An agent-based model to evaluate the performance of reproductive technologies in beef cattle

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Brazilian Beef Cattle

Pasture: **162 M** hectares
Occupancy rate: **1.2** head/ha
Stocking rate: **0.83** AUE/ha

98.4 M heads of cows
53.1 M heads of calves
39.2 M heads of oxen
2.1 M heads of bulls

Herd
193.4 M
million of cattle

42.5 M slaughtered cattle
8.3 M tonnes of carcass

47 cows/bull
0.54 calf/cow

22% slaughtering rate
205.8 kg average carcass weight

8 M semen doses

Objetive

To develop and describe an agent-based simulation model that allows the evaluation of the technical and economic component of two scenarios composed of Natural Mating (NM) and Fixed-time Artificial Insemination (TAI) + NM

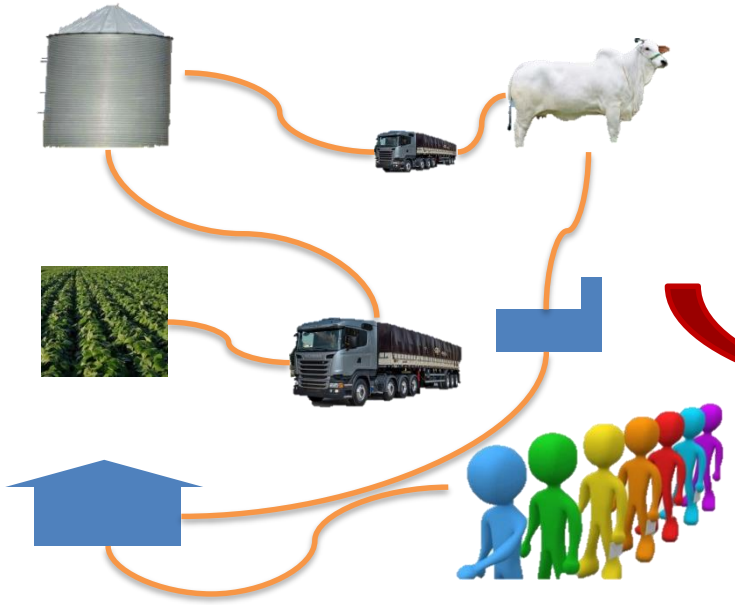
RISK-FREE SPACE

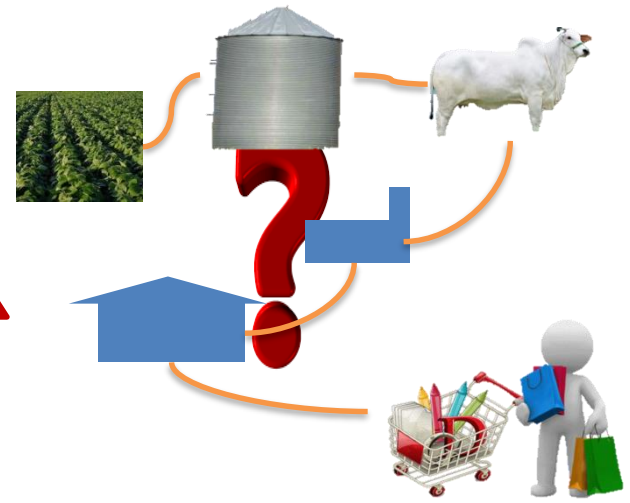
The model

The solution at the model level

The world of models

The real world





Experiments

The problem

The solution

Methodology

- Instituto de Zootecnia - Centro de Bovinos de Corte (Sertãozinho São Paulo State Brazil)
- Data base of 9,781 animals (2015 to 2018)
- Productive and reproductive parameters and performance
- Parameters used in the model include fixed values and probability distributions

Model Translation

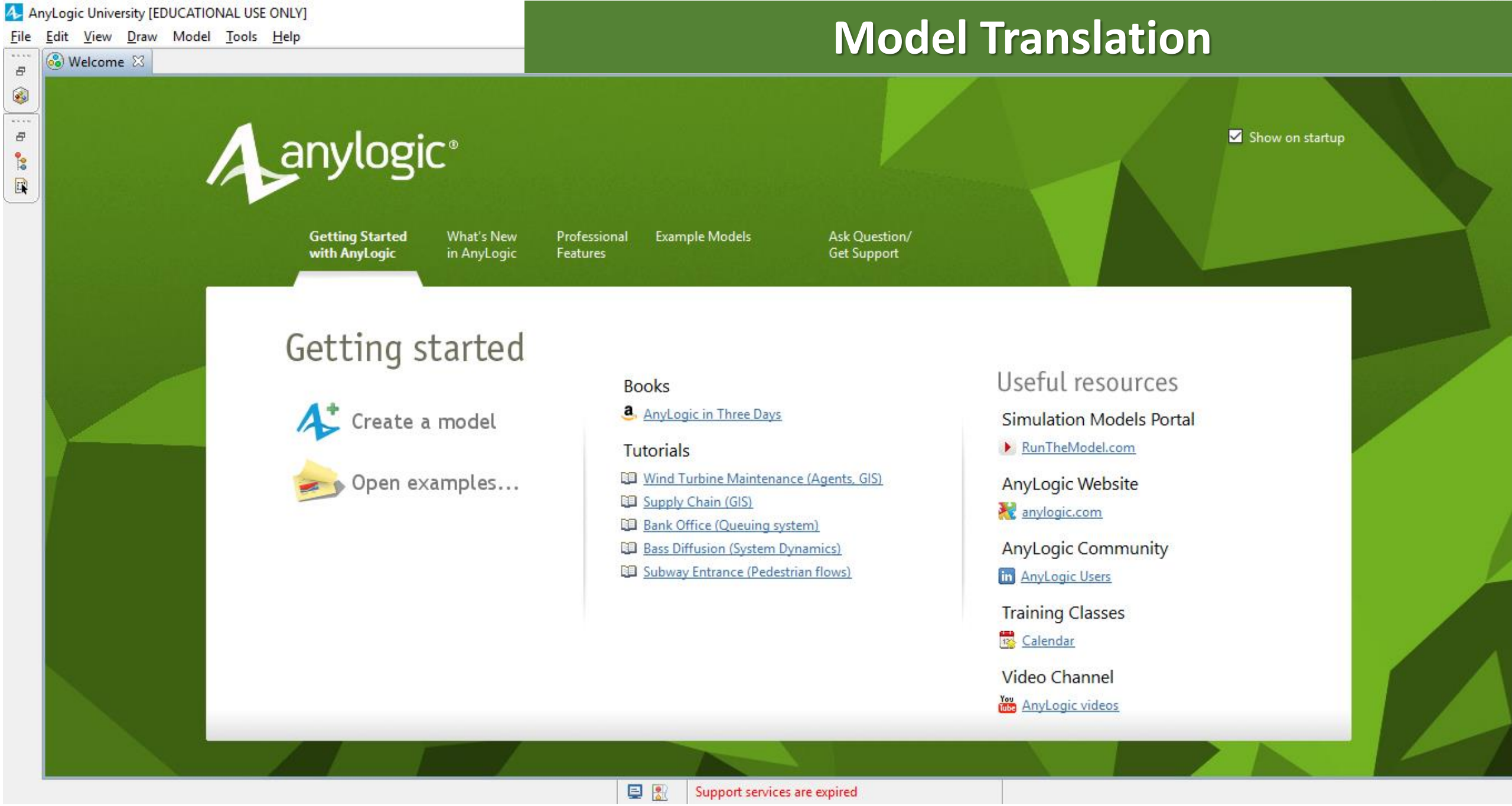


Diagram of the IZ

Conceptual model

ModelThesis : Simulation - AnyLogic University [EDUCATIONAL USE ONLY]

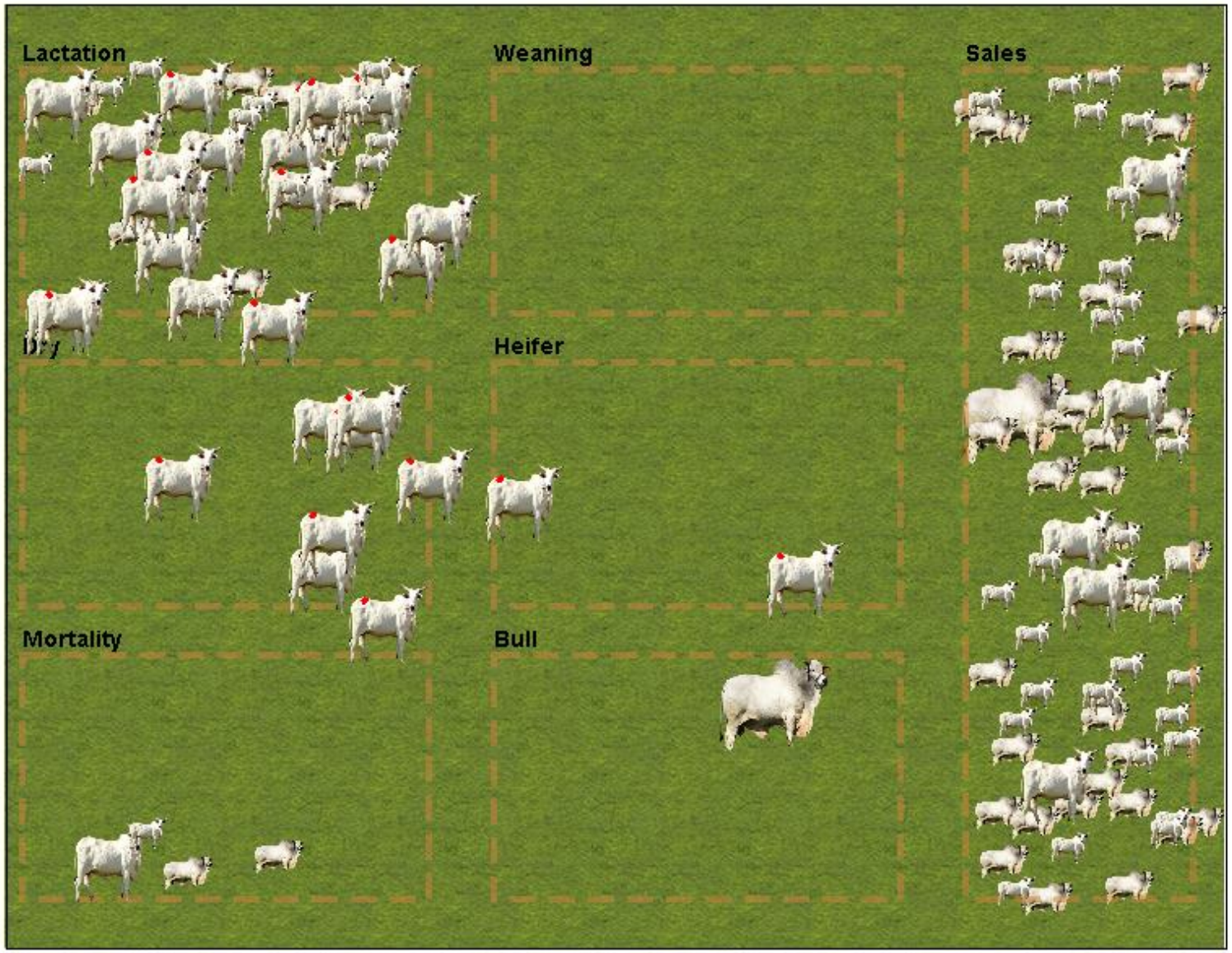
x1 root:Main

cows
Cow [84]

bulls
Bull [51]

staff
Staff

- [ ] Sale Open Heifers
- [ ] Sale Open Dry Cows
- [x] Sale Weaned Males
- [x] Sale Weaned Females



Time unit = Days

Run: 0 Running | Time: 2250.80 | Simulation: 11% | Date: Feb 28, 2025 7:18:54 PM | Memory: 72M of 3,64

AnyLogic University [EDUCATIONAL USE ONLY]

File Edit View Draw Model Tools Help

125% Get Support...

Main Cow Bull Staff

startReproSeason
startNaturalBreeding
WeaningCalves
insemination
transfer
availableStraws
availableMaleEmbryos
availableFemaleEmbryos
inseminationSchedule
tranferSchedule

ReproSeasonManagement
Waiting
InBreedingSeason

StartNaturalBreeding
BullWaiting
InNaturalBreeding

Properties

Staff - Agent Type

Name: Staff Ignore

Agent actions

On startup:

```
// se crean las pajillas y se agregan a la colección
Bull straw1 = new Bull(0.0, "semen1", main.semenFertilityRate, fal
Bull straw2 = new Bull(0.0, "semen2", main.semenFertilityRate, fal

availableStraws.add(straw1);
availableStraws.add(straw2);

// se crean los embriones y se agregan a la colección
Cow embryoCow1 = new Cow(0.0,"embryoCow1", 1.0, 3650, 350);
availableFemaleEmbryos.add(embryoCow1);

Bull embryoBull1 = new Bull(0.0, "embryoBull1", main.semenFertilit
availableMaleEmbryos.add(embryoBull1);
```

On destroy:

On arrival to target location:

On before step:

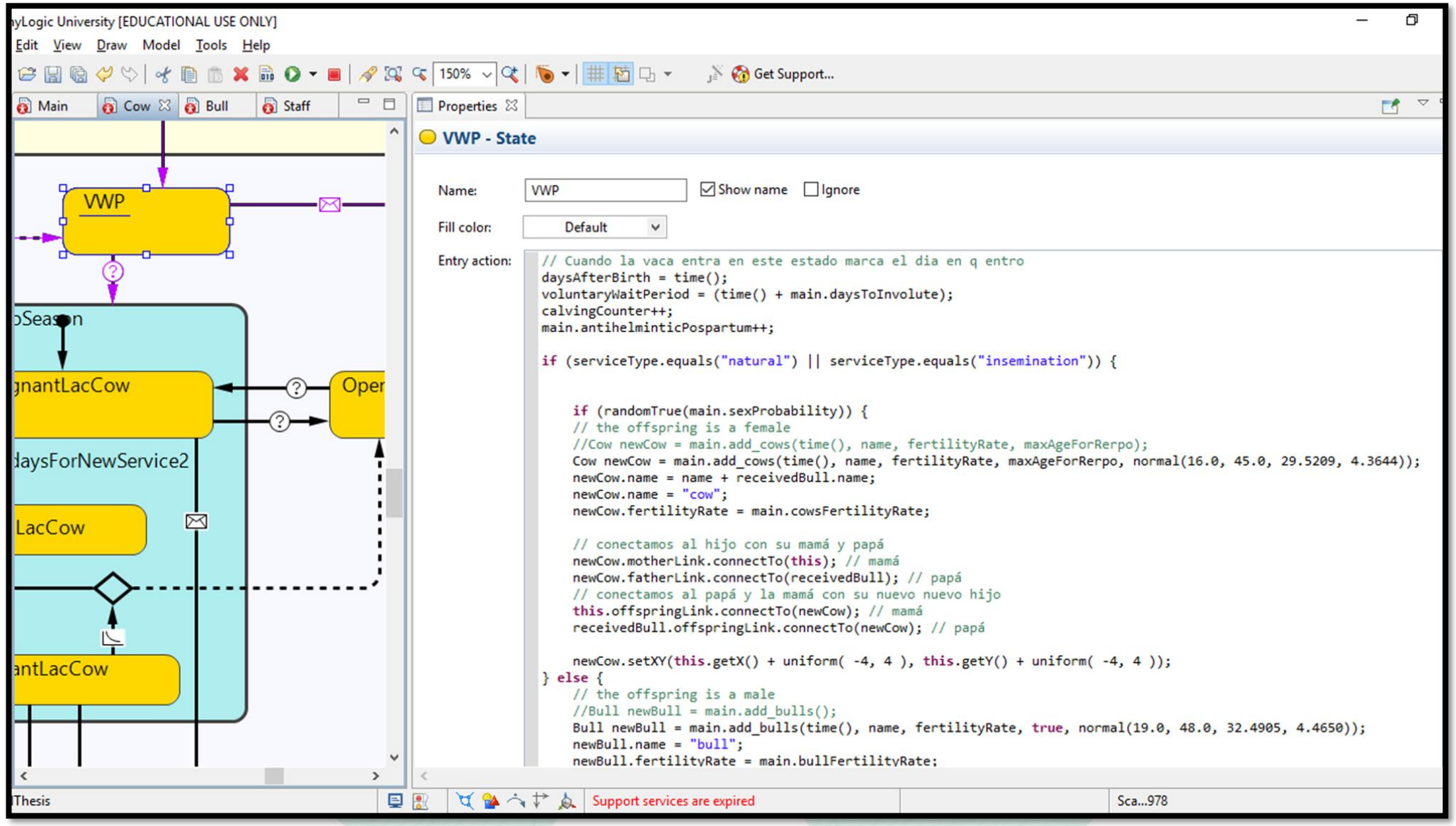
On step:

Agent in flowcharts

ModelThesis

Support services are expired

Sca...268


yLogic University [EDUCATIONAL USE ONLY]
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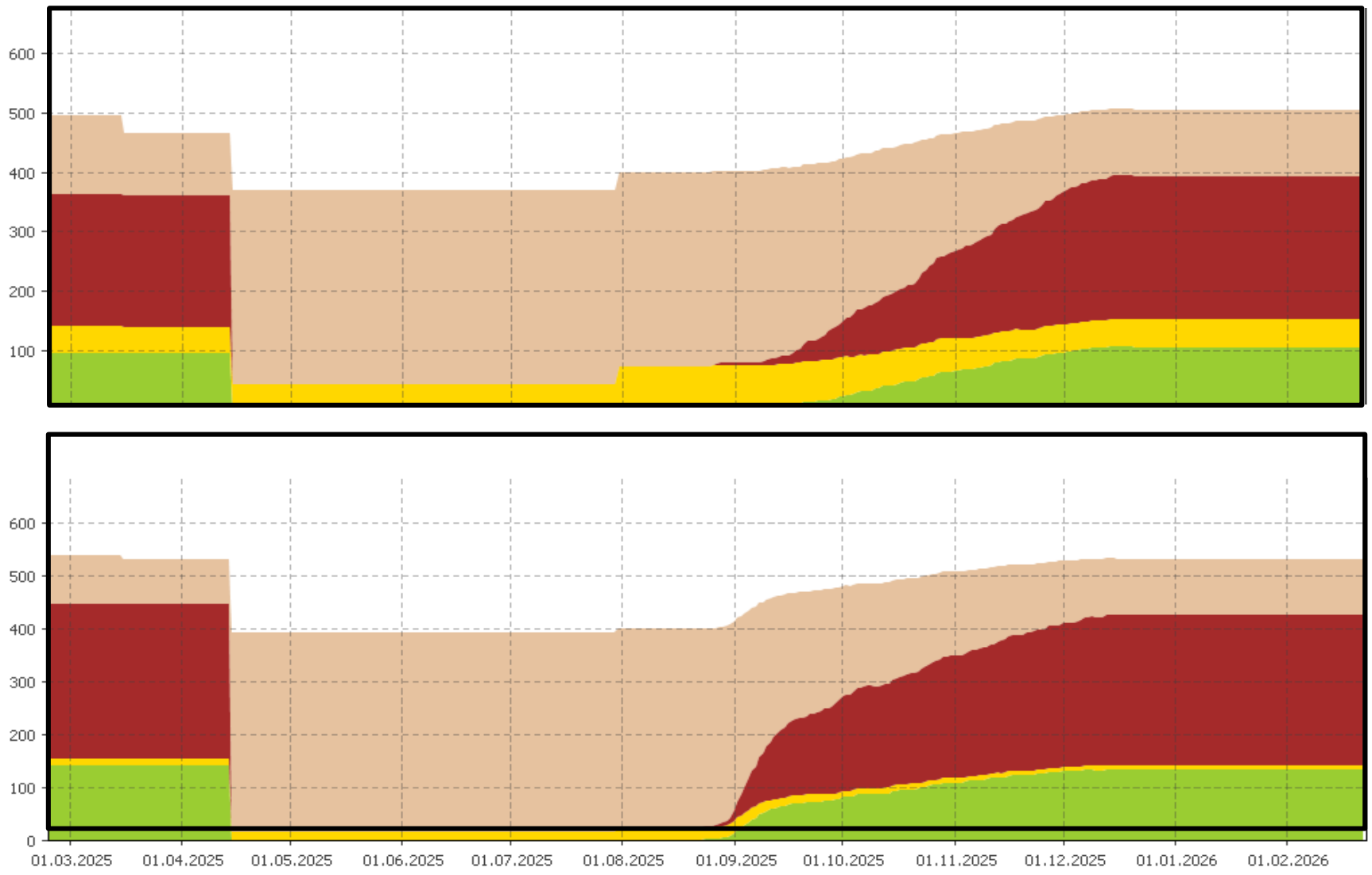
150%
Get Support...
Main
Cow
Bull
Staff
Properties
VWP - State
Name:
VWP
Show name
Ignore
Fill color:
Default
Entry action:
// Cuando la vaca entra en este estado marca el dia en q entro
daysAfterBirth = time();
voluntaryWaitPeriod = (time() + main.daysToInvolute);
calvingCounter++;
main.antihelminticPospartum++;
if (serviceType.equals("natural") || serviceType.equals("insemination")) {
if (randomTrue(main.sexProbability)) {
// the offspring is a female
//Cow newCow = main.add_cows(time(), name, fertilityRate, maxAgeForRerpo);
Cow newCow = main.add_cows(time(), name, fertilityRate, maxAgeForRerpo, normal(16.0, 45.0, 29.5209, 4.3644));
newCow.name = name + receivedBull.name;
newCow.name = "cow";
newCow.fertilityRate = main.cowsFertilityRate;
// conectamos al hijo con su mamá y papá
newCow.motherLink.connectTo(this); // mamá
newCow.fatherLink.connectTo(receivedBull); // papá
// conectamos al papá y la mamá con su nuevo nuevo hijo
this.offspringLink.connectTo(newCow); // mamá
receivedBull.offspringLink.connectTo(newCow); // papá
newCow.setXY(this.getX() + uniform(-4, 4), this.getY() + uniform(-4, 4));
} else {
// the offspring is a male
//Bull newBull = main.add_bulls();
Bull newBull = main.add_bulls(time(), name, fertilityRate, true, normal(19.0, 48.0, 32.4905, 4.4650));
newBull.name = "bull";
newBull.fertilityRate = main.bullFertilityRate;
VWP
gnantLacCow
daysForNewService2
LacCow
antLacCow
Thesis
Support services are expired
Sca...978

Results

Distribution of female herd by category, from March 1 of year 4 to February 1 of year 5, from the simulated time horizon

NM

TAI+NM



Calves **Lactation** **Dry cows**

Results of reproductive parameters for the two scenarios analyzed, NM and TAI+NM[1]

Parameter	NM	TAI+NM
Steer weaning weight	203.55 ± 2.63 kg	214,08 ± 4.11 kg
Heifer weaning weight	184.85 ± 2.63 kg	193.53 ± 2.56 kg
Calves/ha	0.48 ± 0.03 Calf	0.57 ± 0.02 Calf
kg/ha	95.43 ± 6.61 kg/ha	116.84 ± 5.79 kg/ha
Weaning weights/exposed cows	128.07 ± 4.97 kg	155.41 ± 7.57 kg

[1] NM = Natural mating; TAI = Fixed-Time Artificial Insemination. Each model was run 5 times. Values are means ± SD of the 5 runs.

Effect of the scenario, NM and TAI+NM[1], on the reproductive parameters

Parameter	NM	TAI+MN
Pregnancy rate for heifers	76.14 ± 3.34%	88.24 ± 2.92%
Pregnancy rate for cows	70.72 ± 1.35%	80.43 ± 1.72%

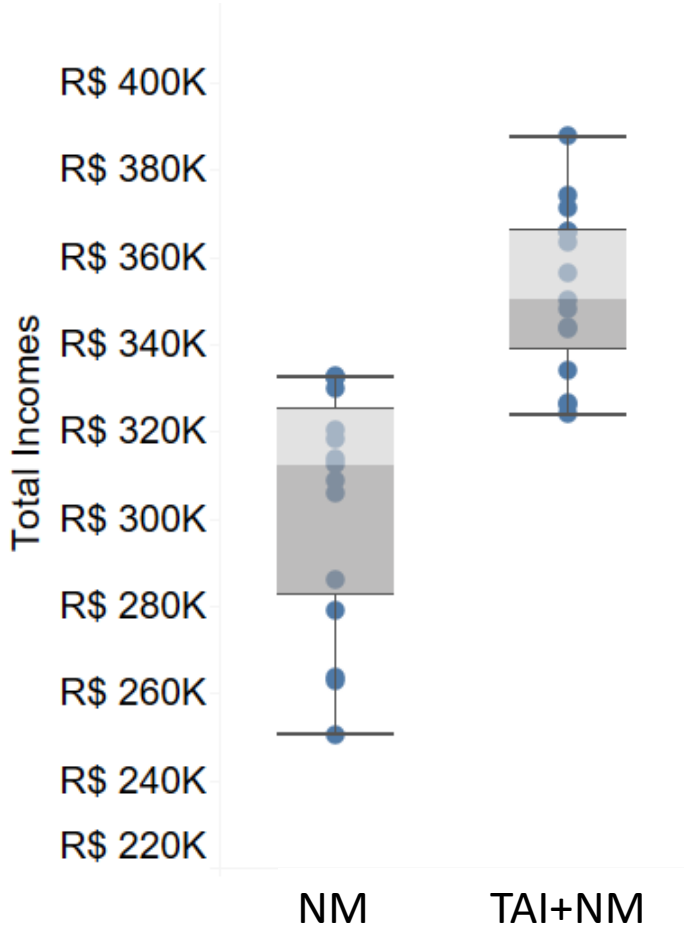
[1] NM = Natural mating; TAI = Fixed-Time Artificial Insemination. Each model was run 5 times. Values are means ± SD of the 5 runs.

Economic analysis: revenue

NM = R$ 303,255.00 ± 27,915.00

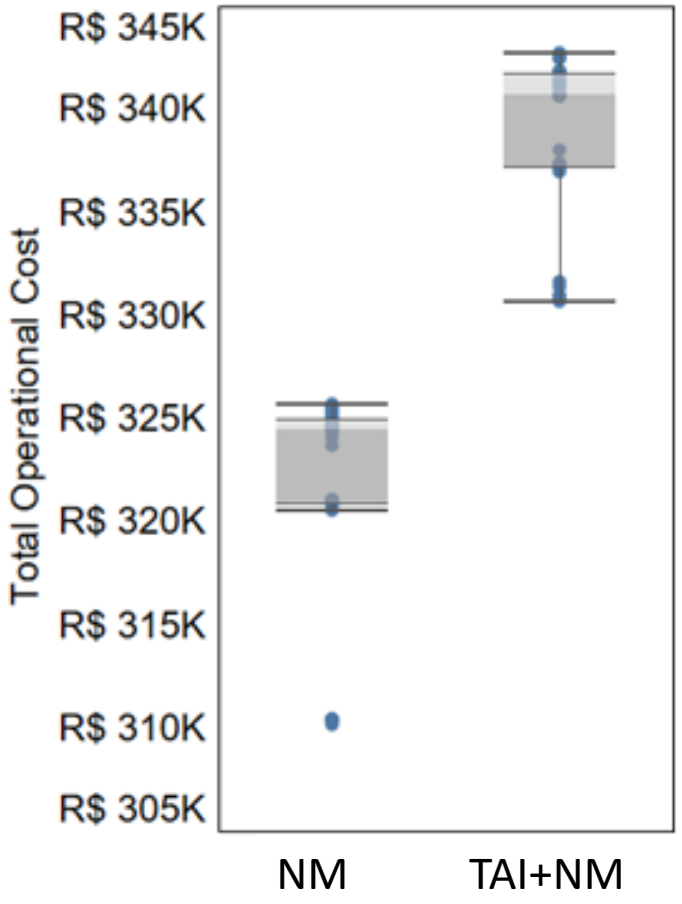
TAI+NM = R$ 352,025.00 ± 19,343.00

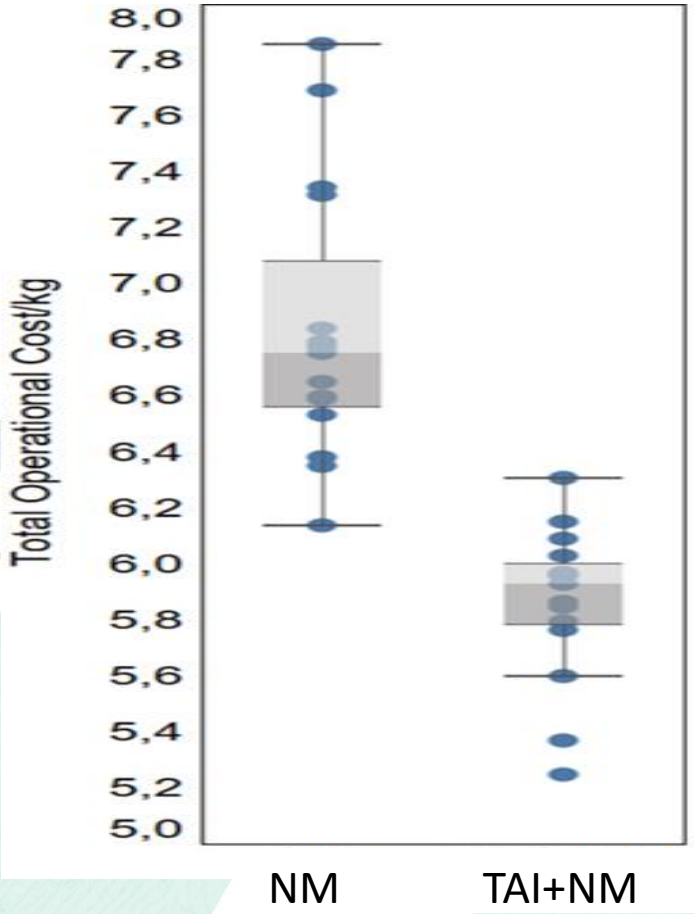
▲ +16.08%

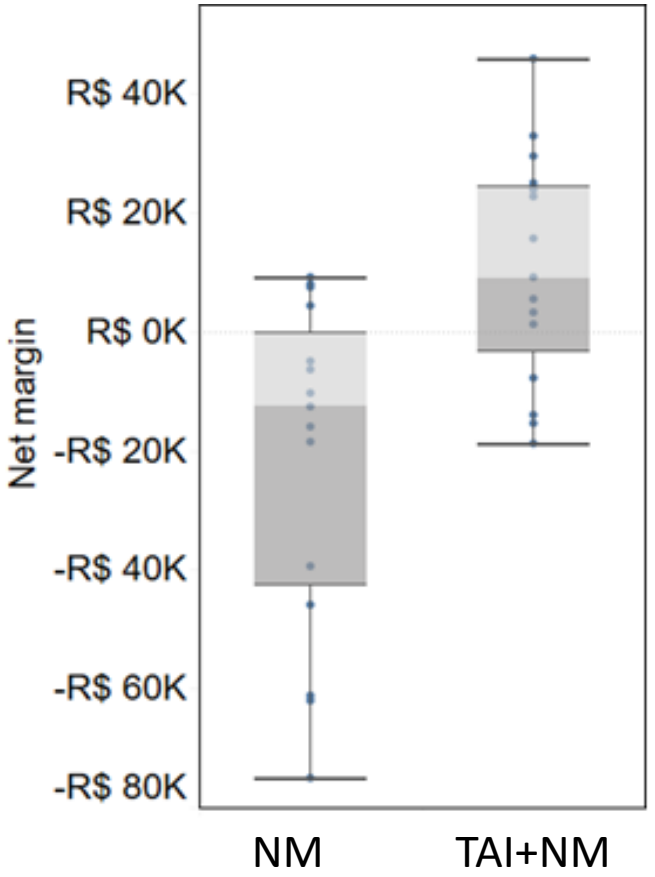


Note: € 1.00 = R$ 4.24

Economic analysis: costs







NM = R$ 321,160.00 ± 5,764.00

TAI+NM = R$ 338,600.00 ± 4,191.00

NM = R$ 6.84 ± 0.49

TAI+NM = R$ 5.86 ± R$ 0.28

NM = R$ -21,611.00 ± 28091.00

TAI+NM = R$ 10,522.00 ± 19451.00

Note: € 1.00 = R$ 4.24

Final considerations

Tool with great contribution potential

Develop multiple scenarios - Predict impacts

Support for future research

Thank you

GAMEIRO@USP.BR

Muito obrigado

Parameters used in the simulation model to describe the transition rates and / or the times used for the agents to move between the different states.

Parameter	Value	Distribution	Reference
General Parameters			
mortalityRateUpTo3DaysOld	*2.66%*		(SCHMIDEK et al., 2013)
mortalityRateFrom3To30Days	*2.62%*		(SCHMIDEK et al., 2013)
mortalityRateFrom30DaysOldToWeaning	*2.71%*		(SCHMIDEK et al., 2013)
adultMortalityRate	*1.00%*		
sexProbability	*50%*		
serviceRateToTAI	*100%*		
semenFertilityRate	95%		
Females Parameters			
ageOfBoughtHeifers		Normal (truncated) (Min. 711 months, Max. 826 months, Mean 780 months, Standard deviation 23.1706 months)	IZ Database
liveWeightOfBoughtHeifers		Uniform (300 kg, 400 kg)	
femaleBirthWeight		Normal (truncated) (Min. 16.0 kg, Max. 45.0 kg, Mean 29.5209 kg, Standard deviation 4.3644 kg)	IZ Database

Parameters used in the simulation model to describe the transition rates and / or the times used for the agents to move between the different states.

Parameter	Value	Distribution	Reference
Average daily gain before weaning *avdDGPreWeaningFemale*		Normal (truncated) (Min. 0.210 kg, Max. 1.025 kg, Mean 0.7360369 kg, Standard deviation 0.112999 kg)	IZ Database
Average daily gain from weaning to heifer *avgDGWeaningToHeifer*		Normal (truncated) (Min. 0. 09148 kg, Max. 0.80541 kg, Mean 0.44720 kg, Standard deviation 0,11381 kg)	
Average daily gain before the breeding season *avgDGPreReproSeaon*		Normal (truncated) (Min. -0.13736 kg, Max. 0.18375 kg, Mean 0.03557 kg, 0.04617)	
Average daily gain during the breeding season *avgDGInPreReproSeaon*		Normal (truncated) (Min. -0.2333 kg, Max. 1.4222 kg, Mean 0.737 kg, 0.2877)	
maximumAgeForBreeding	5000 days		
pregnancyLoss	0.0145% per day		(AONO et al., 2013)
Service interval for natural breeding	21 days		
Service interval for timed artificial insemination	40 days		

Parameters used in the simulation model to describe the transition rates and / or the times used for the agents to move between the different states.

Parameter	Value	Distribution	Reference
gestationLength		Normal (truncated) (Min. 273 days, Max. 314 days, Mean 296.6 days, Standard deviation 5.9 days)	(CHUD et al., 2014)
voluntaryWaitPeriod	45 days		
cowsFertilityRate	60%		
Males Parameters			
ageOfBoughtBulls		Normal (truncated) (Min. 711 months, Max. 826 months, Mean 780 months, Standard deviation 23.1706 months)	
liveWeightOfBoughtBulls			
maleBirthWeight		Normal (truncated) (Min. 19.0 kg, Max. 48.0 kg, Mean 32.4905 kg, Standard deviation 4.4650 kg)	IZ Database
Average daily gain before weaning *avdDGPreWeaningMale*		Normal (truncated) (Min. 0.258 kg, Max. 1.143 kg, Mean 0.8104624 kg, Standard deviation 0.1226086 kg)	IZ Database
bullsFertilityRate	50%		