Model: Samambaia Basin – Hydro-ABM

Files: https://www.comses.net/codebases/47ded80a-75a1-4cca-b939-b7c7a4b58dc7/releases/1.0.0/

ODD – Protocol

1- Purpose of the Model

The purpose of the model is to serve as a tool to support exploration of allocation scenarios and water resources management policies. Supporting joint management and facilitating cooperation among users.

2- Entities, variables and scales

Each step of the model is equivalent to one day and it is programmed to pause after 3600 days (approximately ten years), the environment where the agents are located is a shapefile of the Samambaia river basin. The model contains six types of agents. They can be divided into passive and active, where passive only provide information for the active to carry out their activities. The passive are Water, Weather, Market and Calendar. The active agents are Farmer and CropField.

At the beginning of the simulation ten Farmer agents are created where two are Farmer A (richer), five farmer B (middle) and three farmer C (smaller producers). Farmer C has ten cropfields each, Farmer B has thirty cropfields each and Farmer has fifty cropfiels each. Respecting the proportion of large, medium and small producers raised by a previous ANA study (ANA, 2017). The initial cash of each is defined as the total area of crofields (m²) multiplied by 0.1, value only used as starting point for each producer causing the initial amount of cash to be proportional to the amount of land owned.

The farms C are created in the outskirts of the Rato sub-basin, the FarmerB in the sub-basin of the North Samambaia and the FarmerA in the sub-basin of the South Samambaia, fact that was raised in one of the meetings, where it was pointed out that users with smaller numbers of pivots would be more concentrated in the Rato stream, users with average number of pivots are concentrated in the northern Samambaia and those with the largest quantity in the southern Samambaia.

In the simulation, first the farmer C agents are created, then the farmer B and finally the farmers A. Due to this order the last created agent (farmerA1) has 48 pivots instead of 50 mentioned, this happens because there is not a round number of pivots. Each pivot area is a cell from shapefile, which in the model is called the cropfield.

In the model it is considered that all producers have the same irrigation technology and have the same efficiency. All water abstracted is used in the plantations, so the use of water is 100%. There is no differentiation among the types of users in this question.

The three types of Farmer have different weights in the criteria for choosing the new plantations, the criteria are: sale price of the production (sellv_index); plantation maintenance price (upcost_index); and price per unit of water used, in this case irrigation price (wcost_index). These criteria were raised in the meetings with the representatives of the users, to differentiate between the behavior of each type of user were determined different preference range for each type of farmer, where it was assumed that the big producer has a more calculating thought and has the same weight in all criteria, the average producer has a thought that aims more the amount of money obtained in the sale and ends up neglecting the expenses a little, finally the small producer who cares more about the expenses than with the final price of sales department, they are concerned about whether they will be able to pay the bills. This differentiation was presented at meetings and there were no objections to using it as a simplified way of representing different behaviors in the model.

Farmer agents have actions that are performed only when they are called (action): the first action is "update_farmercrop" that is performed when the farmer does not have the crop set (farmercrop = 0) and is called after the croptime is finished shortly after cells (areas with irrigation pivot, cropfield) sell the production; which is done by the other action "sell_crop" where the farmer asks each cell to execute the action "sell_crop" (action sell_crop inside the cropfield).

In the update_cropfield the agent Calendar is asked the options for possible plantings in the month, the farmer picks up all the options and asks the cells to calculate the best option, where the sales value of the crop (prospect_sellvalue), daily maintenance cost (prospect_upcost) and water / irrigation cost (prospect_wcost). The calculation performed is prospect_crop = (prospect_sellvalue * sellv_index) - (prospect_upcost * upcost_index) - (prospect_wcost * wcost_index). The highest value of prospect_crop is chosen, the values of the prospect (sellvalue, upcost and wcost) are made based on the money spent / gain on a 1-day production of a m². There is a limitation so that you cannot choose the same type of planting twice in a row, this factor is based on phytosanitary issues where this type of action is contraindicated and in the case of soybeans is prohibited by law.

The Water agent is created for each sub-basin, where the agent format is the shape of the sub-basin shapefile. In order to calculate the flow available to the users (withdraw), Q95 of Technical Note no. 132/2010 / GEREG / SOF-ANA (ANA, 2010) was used, where flows were presented for each sub-basin (Córrego do Rato , Samambaia Norte and Samambaia Sul) monthly in l / s / km², it is worth mentioning that the flows during periods of drought are well represented, but during the flood periods the flows are overestimated. Each agent acts as a reservoir and supplies water to the cropfields located in their area, daily is recalculated the amount of available for use.

For weather agent data, the Cristalina station TRMM.2738 of the website http://www.agritempo.gov.br was considered as general for the whole basin (all the historical series used in the models are from 2008 to 2017, ten years) . The temperature data are used to calculate the ETo (evapotranspiration base) needed to calculate the water demand of the plantation. The total rainfall of the month is distributed so that every day there is a 50% chance of a rain event occurring, if the rainy event occurs a random value (from zero to the monthly total) is subtracted from the monthly total. This process occurs daily until the monthly total zeros or the month ends, with the new month a new monthly total is attributed

For the calculation of the ETo, the Hargreaves Samani equation that was used were previously calibrated for the Cristalina region by Fernandes et. al. 2012. HC was determined as 0.00084 and HE as 0.96, R is taken as 0.5.

$$ETo_{HG} = 0{,}408HCR_a\left(T_{max} - T_{min}\right)^{HE}\left(\frac{T_{max} + T_{min}}{2} + 17{,}8\right)$$

The evapotranspiration is calculated as ETo multiplied by the crop coefficient (kc) multiplied by the soil coefficient (ks, in this case considered as 1), this calculation is done by each cropfield agent that is active plantation (farmercrop nonzero), this Demand calculation is done daily as long as there is active planting within the Cropfield

The Calendar agent provides the types of planting for each month, along with the characteristics of each plantation. There are 10 Farmercrop types that Farmer can choose, but each month that availability changes, where they are not all available in the same month. They are farmercrop 0 (no crop), farmercrop 1 (soybean), farmercrop 2 (corn), farmercrop 3(cotton), farmercrop 4(beans), farmercrop 5 (potato), farmercrop 6 (garlic), farmercrop 7 (onion), farmercrop 8 (tomato) and farmercrop 9 (wheat). These types of planting were main plantings raised in meetings with user representatives.

The available characteristics of each farmercrop are: Kc (value used to determine the water demand, is subdivided into kc1, kc2, kc3 and kc4 one for each phase of the development of the plant); time of crop duration and duration of each phase of plant life (f1, f2, f3, f4); crop production (crop_prod) informing how many kg are produced in 1sqm; cost of production (prod_cost) informing the cost to produce 1m² of the given plantation (this cost is diluted by days when the daily cost calculation is made); the sensitivity of depreciation of production due to lack of water (deprewsense) where the irrigated production was verified and without irrigation and defined that where there was no water the production would be similar to the production without irrigation, the more water lacking the more the production would arrive next to the cultivation of dry land; and finally the texture of each plantation (only to represent each plantation with an image of the type of plant produced).

Kc data and planting duration were taken from the Technical Report - Analysis of ANA Resolution 562/2010 - São Marcos River Regulatory Framework, pages 30 and 31 respectively (MONTEPLAN, 2011). The data of production cost and quantity produced were taken from different sources, but preference was given to data computed for the central-west region and performed more recently (2018).

Another important cost is the cost to supply the need for water from the plantation, the cost of irrigation. This cost is calculated daily and takes into account the precipitation of the day and the maximum and minimum temperatures of the month. Demand is determined by subtracting the rain of the day with the water requirement of the plantation; when the rain does not supply the need for planting, the river is withdrawn (where the pumping cost is calculated).

The images used as texture of each type of plantation were taken from the internet. The list of planting types available each month was based on the Goiás agricultural calendar developed for internal use by the Institute of Agricultural Strengthening of Goiás - IFAG in 2018, some types of planting that were not included in the IFAG calendar, they had their planting periods consulted on sites with relevant agricultural information.

For the Market agent, prices used are available at www.agrolink.com.br. It was considered the national quotation for all types of series because it presented a better consistency, since there were plantations that did not present data of price for the state of Goiás. All the prices presented different units (bag of 60kg, bag of 50kg, bag of 15kg, etc.), all values have been converted to price per kg.

Cotton, garlic, potato and tomato presented data failure, especially at the beginning of the series. To fill the series was used price data for the same month of the year closest to the information (year later or earlier).

The price consulted for soy was for the 60kg bag, for the corn was the 60kg bag, for the cotton was the 15kg pen, for the bean was the carioca bean 60kg bag, for the potato was the 50kg bag, for the garlic was 1kg, for the onion was the national onion bag of 50kg, for the tomato was 1kg and for the wheat was the national grain wheat of 60kg.

The sale of the production is done when the total planting time is over, the price is calculated with (the total area of the cell in m²) * (sales value of kg) * (production per m² in kg * (1-depreciation / 100)). In this way it is discounted any period without water in the final production, consequently decreasing the value received. The depreciation was done by comparing irrigated and rainfed production, where the longer the planting was without irrigation, the final production would be closer to the rainfed production. For some types of planting the lack of water in critical periods can ruin all production, but this type of detail was not taken into account.

The cropfield agents represent the areas with irrigation pivots, it is made from a shapefile made by the Agribusiness Coordination of the State Secretariat of Finance - Sefaz on irrigation pivots in 2016 and available on the SIEG website (http: // www.sieg.go.gov.br/) with the delimitation of each pivot.

The cropfield calculates daily crop water demand (wdem), it queries the Weather to see weather data wdem <- (ETo * kc * ks * field_area). The demand for water is reduced from the rain of the day, the rest is taken from the river basin, where the water cost (pumping price * quantity and water) is calculated, in case there is no more water to withdraw, the depreciation counter starts counting , if the planting runs out of water every day from planting to harvesting, the production will be the same as for a rainfed plantation. The pumping price and maintenance price per day (consulted on the calendar) is passed on to the farmer so that he subtracts these amounts from his cash.

One important action is the prospect, which is executed when the farmer wants to choose a new plantation, where he will test all the available options in the month and test how the production of each one would be, he queries the selling price of the day in the Market for see how much it would sell the production (prospect_sellvalue), consult the weather to see what the water demand of the plantation would be considering the data of the same period of the previous year and the availability of water from the basin (prospect_wcost), and finally the maintenance price of the plantation (prospect_upcost). The farmer will choose based on these values.

And the last action is to sell the production, which occurs when the time of a plantation ends. The cropfield consults the Market to calculate the price and in sequence to carry out the sale. After the sale the cycle starts again where the farmer will choose which type of his next plantation.

3- Process overview and scheduling

The overview of the processes and ordering of the same have already been described in the previous item.

4- Design concepts

4.1. Basics

In order to generate the available flows for the users, the same data used by ANA (ANA, 2010) on managing water resources was used. For the data on the characteristics of each plantation, sources indicated by the representatives of the users were used, the same was done with the price data. For the water demands of the plantations, well-known and simplified equations were used. Criteria for choosing new plantations were established based on meetings with producer representatives.

4.2. Emerging phenomena

Farmer agents will react to different water and rainfall availability scenarios (policies, managements or adverse externalities), which will directly impact wealth production, water usage, income distribution and the types of plantations produced in the basin.

4.3. Fitness

Farmer agents will always produce the type of planting that best meets their criteria, different environmental conditions can cause different types of planting to be chosen. They may end up having negative money (representing debt), but do not die in the simulation, being able to recover money and stay positive again.

4.4. Detection

In order to decide the next type of plantation, Farmer agents use the information about the characteristics of each plantation available (maintenance price in the Calendar agent), water availability (water agent), rainfall and temperature occurring at the same time of the last year (Weather agent) and the current selling price of each plantation (Market agent).

There are three criteria used to choose the new plantation, the sale price of the production, the estimated irrigation price, and the maintenance cost price of the plantation. All farmer agents have access to this information. All these criteria are calculated to one square meter, the best plantation alternative is replicated to every area belonging to the farmer

4.5. Interactions

Agent Farmer manages his cropfields and orders them to interact with the other agents. All the steps Farmer ask the cropfields to calculate the maintenance cost of the plantations that are in them, this cost is subtracted from the amount of Farmer's money, in that same step the hydric demand of the plantation is calculated, where the cropfield agent consults the Weather agent on weather information, triggers the Water agent to draw water for irrigation and then subtracts the farmer's irrigation costs. At the end of the planting life cycle, farmers ask cropfields to sell their produce to Agent Market. To choose the next plantation agent Famer asks one of his cropfields to calculate the production costs, irrigation costs, and selling price of each of the available plantations, the best result according to his preferences is replicated to all other cropfields of the same Farmer.

4.6. Stochasticity

As elements of stochasticity we have the position where each Farmer agent will be born, this affects which cropfields they will choose at the beginning of the simulation, where this choice is made based on the nearest cropfield that does not have owner, the weights of the selection criteria for the next type of plantation, each type of Farmer has a range of values to assign weight to criteria, and rain events.

Each criterion of choice for a new plantation has its weight, the criteria are selling price (sellv_index), cost of production (upcost_index) and cost of irrigation (wcost_index). Three ranges of values were assumed for each criterion for each type of farmer. FarmerA because it represents a cold and calculating producer has the weights of each criterion around one (sellv_index, upcost_index and wcost_index with a random value between 0.8 and 1.2), farmerB represents a producer that aims at the sale price (sellv_index a random value between 1.2 and 1.5, upcost_index and wcost_index with a random value between 0.5 and 0.8), the farmerC represents a producer who cares more about the costs and will be able to bear the costs (sellv_index a random value between 0.5 and 0.8, upcost_index and wcost_index with a random value between 1.2 and 1.5).

In the events of rain the stochasticity occurs because the input data of rain is monthly, to distribute the rain in days was used a system in which at the beginning of the month is assigned the total rains of that month, each day has a 50% chance of rainfall if a rainfall event occurs a random value from zero to monthly maximum is subtracted from the monthly maximum, this value represents the precipitation of the day, at each rain event the values are subtracted from the monthly maximum until the zero. This type of simulation was based on the behavior of the rains mentioned in the meetings with representatives of the producers, where it was mentioned that there were cases where a great part of the rain of the month occurred in a single day, followed by dry days interspersed with less intense rains.

4.7. Observation

The main types of data taken from the model for an analysis are the farmers' total income, a distribution of income, the main types of planting chosen, such as the quantity produced by planting and the total amount of water withdrawn to maintain the system. The data can help you take a scenario exam.

5. Initialization

At the initialization is created ten Farmer agents (two farmerA, five farmerB and three farmerC), three water (Rato Stream, Samambaia Norte and Samambaia Sul), two hundred and ninety-eight cropfields (one for each shapefile polygon), one Calendar, a Weather and a Market. The Farmers will choose the nearest crop without an owner and then the initial cash of each one is calculated, then the cropfields are already following the orders of their owners. Passive agents carry their information and make it available for active agents to consult.

6. Input data

As input data we have the shapefiles of the watershed, the same ones were made by the author through the processing of satellite images of the region, these images were free made available by the United States Geological Survey - USGS. Historical series of price, temperature and rain were also used, where data from 2008 to 2017 were used from the aforementioned sources. For the costs of each type of plantation, data from various sources were used, but a good part was from the Institute for the Strengthening of Agriculture in Goiás - IFAG. Finally, the data on the available flows were those made available by ANA (ANA (b), 2010).

The information about the kc of each type of plantation was taken from the Technical Report made by Monteplan (MONTEPLAN, 2011). The production costs of each type of crop were originated from different sources, but the majority came from IFAG (http://ifag.org.br/production-cost-costs). In order to construct the model it was necessary to use data from the production of the crop in the rainfed and irrigated, in the model when the crop had all its demand met the production would be equal to the irrigated production, if there was not enough water the production would decrease proportionally until reaching the level of production in rainfed, when there was no water for the crop. Preference was given to the use of data produced by government agencies or studies, but some specific types of planting did not present these types of data, where data cited in reports on crop productivity were used as a reference, which was the case of irrigated potatoes, soybeans, corn and cotton. It was also difficult to find data on the dry production of onion, tomato and garlic, where the source used did not specify if there was irrigation, but due to the low productivity compared to the irrigated productivity already in the model it was considered as dry production.

For soybean was used the conventional soybean table of IFAG/SENAR (2018e), for the irrigated soybean was used a news conveyed in EMBRAPA (2015).

For the production of dry maize was used the corn table 1st crop of the IFAG/SENAR (2018d), for irrigated maize was used a report of Bosco (2017) that informed a value of irrigated productivity.

For the production of cotton in the rainfed was used the table with the costs of production of transgenic cotton of IFAG/SENAR (2018a), for the production of irrigated cotton was used a report of the site Notícias Agrícolas (2015) that informed a value of productivity.

For the production of beans, the table with the costs of production of irrigated beans IFAG/SENAR (2018c) and bean 1st crop (dry) of the IFAG/SENAR (2018d).

The economic feasibility study of potato cultivation by Amaral et al, (2012) was used for the production costs of potato in the rainfed, and for potato irrigated an information was Somensi (2017).

For garlic, the conventional garlic table irrigated from CONAB / DIPAI / SUINF / GECUP (2018a) was used, for garlic in the dry land was used data from a study carried out on garlic productivity in the Tietê region of São Paulo (TRANI et al 2008).

For the production of irrigated onion the data used were from Vilela (2011), for the production of onion in the rainfed data from IEA (2017).

For tomato was used the table tomato industry (irrigated) of the IFAG/SENAR (2018f), for the production of rainfed tomato was used information Guerreiro et al. (2018).

For wheat, the irrigated wheat table (Trigo – DF) produced by CONAB / DIPAI / SUINF / GECUP (2018c) was used, and the table CONAB/DIPAI/SUINF/GECUP (2018b) was used for dry wheat, but with the data titled Wheat – PR.

Based on the maintenance values of the plantations mentioned, a value was determined for the maintenance of the land without any type of plantation, representing the costs with soil management and the like. This cost was estimated at R $ 0.01 per day per square meter.

All costs and quantities produced were normalized to cost per square meter and production per square meter. For use in the model, irrigated production was used as the maximum produced, the cost of production in the rainfed as the cost of production of the crop (the tables that already presented the costs of irrigation had this value subtracted, considering that all the producers already have the irrigation structure and the only factor that prevents irrigation is the lack of water), since in the model pumping costs (irrigation costs) will be calculated separately and vary according to the demand of the crop, and finally, the difference between rainfed production and irrigated production will present a percentage of production loss due to lack of water. The data used in the model are shown in the Table 1.

Table 1 Crop data

Crop	Max Productivity (Kg/m²)	Production Cost (R$/m²)	Productivity loss due to lack of water (%)
Soy - farmercrop1	0,42	0,4384	26
Corn - farmercrop2	1,26	0,5119	26
Cotton - farmercrop3	0,45	1,0564	62
Beans - farmercrop4	0,30	0,4090	20
Potato - farmercrop5	6,00	1,1309	50
Garlic - farmercrop6	1,60	5,7652	75
Onion - farmercrop7	6,00	1,4655	17
Tomato - farmercrop8	9,50	2,2045	88
Wheat - farmercrop9	0,60	0,3505	53

In order to determine which time of the year could produce each type of plantation, a table prepared by the IFAG / FAEG for their internal usage was used, which indicated each month in which the main crops (soybean, corn, wheat, cotton, beans and tomato) were produced. For the rest of the crops (potatoes, garlic and onion), the data used were from Jacto (2018). Resulting on Table 2.

Tabela 2 Crops available each month

January	February	March	April	May	June
0,3,7	0,2,3,4,6, 7,8	0,2,4,5,6,8	0,4,8,5,9	0,4,8,9	0,4,8,9
July	**August**	**September**	**October**	**November**	**December**
0	0	0,2	0,1,2,3,4	0,1,2,3,4	0,1,3,4

On the meteorological data, data from the site agritempo.gov.br of the Cristalina station TRMM.2738 were used, the historical series from 2008 to 2017 was used, where data of monthly total precipitation, monthly maximum temperature and monthly minimum temperature were used. The data are available at https://www.agritempo.gov.br/agritempo/jsp/PesquisaClima/index.jsp?siglaUF=GO.

Related to the sale price data was the historical data available from the agrolink website (https://www.agrolink.com.br/cotacoes/) where the price history of each type of plantation was consulted. The national quotation was used because some products did not have the prices for the state of Goiás. The historical series used was from 2008 to 2017 (ten years). Some types of product had failures at the beginning of the series, to fill the series was repeated the price of the nearest month, or repeated the price of the same month of the following year. All price data has been normalized to price per kilogram of product.

The flow data used were data from Q95 of Technical Note no. 132/2010 / GEREG / SOF-ANA (ANA (b), 2010), where a data was presented in liters per second per square kilometer and this data was converted to liters per day in the area of the micro basin (Rato stream, Samambaia norte and Samambaia Sul).

The shapefile used to determine the location and area of the pivots was "Central Pivots 2016" which is available in the "ground cover" download session on the SIEG website (http://www.sieg.go.gov.br/ prod.asp? cod = 4712).

The satellite images used for some analyzes were those made available in the USGS, captured on September 26, 2017, path 221 rows 71 and 72. For the delineation of the drainage network and delimitation of the microcatchments, the digital terrain model was used on October 17, 2011 -16.5, -47.5 and -15.5, -47.5, also available from the USGS. All geographic information was handled using ArcGIS.

7. Submodels

To calculate the basal evapotranspiration, the Hargreaves Samani equation calibrated for the Cristalina region (FERNANDES et al, 2012) is used, which in turn is used to calculate the water demand of the plantation (ETr = ETo x Ks x Kc).

8. Diagrams

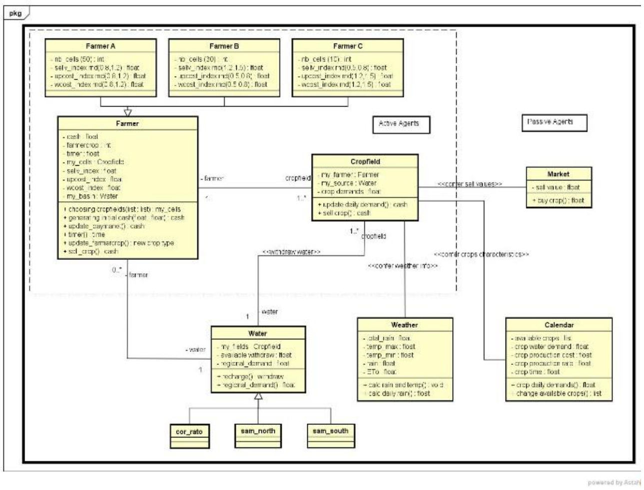

Figure 1 – Class Diagram

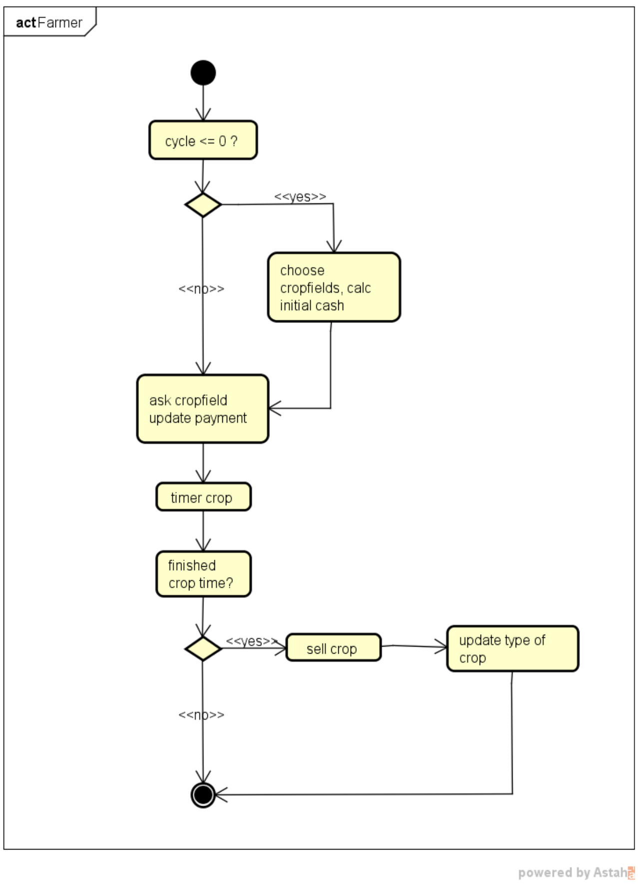

Figure 2 – Farmer Activity Diagram

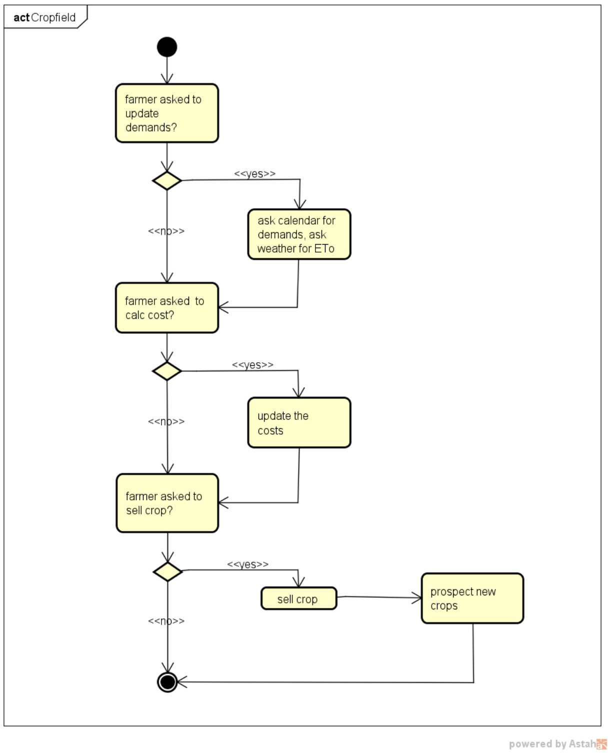

Figure 3 – Cropfield Activity Diagram

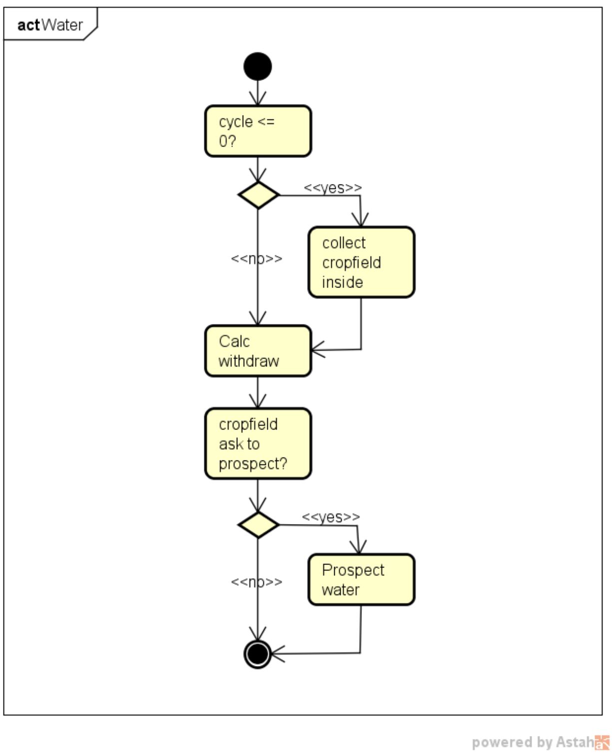

Figure 4 – Water Activity Diagram

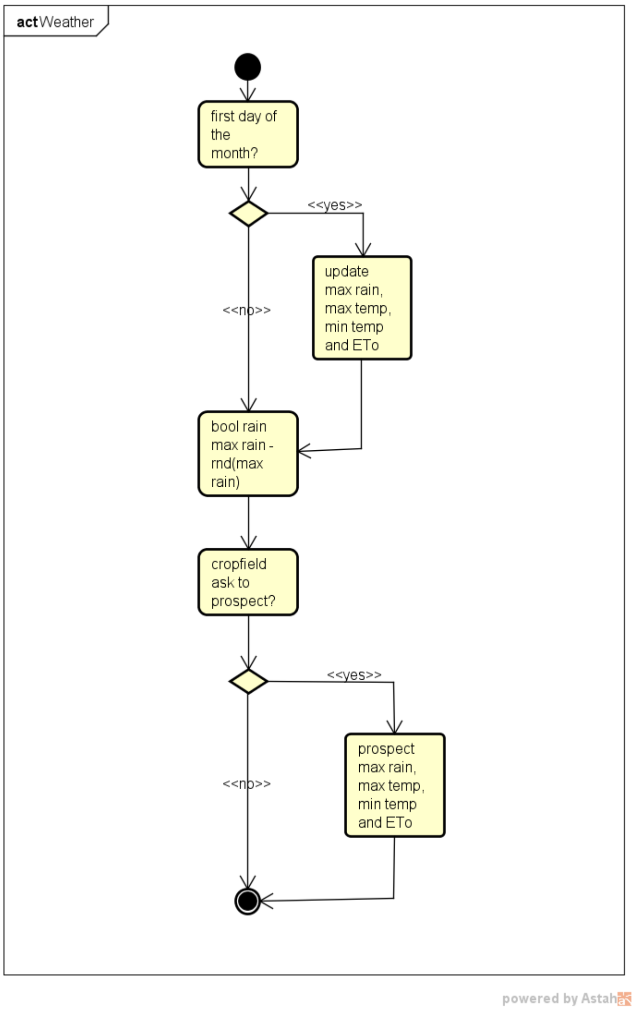

Figure 5 – Weather Activity Diagram

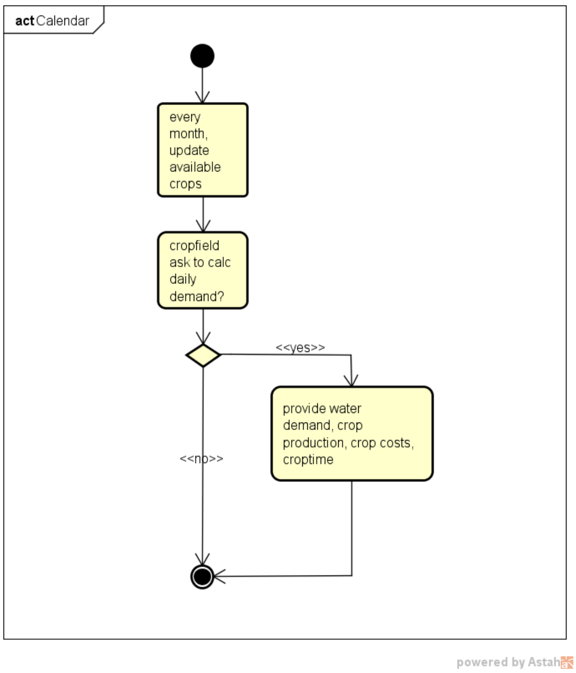

Figure 6 – Calendar Activity Diagram

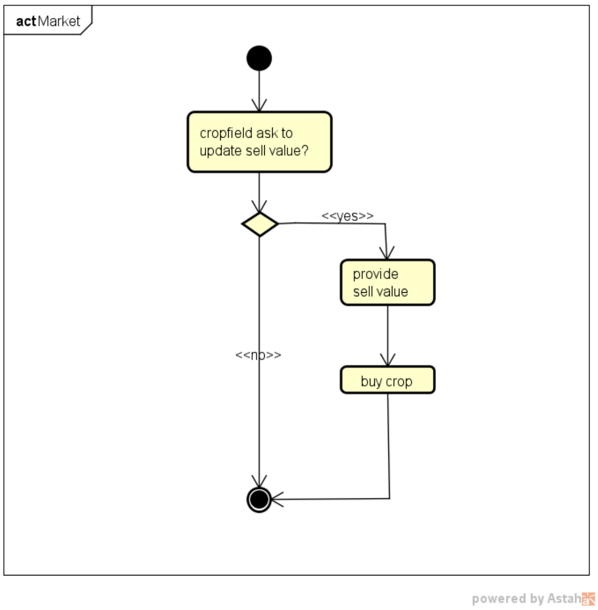

Figure 7 – Market Activity Diagram

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