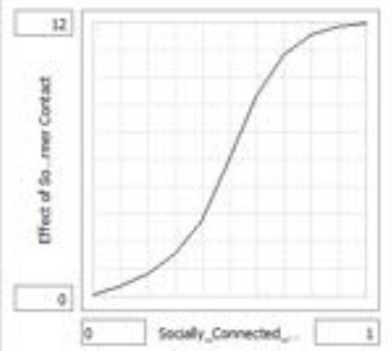
"%_of_Interested_Adoptee" = Interested_Adoptee_Farms/Total_Farms_in_Adoption_Subsystem
UNITS: dmnl
DOCUMENT: The variable calculates the percentage of the interested adoptee in the adoption subsystem - the fraction of farms that are interested in adopting sustainable technology but have yet to implement it.

"%_of_Potential_Adoptee" = Potential_Adoptee_Farms/Total_Farms_in_Adoption_Subsystem
UNITS: dmnl
DOCUMENT: The variable calculates the percentage of the potential adoptee in the adoption subsystem - the fraction of farms that have not learnt about sustainable farming practices and technology.

Contact_Frequency =
Initial_Contact_Frequency*Effect_of_Social_Connectedness_on_Farmer_to_Farmer_Contact
UNITS: contact/year
DOCUMENT: This variable calculates the contact frequency between farmers. It is calculated by multiplying the effect of social connectedness on the initial contact frequency. It represents how many meaningful farmer to farmer interactions there are per year.

Desired_Adjustment_of_Farms = ("#_of_Local_SME_Farms"-Total_Farms_in_Adoption_Subsystem)/DT
UNITS: farm/year
DOCUMENT: This variable represents the desired adjustments in the total number of farms in the adoption subsystem in order to match it with the total number of local SME farms in the industry. The Sustainable Technology Adoption sector represents a subsystem of the internal dynamics of the stock of Local SME Farms. The equation takes the difference between the Local SME Farms and total farms in the subsystem (the gap) which is divided by the delta time of the model. This ensures that the adjustment is made instantaneously rather than over a time period.

Effect_of_Social_Connectedness_on_Farmer_to_Farmer_Contact = GRAPH(Socially_Connected_Food_System)
Points(11): (0.000, 0.0803142110914), (0.100, 0.47), (0.200, 1.00), (0.300, 1.88), (0.400, 3.35), (0.500, 6.00), (0.600, 8.77270294356), (0.700, 10.5695649357), (0.800, 11.4308895219), (0.900, 11.7841654805), ...



UNITS: dmnl
DOCUMENT: This variable represents the effect of the level of social connectedness of food system on the contact frequency between local farmers. As the food system becomes more socially connected, we expect stronger farmer to farmer associations and exchanges (Dubois & Carson, 2020). Hence, we expect an increase in the contact frequency between farmers.
When the social connectedness is 0.2 (initial level), the effect on the contact frequency is 1, indicating that it will be at the initial level. As social connectedness increases from 0.2 towards its maximum 1, the effect increases increasingly before increasing decreasingly towards a maximum of 12. The maximum effect is limited at 12 in order to constrain the the Contact Frequency at a maximum of 12. The assumption here is that when the food system is very socially connected, we will expect more farmers associations or other forms of engagement platforms that holds meaningful exchanges at most 12 times a year.

Effectiveness_of_Adoption = 0.8
UNITS: dmnl
DOCUMENT: This parameter represents the effectiveness of success rate of a farmer implementing sustainable technology. Since we do not expect 100% success rate as some people are bound to fail at implementing new technology, the effectiveness of the adoption is assumed to by at 0.8 (80%). Nevertheless, this is still an optimistic scenario.

"Farms_W/Sustainable_Tech"(t) = "Farms_W/Sustainable_Tech"(t - dt) + (Adopting_Sustainable_Practices - Farms_Removed_from_AF) * dt
INIT "Farms_W/Sustainable_Tech" = Initial_Adopted_Farms
UNITS: farm
DOCUMENT: This stock represents the number of Adopted Farms that have successfully implemented the adoption of sustainable farming technology and practices. It is accumulated by the inflow, Adopting Sustainable Farming Practices and depleted by the outflows, Farms Removed from the sector. The initial value of stock is simply the Initial Adopted Farms.

Adopting_Sustainable_Practices = (Interested_Adoptee_Farms/Time_to_Adopt)*Effectiveness_of_Adoption
UNITS: farm/Year
DOCUMENT: This flow represents the adoption rate of sustainable farming technology and practices. The rate is simply the number of interested adoptee farms divided by the time taken to adopt the technology, this is then multiplied by the effectiveness to calculate the number of farms that are successful at adoption per year.

Farms_Removed_from_AF = IF Desired_Adjustment_of_Farms>0 THEN 0 ELSE -Desired_Adjustment_of_Farms*"%_of_Adopted_Farms"
UNITS: farm/year
DOCUMENT: This outflow decreases the number of farms in the adoption subsystem when the desired adjustment is negative, indicating that existing farms are being removed from the Local SME Farm industry. Farms are removed from each of the three adoption stocks according to the density of the respective stock. This is a simplification to ensure that none of the stocks go to negative.

Initial_%_of_Farms_with_Sustainable_Practices = 0.1
UNITS: dmnl
DOCUMENT: This parameter represents the initial fraction of farms that have adopted sustainable technology and practices. It is assumed that initially 10% of local farms have already done so.

Initial_Adopted_Farms = INIT("#_of_Local_SME_Farms"*Initial_%_of_Farms_with_Sustainable_Practices)
UNITS: farm
DOCUMENT: This parameter calculates the Initial Adopted Farms by multiplying the initial fraction with the initial number of local SME farms.

Initial_Contact_Frequency = 1
UNITS: contact/year
DOCUMENT: This parameter represents the initial contact frequency between farmers. It is assumed that initially, with a low level of social connectedness, farmers have meaningful engagements with only 1 other farmer per year.

Initial_Potential_Adoptee_Farms = INIT("#_of_Local_SME_Farms"*(1-Initial_%_of_Farms_with_Sustainable_Practices))
UNITS: farm
DOCUMENT: This parameter calculates the Initial Potential Adoptee Farms by multiplying the initial number of local SME farms and the initial fraction of farms that have not adopted sustainable practices.

Interested_Adoptee_Farms(t) = Interested_Adoptee_Farms(t - dt) + (Learning_of_Sustainable_Farming_Practices - Adopting_Sustainable_Practices - Farms_Removed_from_IAF) * dt
INIT Interested_Adoptee_Farms = 0
UNITS: farm
DOCUMENT: This stock represents the number of Interested Adoptee Farms that have learnt about sustainable farming technology and practices, but have yet to implement them. It is accumulated by the inflow, Learning of Sustainable Farming Practices. It is depleted by two outflows: (1) Farms Removed from the sector and more importantly, (2) Adopting Sustainable Practices. The initial value of stock is assumed to be 0. This structure and the entire subsystem references the generic Bass Adoption Model.

Learning_of_Sustainable_Farming_Practices = MAX(0, "%_of_Potential_Adoptee"*(Interested_Adoptee_Farms+"Farms_W/Sustainable_Tech")*Probability_of_Learning_per_Contact*Contact_Frequency)
UNITS: farm/Year
DOCUMENT: This flow variable represents the rate of learning of sustainable farming practices. It is determined by the rate of contact between potential adoptee farms and those who have already learnt about sustainable technology (interested + adopted) multiplied with the probability of learning from each contact. The MAX function ensures that the rate does not go below 0 at any point in time. It is an adaptation of the generic Bass Adoption model structure. The Bass Adoption model was chosen for modelling sustainable technology adoption as SME farmers in Australia have been reported to be distrustful of scientific knowledge; rather, they usually prefer to trust their peers who have already adopted new techniques of productions (Dubois & Carson, 2020).

Adopting_Sustainable_Practices = (Interested_Adoptee_Farms/Time_to_Adopt)*Effectiveness_of_Adoption
UNITS: farm/Year
DOCUMENT: This flow represents the adoption rate of sustainable farming technology and practices. The rate is simply the number of interested adoptee farms divided by the time taken to adopt the technology, this is then multiplied by the effectiveness to calculate the number of farms that are successful at adoption per year.

Farms_Removed_from_IAF = IF Desired_Adjustment_of_Farms>0 THEN 0 ELSE -Desired_Adjustment_of_Farms*"%_of_Interested_Adoptee"
UNITS: farm/year
DOCUMENT: This outflow decreases the number of farms in the adoption subsystem when the desired adjustment is negative, indicating that existing farms are being removed from the Local SME Farm industry. Farms are removed from each of the three adoption stocks according to the density of the respective stock. This is a simplification to ensure that none of the stocks go to negative.

Potential_Adoptee_Farms(t) = Potential_Adoptee_Farms(t - dt) + (Farms_Added - Learning_of_Sustainable_Farming_Practices - Farms_Removed_from_PAF) * dt
INIT Potential_Adoptee_Farms = Initial_Potential_Adoptee_Farms
UNITS: farm
DOCUMENT: This stock represents the number of Potential Adoptee Farms that have yet to learn about or implement sustainable farming technology and practices. It is accumulated by the number of Farms Added to the sector, and depleted by two outflows: (1) Farms Removed from the sector and more importantly, (2) Learning of Sustainable Farming Practices. The initial value of stock is simply the Initial Potential Adoptee Farms.

Farms_Added = IF Desired_Adjustment_of_Farms<0 THEN 0 ELSE Desired_Adjustment_of_Farms
UNITS: farm/Year
DOCUMENT: This inflow increases the number of farms in the adoption subsystem when the desired adjustment is positive, indicating that there are new entrants to the Local SME Farm industry. Farms are added to the potential to the Potential Adoptee Farms as it is assumed that the newcomers have yet to learn about the sustainable technology and practices.

Learning_of_Sustainable_Farming_Practices = MAX(0, "%_of_Potential_Adoptee"*(Interested_Adoptee_Farms+"Farms_W/Sustainable_Tech")*Probability_of_Learning_per_Contact*Contact_Frequency)
UNITS: farm/Year
DOCUMENT: This flow variable represents the rate of learning of sustainable farming practices. It is determined by the rate of contact between potential adoptee farms and those who have already learnt about sustainable technology (interested + adopted) multiplied with the probability of learning from each contact. The MAX function ensures that the rate does not go below 0 at any point in time. It is an adaptation of the generic Bass Adoption model structure. The Bass Adoption model was chosen for modelling sustainable technology adoption as SME farmers in Australia have been reported to be distrustful of scientific knowledge; rather, they usually prefer to trust their peers who have already adopted new techniques of productions (Dubois & Carson, 2020).

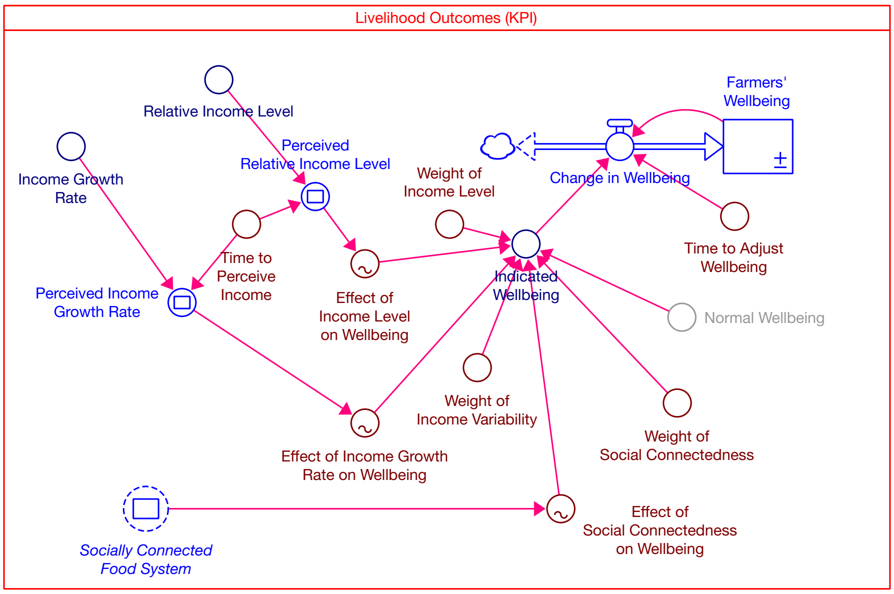
Farms_Removed_from_PAF = IF Desired_Adjustment_of_Farms>0 THEN 0 ELSE -Desired_Adjustment_of_Farms*"%_of_Potential_Adoptee"
UNITS: farm/year
DOCUMENT: This outflow decreases the number of farms in the adoption subsystem when the desired adjustment is negative, indicating that existing farms are being removed from the Local SME Farm industry. Farms are removed from each of the three adoption stocks according to the density of the respective stock. This is a simplification to ensure that none of the stocks go to negative.

Probability_of_Learning_per_Contact = 0.03
UNITS: dmnl/contact
DOCUMENT: This parameter represents the probability of a farmer learning about sustainable farming practices from the contacts they have with other farmers. The value was calibrated to 0.03 based on the reasonable behaviour. However, more data should be collected to optimise this value.

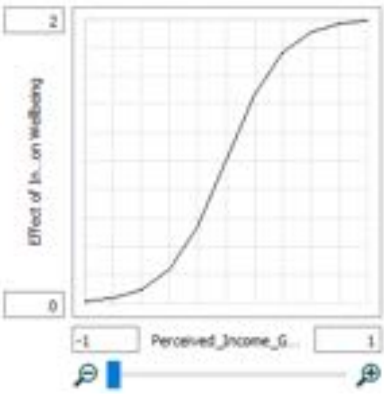
Time_to_Adopt = 2
UNITS: Years
DOCUMENT: This parameter represents the time taken for a farmer to implement the adoption of sustainable technology. It is assumed that it takes about 2 years to realise their interest and make the necessary changes to their farming practices.

Total_Farms_in_Adoption_Subsystem = Interested_Adoptee_Farms + Potential_Adoptee_Farms + "Farms_W/Sustainable_Tech" {SUMMING CONVERTER}
UNITS: farm
DOCUMENT: This summing converter calculates the total number of farms in the adoption subsystem. It is the sum of the Potential Adoptee Farms, Interested Adoptee Farms, and the Adopted Farms.

Livelihood Outcomes Sector



Effect_of_Income_Growth_Rate_on_Wellbeing = GRAPH(Perceived_Income_Growth_Rate)
Points(11): (-1.000, 0.0133857018486), (-0.800, 0.0359724199242), (-0.600, 0.0948517463551), (-0.400, 0.238405844044), (-0.200, 0.53788284274), (0.000, 1.000), (0.200, 1.46211715726), (0.400, 1.76159415596), (0.600, 1.90514825364), (0.800, 1.96402758008), ...

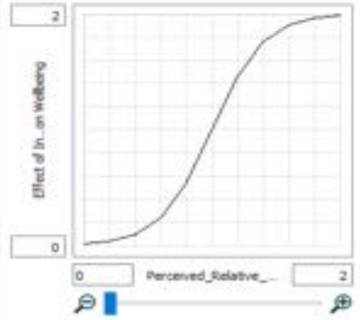


UNITS: dmnl

DOCUMENT: This variable represents the effect of perceived income growth rate on the normal well-being. Growth rate is differentiated to income level since farmers are expected to be attuned to the yearly percentage change in incomes. Variability in changes of income is then conceptualised as a stressor on well-being, since it is a direct comparison of financial performance – where a positive rate indicates growth in business and a negative rate indicates decline.

When the perceived growth rate is 0, the effect on the normal well-being remains at 1 (i.e. the normal level). When the growth rate decreases below 0, the effect on normal well-being decreases decreasingly towards zero. When the growth rate increases above 0, the effect on normal well-being increases decreasingly towards a maximum of 2. The maximum effect is limited at 2 in order to constrain well-being at its maximum at 100%.

Effect_of_Income_Level_on_Wellbeing = GRAPH(Perceived_Relative_Income_Level)
Points(11): (0.000, 0.0133857018486), (0.200, 0.0359724199242), (0.400, 0.0948517463551), (0.600, 0.238405844044), (0.800, 0.53788284274), (1.000, 1.000), (1.200, 1.46211715726), (1.400, 1.76159415596), (1.600, 1.90514825364), (1.800, 1.96402758008), ...

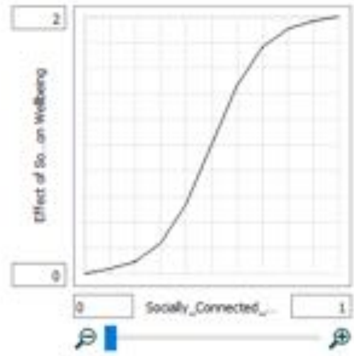


UNITS: dmnl

DOCUMENT: Income level is not only a widely-accepted indicator of one's economic well-being (Levine, 2014), but also correlated with one's emotional well-being (Kahneman & Deaton, 2010). Thus, this variable represents the effect of perceived income level on the normal well-being.

When the perceived relative income level is 1, the farmer's well-being remains at 1 (i.e. the normal level). When the relative income level is less than 1, representing a drop in income level below normal, the effect on normal well-being decreases decreasingly towards zero. When the relative income level increases above 1, the effect on normal well-being increases decreasingly towards a maximum of 2. The maximum effect is limited at 2 in order to constrain well-being at its maximum at 100%. Moreover, the maximum effect occurs when income doubles, and not more, since studies have found that well-being does not increase any further beyond a certain level of income (Kahneman & Deaton, 2010).

Effect_of_Social_Connectedness_on_Wellbeing = GRAPH(Socially_Connected_Food_System)
Points(11): (0.000, 0.000), (0.100, 0.0359724199242), (0.200, 0.0948517463551), (0.300, 0.238405844044), (0.400, 0.53788284274), (0.500, 1.000), (0.600, 1.46211715726), (0.700, 1.76159415596), (0.800, 1.90514825364), (0.900, 1.96402758008), ...



UNITS: dmnl

DOCUMENT: This variable represents the effect of the level of social connectedness of food system on the normal well-being. As the food system becomes more socially connected, we expect greater interactions and relationship building between farmers and other farmers, as well as farmers and consumers, either through direct selling at the farmers markets, visits to local farms, or other initiatives for the establishment of food cooperatives (Parfitt et al., 2012). Improvements in social relations, then, is assumed to positively affect the well-being of farmers since social relationships are a prime source for coping with adversities and building resilience (interview with Dr. Ariella Helfgott). Even though times are hard, knowing that there is a strong community/consumer support base that has the livelihoods of farmers in mind, could buffer shocks to system which bring down the farm's production capacity.

When the social connectedness is 0.5, representing the neutral point, the effect on the normal well-being remains at 1 (i.e. the normal level). When the social connected decreases towards 0, the effect on normal well-being decreases decreasingly towards zero. When the social connectedness increases towards its the maximum, the effect on normal well-being increases decreasingly towards a maximum of 2. The maximum effect is limited at 2 in order to constrain well-being at its maximum at 100%.

Farmers'_Wellbeing(t) = Farmers'_Wellbeing(t - dt) + (Change_in_Wellbeing) * dt
INIT Farmers'_Wellbeing = Normal_Wellbeing
UNITS: dmnl
DOCUMENT: According to Levine (2014), measurement of livelihood is often narrowly focused on economic success. Instead, he calls for the inclusion of non-economic indicators such as "people's ability to cope, the range of their choices and their resilience" (Levine, 2014, p.14). Based on this perspective, we have conceptualised Farmers' Well-being as the primary key performance indicator that accounts for both economic and social aspects of well-being. It represents the average farmer's state of mind in response to changes in overall income level (economic success), income variability (economic success), social connectedness/inclusion (coping mechanism). The resilience of the farmer is taken as the ability of the farmer to maintain their well-being at or above the normal well-being level in spite of shocks to stressors. Farmers' Well-being is represented as a stock in the model as it accumulates over time, and does not respond to stressors instantaneously. The initial value of the stock is simply taken as the normal well-being. Well-being is measured as a dimensionless percentage, ranging between 0 to 100%, where 50% is taken as the normal or neutral point.

Change_in_Wellbeing = (Indicated_Wellbeing-Farmers'_Wellbeing)/Time_to_Adjust_Wellbeing
UNITS: dmnl/year
DOCUMENT: This flow adjusts the Farmers' well-being to the indicated value over an adjustment time. If the current level is less than the indicated level, it adjusts the perceived well-being upwards. If the current level is more than the indicated level, it adjusts the perceived well-being downwards. In other words, it has an explicit goal of equilibrating the Well-being Level to the indicated Level.

Income_Growth_Rate = TREND(Average_Income_per_Year_per_Farm, 1)
UNITS: dmnl/year
DOCUMENT: The TREND function calculates the fractional change in the average income per farm per year with an averaging time of 1 year. In turn, this represents the annual growth rate of the average farm's income, indicating the year to year variability in their income.

Indicated_Wellbeing =
Normal_Wellbeing*Effect_of_Income_Growth_Rate_on_Wellbeing*Weight_of_Income_Variability +
Normal_Wellbeing*Effect_of_Income_Level_on_Wellbeing*Weight_of_Income_Level +
Normal_Wellbeing*Effect_of_Social_Connectedness_on_Wellbeing*Weight_of_Social_Connectedness
UNITS: dmnl
DOCUMENT: The indicated well-being represents the real-time well-being of the farmer before they attempt to update their well-being level. It multiplies the effect of income level, effect of income growth rate, and effect of social connectedness on the normal well-being.

Normal_Wellbeing = 0.5
UNITS: dmnl
DOCUMENT: The normal well-being of the average farmer is taken as 0.5 -the neutral point between 0 to 1.

Perceived_Income_Growth_Rate = SMTH1(Income_Growth_Rate, Time_to_Perceive_Income) {DELAY CONVERTER}
UNITS: dmnl/year
DOCUMENT: This delay converter represents the income growth rate as perceived by the farmer. Since farmers are not expected to have perfect information about farm finances at all times, it represents the process of updating their perception of changes in their annual income growth rate over an adjustment time.

Perceived_Relative_Income_Level = SMTH1(Relative_Income_Level, Time_to_Perceive_Income) {DELAY CONVERTER}
UNITS: dmnl
DOCUMENT: This delay converter represents the relative income level as perceived by the farmer. Since farmers are not expected to have perfect information about farm finances at all times, it represents the process of updating their perception of their income level over an adjustment time.

Relative_Income_Level = Average_Income_per_Year_per_Farm/INIT(Average_Income_per_Year_per_Farm)
UNITS: dmnl
DOCUMENT: The variable shows the ratio of average income per farm to the base year, which indicates how much the variable has changed compared to the base year. Since this is a conceptual model, not concerned with accurate absolute numbers, a relative value serves a better qualitative measure for assessing livelihood.

Time_to_Adjust_Wellbeing = 0.25
UNITS: Year
DOCUMENT: This variable represents the time taken by the farmer to adjust their well-being level to changes in stressors experienced. It is assumed that the farmer takes stock of their well-being every 3 months, i.e. 0.25 of a year.

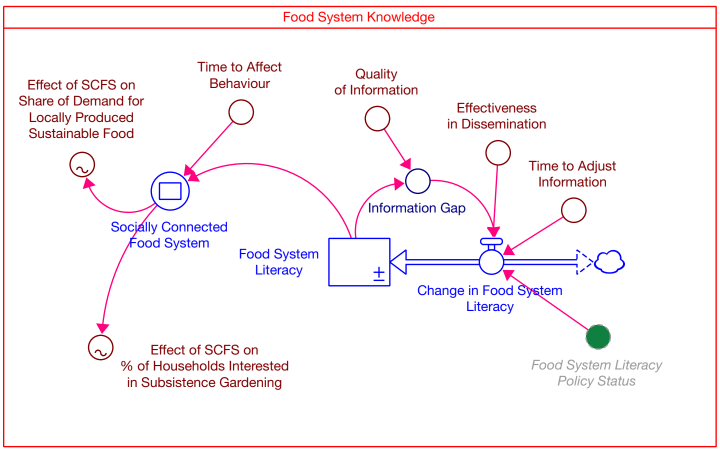
Time_to_Perceive_Income = 1
UNITS: Year
DOCUMENT: This variable represents the time taken by the farmer to perceive changes in their income. It is assumed that the farmer takes stock of their income yearly when they manage the books of the farm finances.

Weight_of_Income_Level = 0.5
UNITS: dmnl
DOCUMENT: This parameter assigns the weight of the income level in influencing the indicated well-being of the farmer. It is assumed that the effect of income level accounts for 50% of the farmer's overall well-being. Income level is conceptualised with a higher weight than income variability. Even though the income growth rate varies year to year, the fact that the overall income level is much higher than it otherwise would have been should carry a larger weight in evaluating one's economic health.

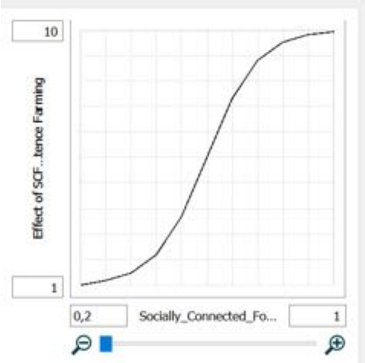
Weight_of_Income_Variability = 0.3
UNITS: dmnl
DOCUMENT: This parameter assigns the weight of the income variability in influencing the indicated well-being of the farmer. It is assumed that the effect of yearly income growth rate accounts for 30% of the farmer's overall well-being.

Weight_of_Social_Connectedness = 0.2
UNITS: dmnl
DOCUMENT: This parameter assigns the weight of social connectedness in influencing the indicated well-being of the farmer. It is assumed that the effect of social connectedness accounts for 20% of the farmer's overall well-being. Overall, it was reasoned that social aspects of well-being carried a smaller weight than economic aspects.

Food System Knowledge Sector



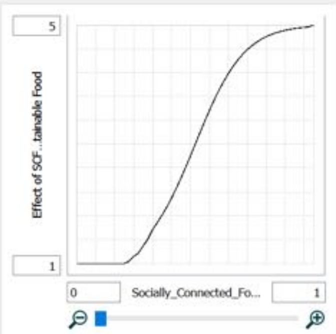
Effect_of_SCFS_on_%_of_Households_Interested_in_Subsistence_Gardening = GRAPH(Socially_Connected_Food_System)
Points(11): (0.2000, 1.000), (0.2800, 1.16187588966), (0.3600, 1.4268328586), (0.4400, 2.0728262982), (0.5200, 3.42047279233), (0.6000, 5.500), (0.6800, 7.57952720767), (0.7600, 8.9271737018), (0.8400, 9.5731671414), (0.9200, 9.83812411034), ...



UNITS: dmnl

DOCUMENT: This variable represents the effect of the level of social connectedness of food system on the proportion of individuals interested in subsistence gardening. As the food system becomes more socially connected, we expect people to be more involved in community gardening or other similar initiatives – this is also one of the common objectives of food literacy education interventions (Parfitt et al., 2012). Hence, we can expect an effect on the percentage of households interested in subsistence gardening. For simplification, we have used households as measure of subsistence gardening, assuming that each household has a backyard or some other suitable space for a garden. In reality, we also expect an increase in community gardens and school gardens. When the social connectedness is between 0 and 0.2, the effect on percentage of households interested in subsistence gardening is 1, indicating that it will be at the initial level. This has been set as such since the initial level of SCFS is assumed to be at 0.2. As social connectedness increases from 0.2 towards its maximum 1, the effect increases increasingly before increasing decreasingly towards a maximum of 10. The maximum effect is limited at 10 in order to constrain the percentage of households at a maximum of 10%. The assumption here is that the modern living and livelihoods is often not suited for maintaining a subsistence garden for most individuals and households. Often households with stay-at-home parents and/or retired individuals are better committed to maintaining a subsistence garden. Hence, we have constrained this to 10% of total households in Greater Adelaide.

Effect_of_SCFS_on_Share_of_Demand_for_Locally_Produced_Sustainable_Food = GRAPH(Socially_Connected_Food_System)
Points(51): (0.000, 1.000), (0.020, 1.000), (0.040, 1.000), (0.060, 1.000), (0.080, 1.000), (0.100, 1.000), (0.120, 1.000), (0.140, 1.000), (0.160, 1.000), (0.180, 1.000), ...



UNITS: dmnl

DOCUMENT: This variable represents the effect of the level of social connectedness of food system on the share of demand for locally produced sustainable food. As the food system becomes more socially connected, we expect people to better navigate the food system and source out not only sustainably produced food, but also locally produced food to support the local community (Parfitt et al., 2012). Hence, we expect an increase in the share of demand for locally produced sustainable food, taking away from the share of demand of commercial food supplied by non-local producers.

When the social connectedness is between 0 and 0.2, the effect on share of demand is 1, indicating that it will be at the initial level. This has been set as such since the initial level of SCFS is assumed to be at 0.2. As social connectedness increases from 0.2 towards its maximum 1, the effect increases increasingly before increasing decreasingly towards a maximum of 5. The maximum effect is limited at 5 in order to constrain the share of demand for local food at a maximum of 25%. The assumption here is that the demand for locally sourced food cannot cover 100% of total demand, as people are bound to still seek out commercially produced foodstuff as well as imports that local producers are not able to produce.

Effectiveness_in_Dissemination = 0.8
UNITS: dmnl
DOCUMENT: A parameter that serves as a measure of the quality of the policy intervention that can range between 0 to 1; 1 being the most effective intervention and 0 the opposite. Since we do not expect perfect intervention, the effectiveness of the intervention is assumed to by at 0.8 (80%). Nevertheless, this is still an optimistic scenario of intervention.

Food_System_Literacy(t) = Food_System_Literacy(t - dt) + (Change_in_Food_System_Literacy) * dt
INIT Food_System_Literacy = 0.2
UNITS: dmnl
DOCUMENT: The information stock, Food System Literacy, accumulates the inflow Change in Food System Literacy. It is a measure of the food systems literacy level of the stakeholders in Adelaide. A value of 1 means that the overall literacy level is at 100%, and a value of 0 means 0%. The initial value of the Food System Literacy is assumed to be low at 20%, but not abysmal since we expect segments of the population to be already informed about sustainable food systems. Food system literacy, here, is assumed to have an expansive definition beyond simple nutritional literacy on food choices (Palumbo, 2016). It involves elements of social connectedness; reconnecting the community to all levels and dimensions of the food system, including food production. In doing so it has a social justice perspective in transforming the entire food system to be more just and equitable for all members involved (Renwick & Powell, 2019).

Change_in_Food_System_Literacy = IF Food_System_Literacy_Policy_Status=1 THEN (Information_Gap/Time_to_Adjust_Information)*Effectiveness_in_Dissemination ELSE 0
UNITS: dmnl/year
DOCUMENT: If the policy status is 1, this bi-flow closes the information gap over a certain adjustment time, with the goal of equilibrating the Food System Literacy level with the Quality of Information disseminated. The adjustment of the stock is mediated by the Effectiveness in Dissemination, acting as a multiplier; thereby minimising the adjustment according to how effective the policy intervention is in closing the gap.
If the policy status is 0, there is no policy intervention, and therefore the flow is deactivated – there will be no change in Food System Literacy.

Information_Gap = Quality_of_Information-Food_System_Literacy
UNITS: dmnl
DOCUMENT: This variable calculates the difference between the Quality of Information level (goal for the population) and the actual Food System Literacy level of the population. Hence, it represents the Information Gap, to be closed by the policy intervention.

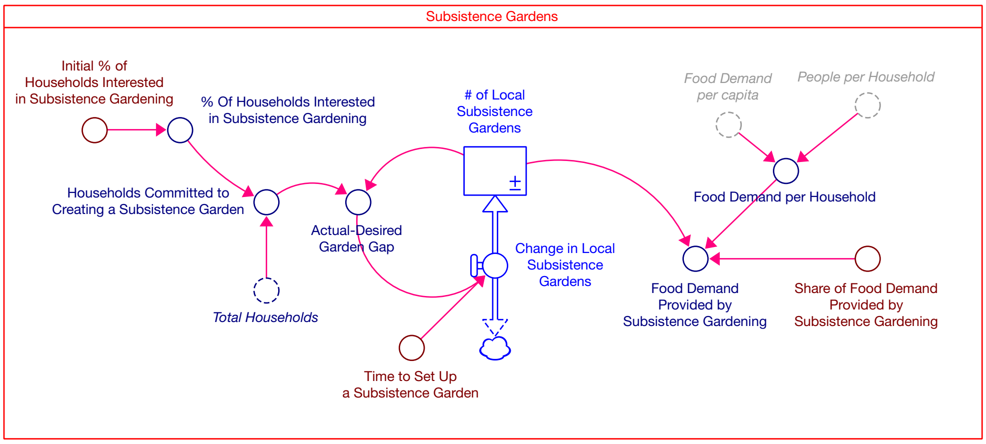
Quality_of_Information = 0.8
UNITS: dmnl
DOCUMENT: A parameter that serves as a measure of the quality of the information provided to stakeholders regarding food systems that can range from 0 to 1; 1 being perfect information and 0 the opposite.

Socially_Connected_Food_System = SMTH1(Food_System_Literacy, Time_to_Affect_Behaviour, 0.2)
{DELAY CONVERTER}
UNITS: dmnl
DOCUMENT: The overarching goal of Food System Literacy is to transform the food system, making it more socially (re)connected. Literacy or knowledge is insufficient in driving immediate behavioural outcomes, and thus social connectedness of the food system is delayed by the time for knowledge to affect behaviour. This delay converter, thus, represents the level of connectedness of the food system at any one point in time, accounting for this delay time.

Time_to_Adjust_Information = 2
UNITS: year
DOCUMENT: This variable represents the time taken by the population to close the gap in their literacy level. It is assumed that policy interventions for increasing food system literacy takes about 2 years for it to take effect.

Time_to_Affect_Behaviour = 2
UNITS: Year
DOCUMENT: The theory of planned behaviour posits that behavioural change does not flow immediately from information gain. Instead, there is a knowledge-attitude-behaviour continuum that requires a processing time from individuals (Bettinghaus, 1986). In this vein, this parameter serves as the processing time, or the adjustment time required of individuals to affect their behaviour from the food system knowledge that they gained from the policy intervention.

Subsistence Gardens Sector



"#_of_Local_Subsistence_Gardens"(t) = "#_of_Local_Subsistence_Gardens"(t - dt) + (Change_in_Local_Subsistence_Gardens) * dt
INIT "#_of_Local_Subsistence_Gardens" = Total_Households*0.01
UNITS: household
DOCUMENT: The Number of Local Subsistence Gardens is a stock, which accumulates the bi-flow Change in Local Subsistence Garden. It represents the number of operational subsistence gardens in Greater Adelaide. The initial value of the stock is simply the initial Households Committed to Create a Subsistence Garden. For simplification, we have used households as measure of subsistence gardening, assuming that each household has a backyard or some other suitable space for a garden. The assumption here is that households without a suitable space will likely be involved in community gardens and/or school gardens.

INFLOWS:
Change_in_Local_Subsistence_Gardens = "Actual-Desired_Garden_Gap"/Time_to_Set_Up_a_Subsistence_Garden
UNITS: household/Year
DOCUMENT: This bi-flow increases or decreases the number of local subsistence gardens every year by closing the Actual-Desired Garden Gap over a certain adjustment time. It has an explicit goal of equilibrating the number of local subsistence gardens with the number of households committed to subsistence gardening.

"%_Of_Households_Interested_in_Subsistence_Gardening" = Initial_%_of_Households_Interested_in_Subsistence_Gardening*Effect_of_SCFS_on_%_of_Households_Interested_in_Subsistence_Gardening
UNITS: dmnl
DOCUMENT: This variable dynamically calculates the percentage of households interested in subsistence gardening at any one point in time. It does so by multiplying the effect of socially connected food system on the initial percentage.

"Actual-Desired_Garden_Gap" = Households_Committed_to_Creating_a_Subsistence_Garden-"#_of_Local_Subsistence_Gardens"
UNITS: household
DOCUMENT: This variable calculates the gap between the actual number of local subsistence gardens (measured in households for simplicity) and the number of households committed to setting up one.

Food_Demand_per_Household = Food_Demand_per_capita*People_per_Household
UNITS: Tons/household/Years
DOCUMENT: The Food Demand per Household is a constant parameter that is calculated by multiplying the Food Demand per capita with the average number of People per household.

Food_Demand_Provided_by_Subsistence_Gardening = "#_of_Local_Subsistence_Gardens"*Food_Demand_per_Household*Share_of_Food_Demand_Provided_by_Subsistence_Gardening
UNITS: Tons/Years
DOCUMENT: This variable calculates the total food demand that is provided by subsistence gardening. It is calculated by multiplying the food demand per household with the total households with subsistence gardening, and the fraction of the demand that is provided by subsistence gardening. This food demand is then subtracted from the total local food demand in Greater Adelaide.

Households_Committed_to_Creating_a_Subsistence_Garden = Total_Households*"%_Of_Households_Interested_in_Subsistence_Gardening"
UNITS: household
DOCUMENT: This variable calculates the number of households committed to creating a subsistence gardening at any one point in time by multiplying the percentage of households interested with the total households in Greater Adelaide. The assumption is that all households who are interested will eventually set up a subsistence garden in their backyard or elsewhere.

Initial_%_of_Households_Interested_in_Subsistence_Gardening = 0.01
UNITS: dmnl
DOCUMENT: This parameter represents the initial percentage of households interested in subsistence gardening. This is expected to be small given the low level of food system literacy initially assumed, and thus this value is set to 1%.

Share_of_Food_Demand_Provided_by_Subsistence_Gardening = 0.1
UNITS: dmnl
DOCUMENT: This parameter represents the share or percentage of food demand that can be provided by subsistence gardening. It stands to reason that gardening can hardly cover one's total food consumption, but only a fraction. We have used a liberal estimate of 10% of total consumption that is covered by subsistence gardening. A liberal estimate is chosen in order to test its effect on farmers' livelihood, since subsistence gardening is afterall a competitor of food producers. This ensures that there is no unintended consequences from the Food System Literacy policy.

Time_to_Set_Up_a_Subsistence_Garden = 2
UNITS: year
DOCUMENT: This parameter represents the time taken to close the Actual-Desired Garden Gap. It is assumed that it takes about 2 years to set up a subsistence garden and have it bearing food/produce for consumption.

Model Testing Results

Integration Error Test

The model was tested with half (1/64) and double (1/16) time step, with two integration methods: Euler and Runge-Kutta 4. The simulation results remained the same. However, it must be noted that the shortest adjustment time in the model is 0.25 years and, thus, the minimum DT should at least be 1/8 with Euler to prevent integration errors.

Sensitivity Analysis

The model's sensitivity to all parameters and table functions was tested on the optimistic policy scenario – in order to observe the changes in the two key KPIs: Relative Income Level and Farmers Well-Being. For constant parameters, Sensitivity Analysis was conducted with Stella's Model Analysis Tools. Each test was configured for 6 runs with Incremental Distribution and Latin Hybercube Sampling. As for table functions, Sensitivity Analysis was performed by changing table values and simulating with comparative graphs. Given the sheer number of parameters and table functions in this model, the results will be grouped according to the type of parameter and only the most sensitive of each type will be presented in this section.

Normal or Initial Values

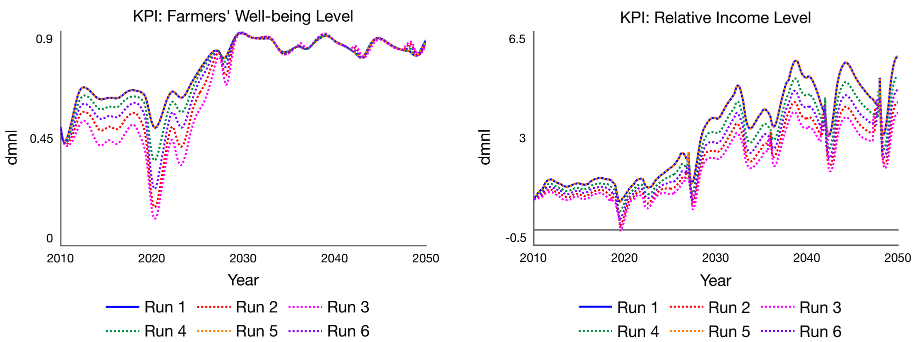


Fig.1 Normal Rainfall (Range: 400 – 500)

The model is moderately sensitive to Normal Rainfall, but this is to be expected as it sets the base for the relative rainfall, which has an exogenous effect on the yield as well as relative variable input. Hence, as the normal rainfall increases, the yield decreases and the cost of production increases, leading to a lower relative income level, and therefore a lower well-being level than it otherwise would have been. Nevertheless, confidence of this parameter value should not be diminished as it was estimated from data available on the mean rainfall in Australia.

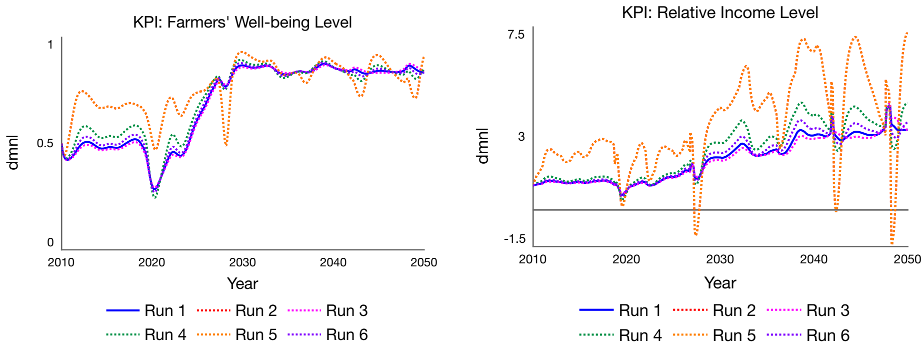


Fig.2 Initial Share of Demand for Locally Produced Sustainable Food (Range: 0.01– 0.2)

The model is moderately sensitive to the Initial Share since it retains its behaviour mode across all runs. Yet, the model appears to be very sensitive for small values of initial share (less than 0.02), as shown in the outlier Run 3 in the graphs below. This can be explained by the fact that the graph shown is the relative value, where the base value is simply set at the initial. For small values of the initial share, the demand for local produce is very small and therefore the value of production and profits is much smaller than it otherwise would have been. When looking at the sensitivity run for the absolute income level rather than the relative level, then we see below that the model does indeed retain the behaviour mode:

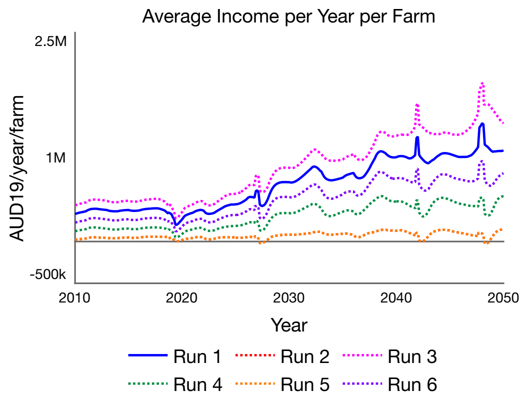


Fig.3 Initial Share of Demand for Locally Produced Sustainable Food (Range: 0.01– 0.2)

To build further confidence in this model parameter, then, there needs to be more robust data collection on the initial share of demand for locally produced sustainable food.

Adjustment Times

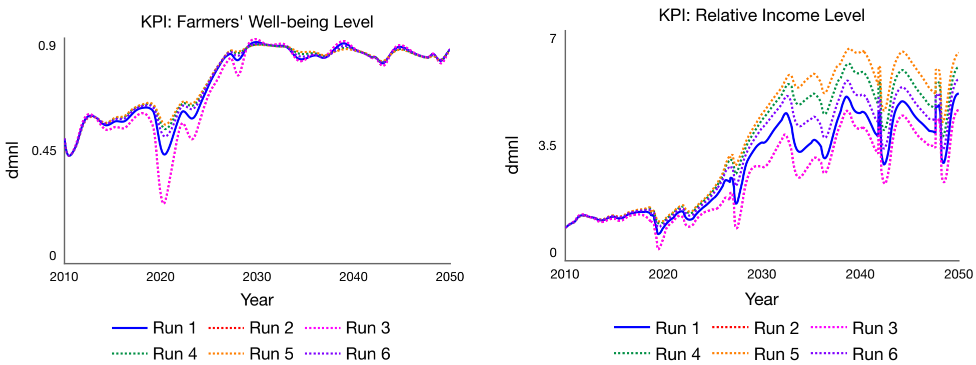


Fig.4 Time to Adjust Inventory (Range: 1 – 5)

The model is sensitive to time taken to adjust the inventory, but this is to be expected as it has an effect on desired food production. A slow adjustment of the inventory has further effects on the supply, demand and price dynamics since the relative inventory will always be below the desired level. The reinforcing loop with supply and price dominates, increasing food prices and the profits for the farmers. Hence, the income level increases with a longer inventory adjustment time. Though not necessary for a conceptual model, data could be collected for estimating a more accurate delay time for adjusting inventory in order to increase the model's robustness.

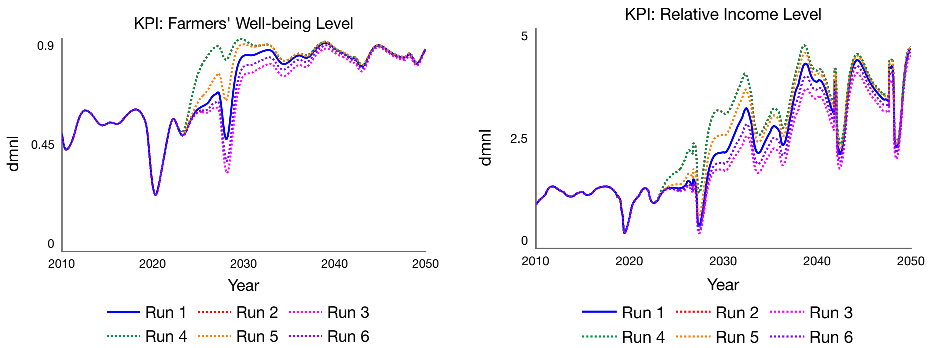


Fig.5 Time to Adjust Information (Range: 1 – 10)

The model is expectedly sensitive to the adjustment time for the food system literacy policy. It is the delay time for the policy to take effect, and therefore produces variations in the well-being level and relative income level. Given this sensitivity, it serves as a leverage point for policy implementation.

Elasticities

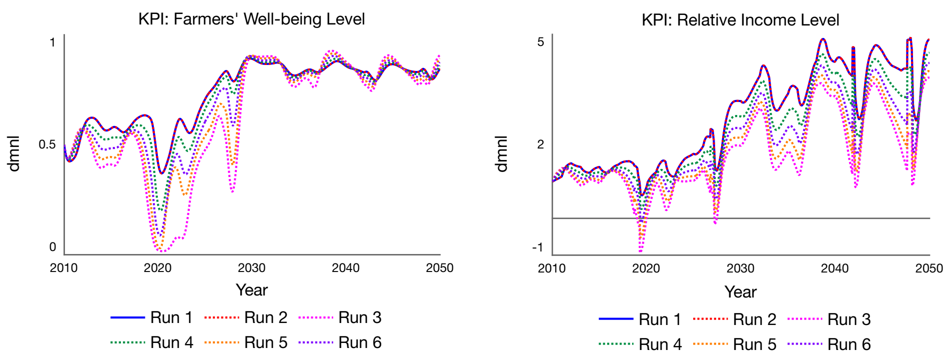


Fig.6 Elasticity of Variable Cost to Variable Inputs (Range: 0 – 5)

The model is sensitive to the Elasticity of Variable Cost to Variable Inputs. The elasticity determines the size of the relative changes between the two variables. As the elasticity increases, the effect of changes in variable inputs increases disproportionately higher on the variable costs. Hence, we see that the much higher variable cost brings down the profits and therefore income level, which in turn brings down the well-being of the farmer. The elasticity could be better calibrated with robust data collection and statistical analysis. However, for this conceptual model, this estimation suffices given the retention of the overall behaviour mode.

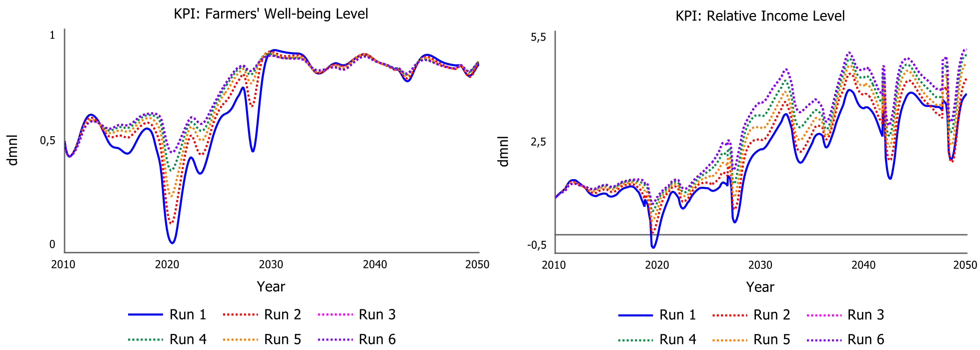


Fig.7 Elasticity of Price to Relative Inventory (Range: -2 – -0.1)

The model is moderately sensitive to the Elasticity of Price to Relative Inventory, which determines the effect of supply/demand ratio to price. Elasticities are meant to be sensitive, but given the same behaviour mode throughout all runs, the estimated value need not diminish the confidence in the model results.

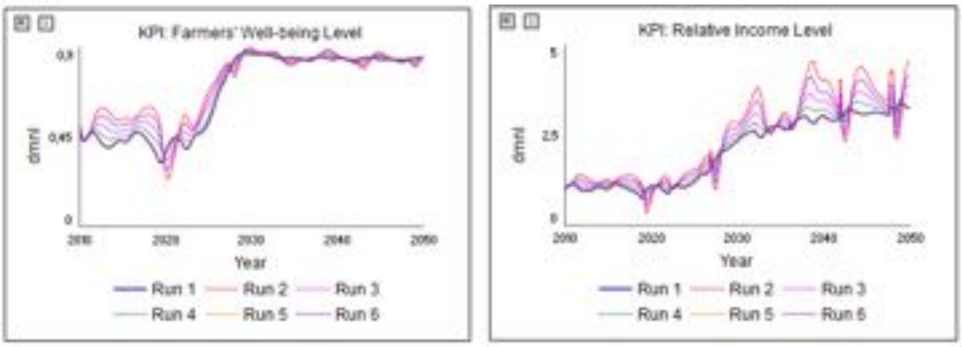


Fig.8 Elasticity of Rainfall to Yield (Range: 0 – 2)

The model is sensitive to the Elasticity of Rainfall to Yield. This is to be expected as the effect of rainfall to yield is conceptualised to be an exogenous stressor that shocks the system. The higher the elasticity, the greater the effect on the Yield, which affects the production capacity of the farm industry. Data could be collected for a more accurate elasticity value. However, given the intention of shocking the system, the retention of the overall behaviour mode suggests that we can build confidence in the model results.

Effects (Table Functions)

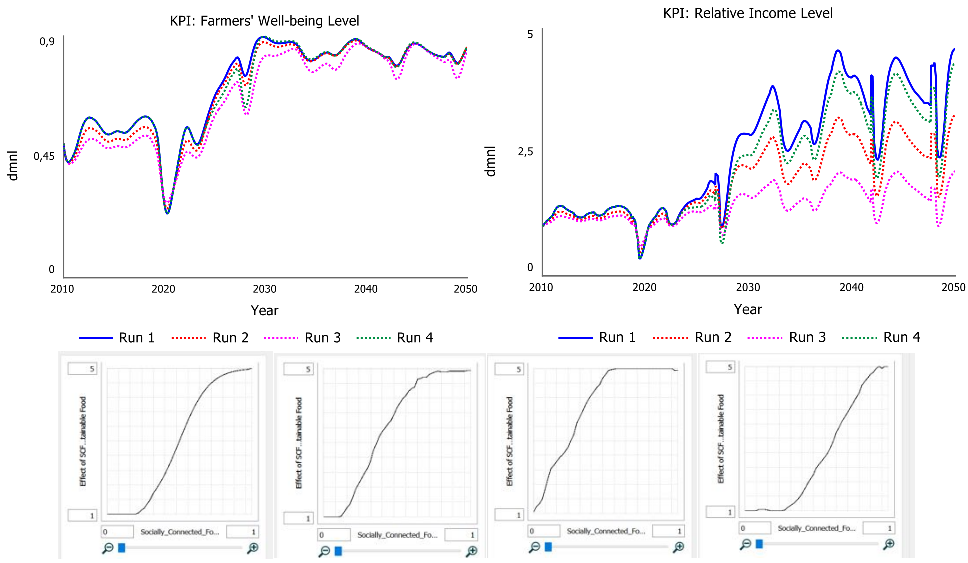


Fig.9 Effect of SCFS on Share of Demand for Locally Produced Sustainable Food

The model is sensitive to the Effect of the food system's social connected on the demand for local produce. Changes to this effect variable determine the overall effectiveness of the policy intervention. Hence, the sensitivity runs show the range of possible outcomes between business as usual and effective policy intervention. As mentioned in the report, this conceptual model does not provide certainty on exactly how much income or well-being increases. Nevertheless, we can still maintain our confidence that the policy will increase the KPI regardless of the actual shape.

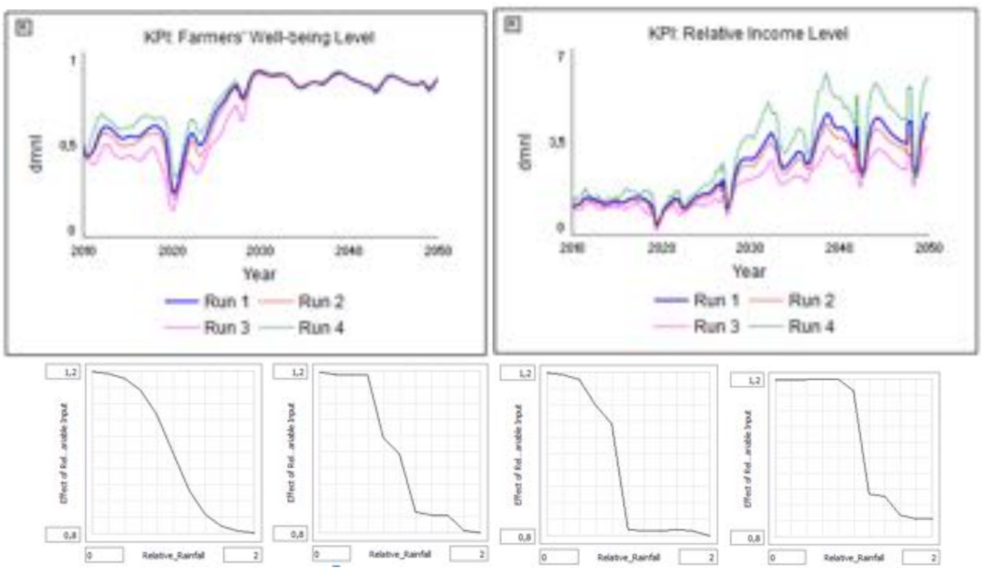


Fig.10 Effect of Relative Rainfall on Relative Variable Input

The model is moderately sensitive to the Effect of Relative Rainfall on Relative Variable Input. As relative variable input increases or decreases, the variable cost increases or decreases, and therefore has implications for the income and well-being of farmers. Again, the retention of the behaviour mode suggests that we can be confident of the model results.

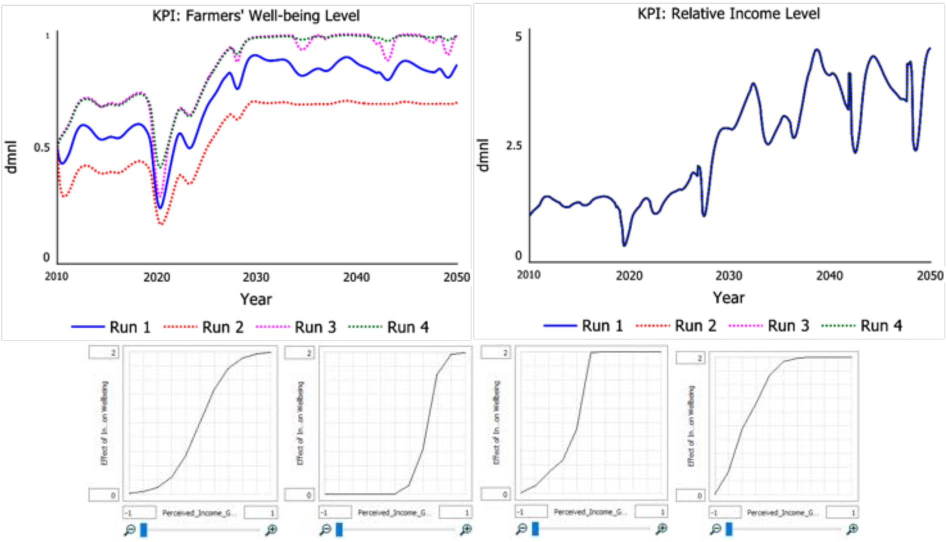


Fig.11 Effect of Income Growth Rate on Wellbeing

The Farmers' Well-being Level is sensitive to the Effect of Income Growth Rate on Wellbeing. In fact, the well-being is moderately sensitive to all effect variables of the secondary KPIs (income level, growth rate, social connectedness). This, of course, is by design as the secondary KPIs directly determine the well-being level. For a more accurate well-being level, then, more robust data should be collected on formulating the effect variables. Nevertheless, it does not detract from the key insight that increasing the food system literacy level increases the well-being of farmers.

Weights

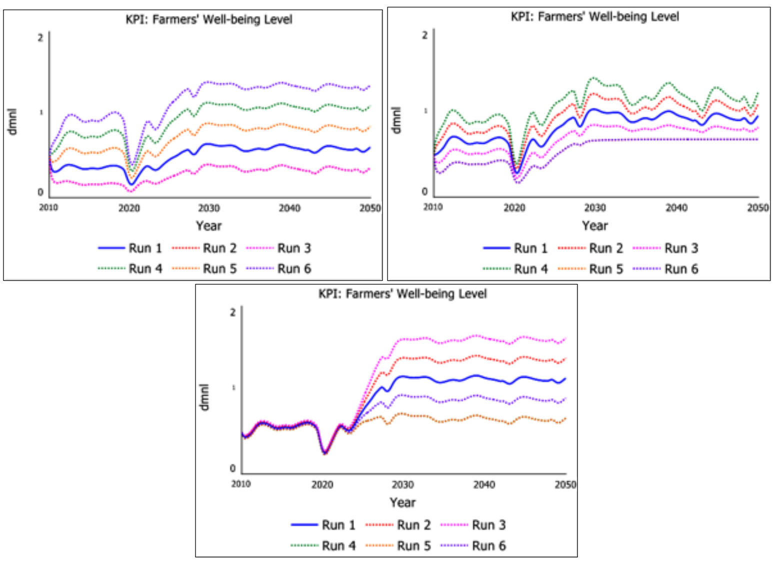


Fig.12 Weight of Income Level/ Income Variability/ Social Connectedness (Range: 0 – 1)

Like the previous effect variable, the Well-being is sensitive to the respective weights of the secondary KPIs. Here, the sensitivity runs do not dynamically take into account the other two weights, hence allowing the well-being to increase above 1. The model runs on the assumption that income level has the greatest weight (0.5), followed by income variability (0.3), and lastly social connectedness (0.2). This is based on our assumption, which was corroborated by the client during an interview. Nevertheless, well-being could be further made robust by collecting data from actual farmers in the region to determine better estimates of the respective weights.

All Other Parameters

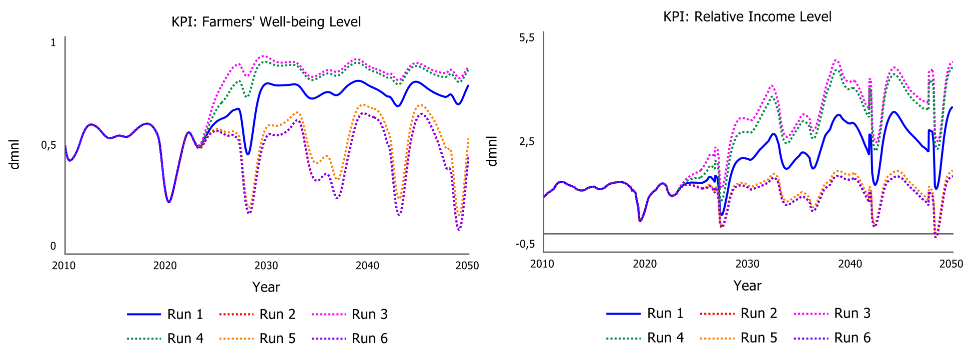


Fig.13 Quality of Information (Range: 0 – 1)

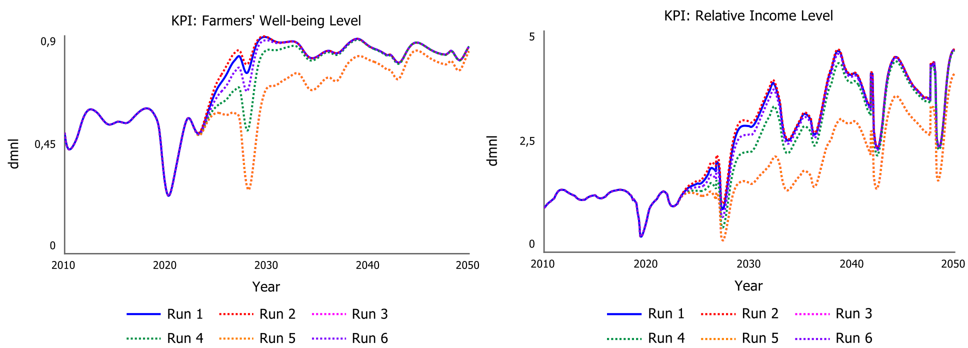


Fig.14 Effectiveness of Dissemination (Range: 0 – 1)

Expectedly, the model is sensitive to the parameters of the food system literacy policy: quality and effectiveness of the policy. The better the quality and more effective the policy intervention in increasing the food system literacy, the better the outcomes for the KPIs. Hence, these parameters serve as key leverage points for policy implementation.

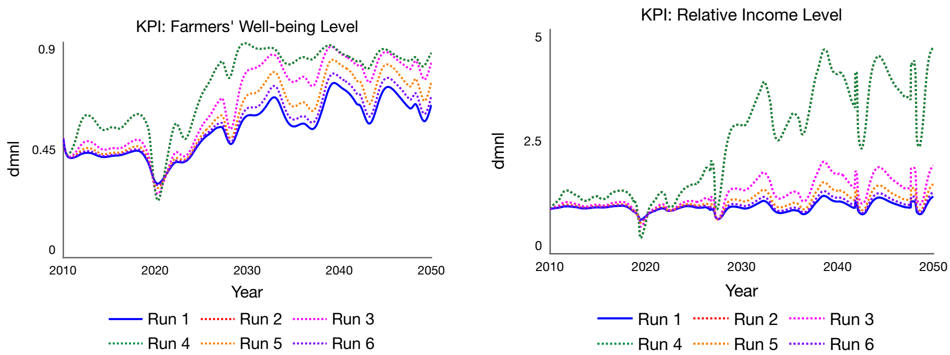


Fig.15 Earnings per Dollar from Retailers (Range: 0.1 – 0.5)

The model is sensitive to the various Earnings per dollar, as they directly determine the level of profits, and therefore income. Of these, Earnings per Dollar from Retailers is the most sensitive. As the Earnings increases, the relative income level, counter-intuitively decreases. However, this can be explained by the large initial base of the income level with increases in earnings, as in the earlier case of the initial share demand for local produce. When looking at the sensitivity runs for the absolute income level rather than the relative level, then we see below that the model does indeed produce the intended behaviour pattern:

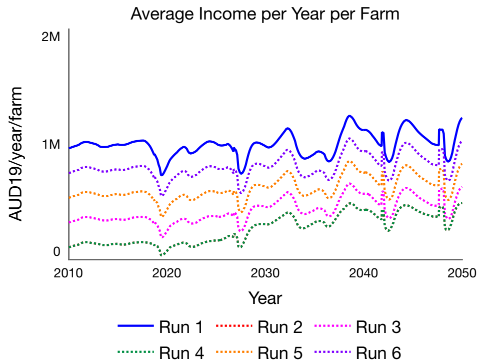


Fig.16 Earnings per Dollar from Retailers (Range: 0.1 – 0.5)

Again, the relative measure of income was chosen in order to reflect the qualitative nature of the model and therefore a qualitative nature of the KPI. Nonetheless, this problem of relativity for very large initial values of income, should be noted to the clients for further clarity.

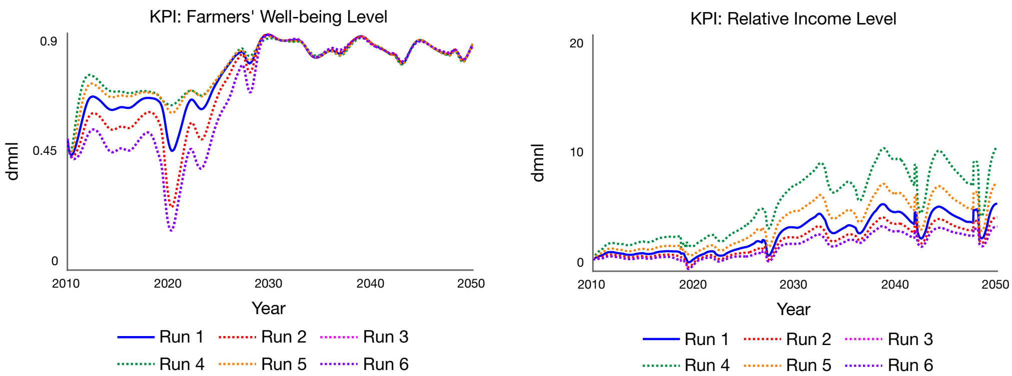


Fig.17 Fractional Waste Rate (Range: 0 – 0.2)

The model is moderately sensitive to the Fractional Waste Rate. This is to be expected as food wastage rate determines the inventory level, which then feedback through the demand, supply, price dynamics. The fractional waste rate is assumed to be low at 5%. More accurate data could be collected for a better estimate of this value. Importantly, this sensitivity run also indicates that decreasing the fractional waste rate could be a leverage point for policy intervention and therefore produce better outcomes in the KPI.

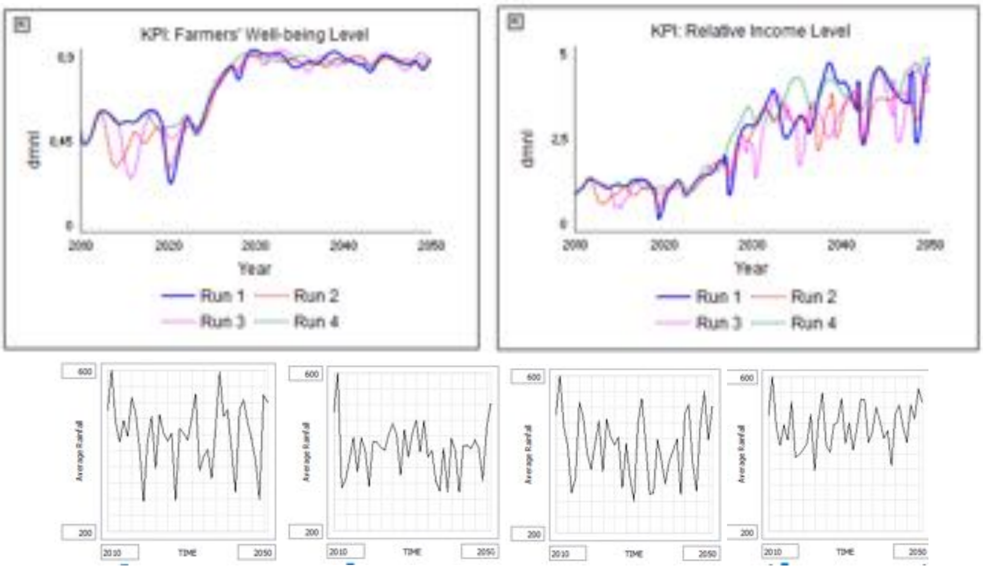


Fig.18 Average Rainfall

The model is sensitive to the Average Rainfall. As mentioned, this is to be expected as rainfall is an exogenous parameter introduced to shock the system – mainly through impacting yield and costs. The average rainfall was formulated based on historical data up to 2020 and estimated thereafter on a similar behaviour pattern with the assumption recurrent drought situations.

Simulation Experiment Report

This section provides the minimum simulation reporting guidelines recommended by Rahmandad & Sterman (2012).
Modelling Software: Stella Architect 2.1.1
Integration Method: Euler's Integration
DT = 1/32
Time Units: Years
Simulation Start Time: 2010
Simulation End Time: 2050

Business as Usual Scenario

This scenario reproduces the reference mode and represents the business-as-usual scenario where no policy intervention is considered. The initial values for parameters are as follows:

Model Settings Sector

SWITCH Food System Policy = 0
Policy Start Time = 2022

Food Supply Sector

Fractional Waste Rate = 0.05
Elasticity of Commercial Orders to Price = -1.2
Share of Demand supplied by SME Farms in Australia = 0.49
Supply Coverage = 1.5
Shipment Time = 1
Processing Time = 1
Time to Perceive Demand = 3
Time to Adjust Inventory = 1
Time to Adjust Utilisation = 1
Desired Inventory Coverage = 1.5
Effect of Markup on Capacity Utilisation = GRAPH (Expected Price to Cost Ratio)

Food Production Capacity Sector

Average Farmland per Farm = 100
Normal Rainfall = 450
Average Rainfall = GRAPH (TIME)
Elasticity of Rainfall to Yield = 1
Elasticity of Fixed Input to Yield = 0.5
Elasticity of Variable Input to Yield = 0.5
Effect of Relative Rainfall on Relative Variable Input = GRAPH (Relative Rainfall)
Effect of Sustainable Technology on Fixed Input = GRAPH (% of Adopted Farms)
Effect of Profitability on Farms = GRAPH (Expected Longterm Profitability)
Effect of Demand Pressure on Farms = GRAPH (Desired Capacity Utilisation)

Elasticity of Fixed Cost to Fixed Inputs = 1
Elasticity of Variable Cost to Fixed Inputs = 1
Time to adjust Farms = 3

Sustainable Technology Adoption Sector

Probability of Learning per Contact = 0.03
Effectiveness of Adoption = 0.8
Time to Adopt = 2
Initial Contact Frequency = 1
Effect of Social Connectedness on Farmer to Farmer Contact = GRAPH (Socially Connected Food System)

Food Demand Sector

Fractional Growth Rate = 0.011
Food Demand per Capita = 0.548
Elasticity of Sustainable Food Demand to Price = -0.6
Ratio of Local to National Population = 0.05
Birth Rate = 0.012
Death Rate = 0.008
Net Migration Rate = 0.004
People per Household = 2.5
Food Consumption per Household = 10000
Initial Share of Demand for LPSF = 0.05
Weight of Farmers Market = 0.3
Weight of Food Imports = 0.15

Farm Finances Sector

Effect of Markup on Capacity Utilisation = GRAPH (Expected Price to Cost Ratio)
Effect of Desired Utilisation on Variable Costs = GRAPH (Desired Capacity Utilisation)
Effect of Desired Utilisation on Variable Costs = GRAPH (Capacity Utilisation)
Time to Form ShortRun Expectations = 2
Effect of Relative Fixed Input on Fixed Costs = GRAPH (Relative Fixed Inputs ^ Elasticity of Fixed Cost to Fixed Inputs)

Livelihood Outcomes (KPI) Sector

Time to Perceive Income = 1
Effect of Income Level on Wellbeing = GRAPH (Perceived Relative Income Level)
Effect of Income Growth Rate on Wellbeing = GRAPH (Perceived Income Growth Rate)
Effect of Social Connectedness on Wellbeing = GRAPH (Socially Connected Food System)
Weight of Income Level = 0.5
Weight of Social Connectedness = 0.2

Weight of Income Variability = 0.3
Time to Adjust Wellbeing = 0.25

Price Setting Sector

Earnings per dollar from Farmers Market = 0.5
Earnings per dollar from Food Cooperatives = 0.3
Earnings per dollar from Retailers = 0.1
Time to Adjust Price = 1
Elasticity of Price to Inventory = -1

Food System Knowledge Sector

Effect of SCFS on Share of Demand for Locally Produced Sustainable Food = GRAPH (Socially Connected Food System)
Time to Affect Behaviour = 2
Quality of Information = 0.8
Effectiveness in Dissemination = 0.8
Time to Adjust Information = 2
Effect of SCFS on % of People Interested in Subsistence Farming = GRAPH (Socially Connected Food System)

Subsistence Gardens Sector

Initial % of Households Interested in Subsistence Farming = 0.01
Time to Set Up a Subsistence Garden = 2
Share of Food Demand Provided by Subsistence Gardening = 0.1

Optimistic Policy Scenario

This scenario tests the effect of food system literacy policy – a policy simulation. If policy is active, the key performance indicators increase: the farmer's well-being level fluctuates around 0.8-0.9 and relative income level around 2.5-4.5. For these results, the assumption of this scenario is that the policy intervention will entail the dissemination of high quality of information with high effectiveness.

All parameter and initial values are the same as the BAU run except for the following:

SWITCH Food System Policy = 1

Pessimistic Policy Scenario

This scenario tests the effect of a poorly implemented food system literacy policy, therefore dampening the effects of the policy intervention. The assumption here is that the policy intervention will entail the dissemination of relatively poor quality of information with low effectiveness. Moreover, the effectiveness of sustainable technology adoption is also reduced.

All parameter and initial values are the same as the BAU run except for the following:

SWITCH Food System Policy = 1
Quality of Information = 0.4
Time to Adjust Information = 5
Effectiveness in Dissemination = 0.4
Effectiveness of Adoption = 0.4