

**Farming the Unfarmable**

New Mexico SuperComputing Challenge

Final Report

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*Harrison Middle School*

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**Table of Contents**

<b>Executive Summary</b>	<b>3</b>
<b>Introduction</b>	<b>4</b>
Problem Statement	
Background Research	
<b>Computational Model</b>	<b>6</b>
Selection	
Modification & Visualization	
Limitations	
Verification & Validation	
<b>Conclusion</b>	<b>7</b>
Results	
Discussion	
Future Work	
Acknowledgements	
<b>References</b>	<b>12</b>
<b>Appendix: Code</b>	

## **Farming the Unfarmable**

### **Executive Summary**

The purpose of this experiment was to determine if yams would be a worthwhile crop to grow in the desert environment of New Mexico as a food source for the many people who go hungry in our area. We chose to use yams as the food crop to test because we learned from our NSBE mentor who is Igbo that yams are sacred in his culture because they are able to be grown and eaten in the desert environment of Africa already.

We decided to model our hypothesis about yams on a computational model because it can show the larger scale of growth. We used NetLogo to create a model to use as a foundation. We used Python to input data from national databases.

We ran simulations with our model several times to see the results when we changed variables on the sliders in our model. Our model showed us results from several runs where we adjusted precipitation, temperature, and amount of farmland.

Our model ultimately was able to demonstrate to us that our original hypothesis is correct - the temperature affected the success of the yam growth more than precipitation. This means that if we can affect the temperature (for example with shade structures), then yams can be a successful food crop for New Mexico.

## **Farming the Unfarmable**

### **Introduction**

#### *Problem Statement*

Our team decided to tackle one of the world's biggest issues, world hunger. Some of the reasons for this is because there are millions of people living in countries that have little to zero farmable land. This is a huge problem because there are 100 million people going hungry every day. 25,000 people die every day from hunger. So our solution is to find a way to make infertile land fertile. In fact, our own state of New Mexico faces a huge problem with food insecurity among the population. There are many solutions. One of these solutions is using organic matter to fertilize the soil.

We also looked at which crops are the most nutritious. We settled on using yams in our project because of how successful they are in environments similar to our own desert environment here in New Mexico. We learned about using yams from one of our NSBE Jr. mentors who is African and told us about how important yams are in his culture. For the Igbo culture, yams are a sacred vegetable. Our hypothesis is that yams can grow well in the desert environment of New Mexico since they do in other desert environments around the world.

#### *Background Research*

The desert of New Mexico is actually called the Chihuahuan desert. The Chihuahuan Desert is the largest desert in North America. The largest gypsum dune field in the world is located at White Sands National Monument in south-central New Mexico. This region of glistening white dunes is in the northern end of the Chihuahuan Desert within an "internally drained valley" called the Tularosa Basin. Much of New Mexico is located in the Upper Chihuahuan Desert, which is colder than the Sonoran desert in Arizona. The saguaro cactus, a

## FARMING THE UNFARMABLE

symbol of the wild west, is rarely found in New Mexico due to prolonged freezing temperatures. Does New Mexico's desert get cold in the winter? New Mexico enjoys a fairly pleasant, arid to semi-arid climate that experiences snow during winter and hot weather during summer. The average temperatures in winter can differ depending on the location but generally, winter is quite cold at around 40°F. New Mexico's desert is about 193,783 sq mi. (kids.nationalgeographic.com)

Yams have a lot of nutritional benefits. They have essential vitamins A, essential vitamin C, potassium and dietary fiber. These things mean that not only does this vegetable make someone feel full but it is very nutritious and helps with eye health, immunity, skin health, blood pressure, and antioxidants. Yams are a complex carbohydrate which means that people who eat them get long-lasting energy over the whole day. "One cup of cooked sweet potatoes, weighing around 200 grams, typically provides approximately 180 calories, 41 grams of carbohydrates, 4 grams of fiber, and 3.4 grams of protein." (healthline.com)

To grow yams, you need to pick a variety that will be suitable for the environment as there are a lot to choose from. You start growing them by putting them in water until they get roots and sprouts. They need, "well-drained, loose soil with a slightly acidic to neutral pH, incorporating organic matter for nutrients." (quora.com) Then the yams need consistent moisture as they grow, and while growing they need mulch to keep that moisture and prevent too many weeds. It is also important for the yams to get a fertilizer that doesn't have too much nitrogen while they are growing. Once you pick them, then they need to be stored in a warm, humid location for a few weeks.

## FARMING THE UNFARMABLE

### **Computational Model**

*Selection*      You can select a country from the chooser on the left to get the average annual Yams (Pounds), average annual precipitation (MM), average daily temperature (F), amount of mapped yams, amount of yams per mapped yam, estimated annual profit (USD), and the percent malnourished for that country

*Modifications & Visualization*      You can modify the precipitation, temperature, country population, country exports, percentage of agricultural land, and countries military presents. Making these modifications can generate a variety of predictions. The model allows observers to visualize an attainable amount of yam production in a given country.

*Limitations*      The model limits you to a general area but can not pinpoint a specific location. Additionally the model can not use real time data. Lastly, the model can only pick certain countries to run scenarios.

*Verification & Validation*      We used real life data from countries that already grow yams for our model. We input the information about temperature and precipitation to the model. We then tested to see if our model produced results which were similar to the real life yam production for those countries. Our model was able to produce realistic results.

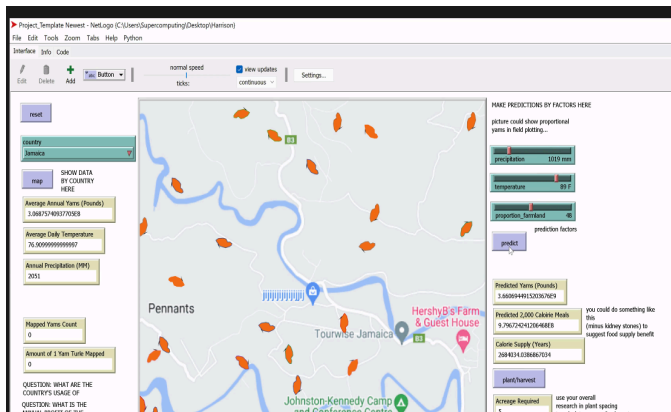
# FARMING THE UNFARMABLE

## Conclusion

### Results

To gather results, we ran our model several times with lots of different scenarios. We tried setting extreme parameters with our sliders to see what would happen with yam growth.

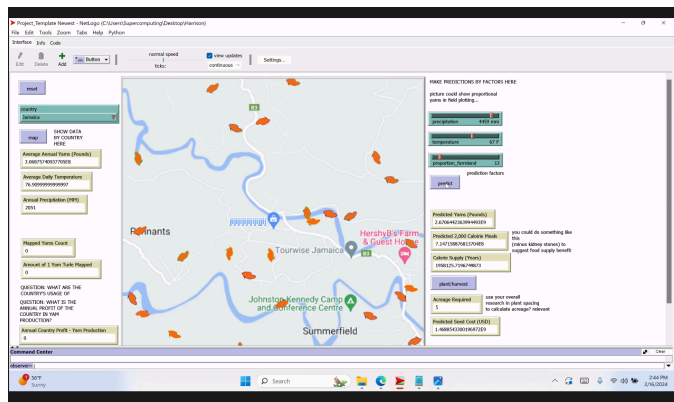
Below are some images of the results and our explanation of each.



*Image 1 - Low rain, mod high temp, moderate land*

We ran our initial tests in Jamaica. First, we set the precipitation to 1019, the temperature to 89 Fahrenheit and the land to 48, and we hit predict. It changed from 0 yams to 3.6e9 yams, the meals

changed from 0 to 9.8e8. This means that with settings where there is low precipitation, high temperature, and a moderate amount of land that some yams were produced.



*Image 2 - Very high rain, low temp, low farmland*

Next we changed the precipitation slider to a higher level. We changed it to 4,059mm, the temperature to 67 Fahrenheit, and farmland to 13. This scenario produced 2.6e9 pounds of yams and 7.1e8 meals. So

increasing rainfall and decreasing temperature resulted in more yams even with a smaller amount of farmland.

# FARMING THE UNFARMABLE

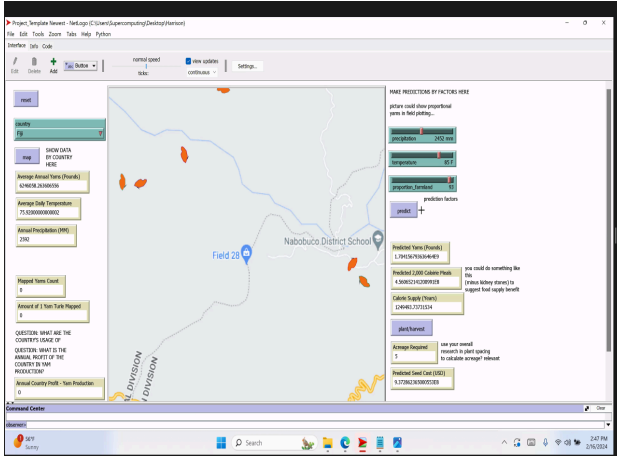


Image 3 - Moderate rain, mod high temp, high farmland

Next we tested in Fiji. We set precipitation to 2,452 mm, temperature to 85 Fahrenheit, and farmland at 93. When we hit the predict button, we got 1.7e9 pounds of yams and 4.5e8 meals. In this scenario, the

precipitation is moderate, the temperature is high, but there is more farmland. This scenario produced less yams on more farmland.

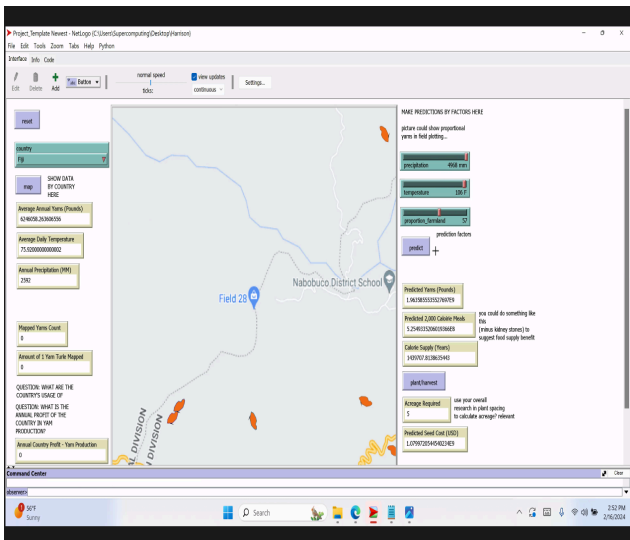


Image 4 - High rain, high temp

Now, we decided to test just between the effects of rainfall and temperature since the amount of land did not seem to have as big an impact. We set precipitation 4968 and temperature to 106 Fahrenheit but left farmland around the middle at 57. This scenario resulted in 1.9e9 pounds of yams.

So we see that extremely high temperatures, as long as there is also high precipitation, still gives us a lot more yams than the first scenario.



# FARMING THE UNFARMABLE

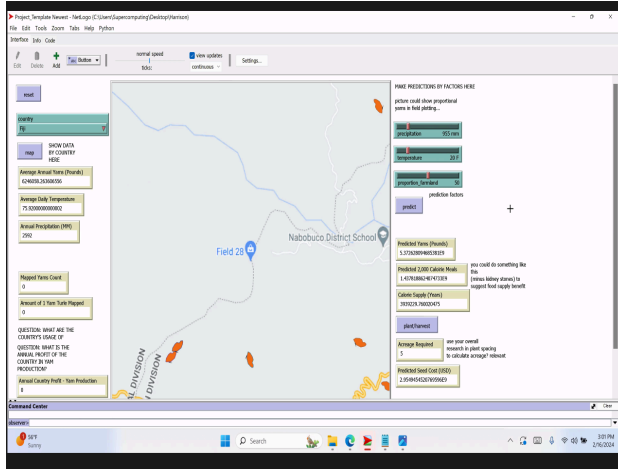


Image 5 - Low rain, low temp

Next we tested in Panama at 955mm rainfall and a temperature of 20 Fahrenheit with farmland still in the middle at 50. The model showed us results of 5.3e9 lbs yams, 1.4e9 meals.

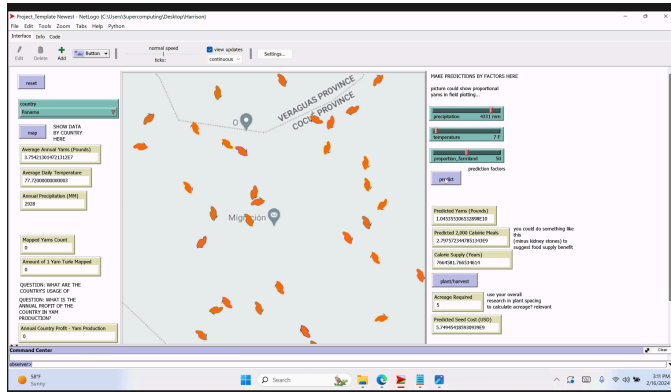


Image 6 - High rain, extremely low temp

4,331 rainfall, temperature at 7 degrees 450 farmland. Lowering the temperature and keeping high precipitation resulted in an increase from 5.3e9 yams to 1.04e10, or from 1.4e9 meals to 2.8e9 meals - doubling the harvest.

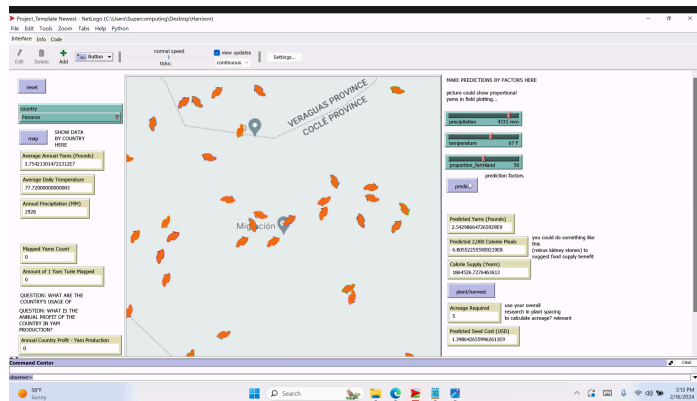


Image 7 - High rain, low temp

We decided to retest the best scenario from Jamaica in Panama with rainfall at 4,331 and temperature at 67. This resulted in 2.5e9 pounds, 6.8e8 meals which is again a very good result, similar to Fiji with 5.3e9 meals.

## FARMING THE UNFARMABLE

### *Discussion*

We ran several scenarios with different amounts of rainfall, different temperatures, and different amounts of farmland. We used the sliders to set up the different amounts we wanted to test in different countries. After looking at the results from the scenarios, it seems like precipitation is important, but the temperature has a really big effect. We saw overall through the different scenarios we ran, that even when there was rainfall, if the temperature was too low, below freezing or too high, above 100 degrees, we didn't get good yam production. So now, we need to put in the actual data for New Mexico about temperature and rainfall so we can see if our conditions can be adjusted to grow yams well here.

With this project our team decided to tackle one of the world's biggest issues, world hunger. Here in New Mexico, we are one of the states facing the highest rate of food insecurity. Our residents, especially the children, struggle with knowing where their next meal will come from, if they will even be able to eat each day. According to Roadrunner Food Bank, the largest food distributor to those in need in the state, before the pandemic, 1 in 5 kids were already struggling with hunger in New Mexico. Now, post 2020, that statistic has grown to 1 in 3 children in New Mexico facing food insecurity regularly.

We designed a computational model to show whether or not yams would be a viable food crop in New Mexico. This idea came from one of our mentors in our NSBE Jr. chapter, Dr. Emmanuel Asonye. Yams are sacred in IGBO culture, at the IGBO festival they bless the Yam and hand a piece to everyone because it is very important, it grows well in the desert of Africa and allows people to eat it. The yam is very nutritious in the African desert so we hypothesized it would also grow in our New Mexican desert.

## FARMING THE UNFARMABLE

So far we have been able to use our model to test for ideal conditions in countries that already are growing yams. Our next steps for our work with our model is to add in the data specific to New Mexico so we can see if we can set up those conditions for farmers here to successfully grow yams as a food crop for our hungry population

### *Future Work*

Our model ultimately was able to demonstrate to us that our original hypothesis is correct - the temperature affected the success of the yam growth more than precipitation. This means that if we can affect the temperature (for example with shade structures), then yams can be a successful food crop for New Mexico. In the future, we would like to add to our model soil composition to better predict yam production.

### *Acknowledgments*

We want to thank our mentors Ms.Patty and Ms. Michelle. They helped us set up our model in NetLogo and are teaching us more and more about Python and datasets. We also want to thank our NSBE Jr. club sponsor, Ms.Campbell for helping us with learning to write research papers. We want to thank Albuquerque Public Schools Education Foundation for giving us grants to afford the trip here to Atlanta to participate in the Technical Innovations Challenge. Thank you to our chapter Director, Ms. Brown. Lastly, we want to thank our families for supporting and encouraging us and for reminding us to finish all of our tasks and work together for our project.

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7. Michelle Fairow, BS in Statistic, Post-Bachelor in Biochemistry, 3rd yr student at UNM in Cybersecurity and Business Analytics, Coding mentor.

# FARMING THE UNFARMABLE

## Appendix: Code

```
globals [tct nct yams_predicted meal_predict meal_predicted
  predicated_calyr predicted_acreage seed_cost avg_year_yam
  avg_annual_prec avg_annual_temp jpg my_yams_pred one_yam_turtle
  yam_turtles annual_yam_profit cx cy growth_time seed_spacing
  plants_plotted county_farmland average_rainfall
  county_acreage average_temp_high yam_calc_temp
  percent_mal protein_content potassium_content
  carbohydrate_content vitc_content iron_content
  vitb6_content magnesium_content crtt minpx maxpx
  minpy maxpy s px py
  new_mexico_temp
  new_mexico_annual_prec
  new_mexico_population
  new_mexico_land_km
  new_mexico_yam_pred
  new_mexico_acre_reg
  new_mexico_plot_required
  nm_water_km_squared
]

extensions [py]

to setup
  clear-all
  clear-output
  ask patches [ set pcolor white ]
  py:setup
  "C:\\Users\\Supercomputing\\AppData\\Local\\Programs\\Python\\Python39\\python.
  exe"
  set yams_predicted 0
  set meal_predicted 0
end

to mapc
  clear-drawing
  clear-turtles
  py:run "import subprocess, os"
  py:run "import pandas as pd"
  py:set "df_pth"
  "C:\\Users\\Supercomputing\\Desktop\\Harrison\\final_data_with_import_export.cs
  v"
  py:set "c" country
  py:run "df = pd.read_csv(df_pth)"
  py:run "t = df.loc[(df['Entity'] == c) & (df['JPG'].isna() == False)]"
  py:run "print(len(t))"
  if py:runresult "len(t)" > 0 [
    ;; FIRST SET BACKGROUND
    set jpg (word "C:\\Users\\Supercomputing\\Desktop\\Harrison\\JPG\\"
  py:runresult "t['JPG'].unique()[0]")
  show jpg
  clear-drawing
  ask patches [ set pcolor white ]
```

## FARMING THE UNFARMABLE

```
import-drawing jpg
import-pcolors jpg
;;; NOW SET AVERAGE ANNUAL YAMS IN POUNDS FOR COUNTRY
py:run "tg = t.loc[:, ['Year', 'yam_pounds', 'Temperature_F', 'MM_Year']]"
set avg_year_yam py:runresult "tg['yam_pounds'].mean()"
set avg_annual_prec py:runresult "tg['MM_Year'].mean()"
set avg_annual_temp py:runresult "tg['Temperature_F'].mean()"
;;; SHOW YAM COUNTS WHERE ONE TURTLE IS 1000000 YAMS
;;show (word "New Mexico avg_year_yam: " avg_year_yam)
;;show (word "New Mexico (avg_year_yam / 1000000000): " (avg_year_yam /
1000000000))
if avg_year_yam > 0 [
  (ifelse (avg_year_yam / 100) < 50 [
    set crtt (avg_year_yam / 100)
    set one_yam_turtle (avg_year_yam / crtt)
  ] (avg_year_yam / 1000) < 50 [
    set crtt (avg_year_yam / 1000)
    set one_yam_turtle (avg_year_yam / crtt)
  ] (avg_year_yam / 10000) < 50 [
    set crtt (avg_year_yam / 10000)
    set one_yam_turtle (avg_year_yam / crtt)
  ] (avg_year_yam / 100000) < 50 [
    set crtt (avg_year_yam / 100000)
    set one_yam_turtle (avg_year_yam / crtt)
  ] (avg_year_yam / 1000000) < 50 [
    set crtt (avg_year_yam / 1000000)
    set one_yam_turtle (avg_year_yam / crtt)
  ] (avg_year_yam / 10000000) < 50 [
    set crtt (avg_year_yam / 10000000)
    set one_yam_turtle (avg_year_yam / crtt)
  ] (avg_year_yam / 100000000) < 50 [
    set crtt (avg_year_yam / 100000000)
    set one_yam_turtle (avg_year_yam / crtt)
  ]
  (avg_year_yam / 1000000000) < 50 [
    set crtt (avg_year_yam / 1000000000)
    set one_yam_turtle (avg_year_yam / crtt)
  ]
  ) ;;! etc. - check all cases work
]
py:set "pth1" "C:\\Users\\Supercomputing\\Desktop\\Harrison\\coords.csv"
py:run "df1 = pd.read_csv(pth1)"
py:run "r = df1.loc[(df1['Country'] == c) & (df1['minx'].isna() == False) &
(df1['maxx'].isna() == False) & (df1['miny'].isna() == False) &
(df1['maxy'].isna() == False)]"
set nct 0
(ifelse py:runresult "len(r)" > 0 [
  set minpx py:runresult "r.iloc[0]['minx']"
  set maxpx py:runresult "r.iloc[0]['maxx']"
  set minpy py:runresult "r.iloc[0]['miny']"
  set maxpy py:runresult "r.iloc[0]['maxy']"
  ;; show (word "minx, maxx, miny, maxy: " minpx maxpx minpy maxpy)
  create-turtles crtt ;; attemptIPs
  set tct count turtles
  while [nct < tct] [
    set s 1
    if remainder nct 2 != 0 [
```

## FARMING THE UNFARMABLE

```
        set s -1
    ]
    ;;; THESE LINES ADJUST RANGE BETWEEN MINX/MAXX AND MINY/MAXY
    set px ((minpx) + (random((maxpx)-(minpx)))) + ((random-float 0.0005) *
s)
    set py ((minpy) + (random((maxpy)-(minpy)))) + ((random-float 0.0005) *
s)

    show (word px py)
    ask turtle nct [
        set shape "yam 1"
        ;;set color red
        setxy px py
        set size 2
        set heading 0
    ]
    set nct nct + 1
]
;; show (word "in base " Country " " cct)
] [ ;;; no data
create-turtles crtt
ask turtles [
    set shape "yam 1"
    setxy random-xcor random-ycor
    set size 2
    set heading 0
]
])

(ifelse count turtles > 0 [
    set yam_turtles count turtles
] [
    set one_yam_turtle 0
    set yam_turtles 0
])
]
estCst
maln
end

to nutrition
    set protein_content (((yams_predicted * 453.592) / 150) * 2.3)
    set carbohydrate_content (((yams_predicted * 453.592) / 150) * 42)
    set potassium_content (((yams_predicted * 453.592) / 150) * 1224)
    set vitc_content (((yams_predicted * 453.592) / 150) * 0.42) * 100)
    set iron_content (((yams_predicted * 453.592) / 150) * 0.04) * 100)
    set vitb6_content (((yams_predicted * 453.592) / 150) * 0.20) * 100)
    set magnesium_content (((yams_predicted * 453.592) / 150) * 0.07) * 100)
end

to maln
    py:run "import pandas as pd"
    py:set "df_pth" "C:\\Users\\Supercomputing\\Desktop\\Harrison\\maln_data.csv"
    py:set "c" country
    py:run "df = pd.read_csv(df_pth)"
    py:run "df_temp = df.loc[(df['Country Name'] == c)]['2021'].unique()"
    if py:runresult "len(df_temp)" > 0 [
```

## FARMING THE UNFARMABLE

```
        carefully [
            set percent_mal py:runresult "df_temp[0]"
        ] [ set percent_mal 0 ]
    ]
end

to estCst
    (ifelse country = "Mexico" or country = "New Mexico" [
        set annual_yam_profit (avg_year_yam * 0.96)
    ] [
        set annual_yam_profit (avg_year_yam * 2.49)
    ])
end

to predict
    show precipitation
    show temperature
    py:run "import pandas as pd"
    py:run "import numpy"
    py:run "from sklearn.model_selection import train_test_split"
    py:run "from sklearn.linear_model import LinearRegression"
    py:run "from sklearn import metrics"
    py:set "ds"
"C:\\Users\\Supercomputing\\Desktop\\Harrison\\final_data_mrg2_noo.csv"
    py:run "mod = pd.read_csv(ds)"
    py:run "mod = mod.loc[(mod['yam_pounds'].isna() == False) &
(mod['Temperature_F'].isna() == False) & (mod['MM_Year'].isna() == False) &
(mod['Population'].isna() == False) & (mod['land_kilometers_squared'].isna() ==
False) & (mod['Percent Agricultural Land'].isna() == False) &
(mod['Exports'].isna() == False) & (mod['total_military_2024'].isna() ==
False)]"
    py:run "X = mod[['MM_Year', 'Temperature_F', 'Population', 'Percent
Agricultural Land', 'Exports', 'total_military_2024']]"
    py:run "Y = mod['yam_pounds']"
    py:run "X_train, X_test, Y_train, Y_test = train_test_split(X, Y,
test_size=0.2, random_state=42)"
    py:run "mdl = LinearRegression(positive=True, fit_intercept=True)"
    py:run "mdl.fit(X_train, Y_train)"
    py:run "Y_pred = mdl.predict(X_test)"
    py:set "mm" precipitation
    py:set "dfn" temperature
    py:set "cpop" country_population
    py:set "expr" country_exports_thousands_usd
    py:set "pagr" percent_agricultural_land
    py:set "tmil" country_military_present
    py:run "X_test_input_FROM_NL = pd.DataFrame({'MM_Year': [mm],
'Temperature_F': [dfn], 'Population': [cpop], 'Percent Agricultural Land':
[pagr], 'Exports': [expr], 'total_military_2024': [tmil]})"
    py:run "t = mdl.predict(X_test_input_FROM_NL)"
    py:run "print(t)"
    set yams_predicted py:runresult "t[0]"
    ;;; PLOT YAMS (GENERIC WAY)
    calcyam
    seedCost
    set one_yam_turtle 0
    set yam_turtles 0
    nutrition
```



## FARMING THE UNFARMABLE

```
end

to generate_new_mexico
  py:set "pth" "C:\\Users\\Supercomputing\\Desktop\\Harrison\\df_test_pos.csv"
  py:run "df = pd.read_csv(pth)"
  show py:runresult "len(df)"
  py:set "x" (1 + (random-float (302 - 1)))

  set new_mexico_temp py:runresult "df.iloc[int(x)]['Temperature_F']"
  set new_mexico_annual_prec py:runresult "df.iloc[int(x)]['MM_Year']"
  set new_mexico_population py:runresult "df.iloc[int(x)]['Population']"
  set new_mexico_land_km py:runresult
"df.iloc[int(x)]['land_kilometers_squared']"
  set nm_water_km_squared py:runresult "df.iloc[int(x)]['water_km_squared']"
  set new_mexico_yam_pred py:runresult "df.iloc[int(x)]['yam_pounds']"
  ;;; Using 2 Pounds/Plant, 4900 Plants/Acre
  set new_mexico_acre_reg ((new_mexico_yam_pred / 2) / 4900)
  ;;; 27,899,950 in New Mexico
  set new_mexico_plot_required (new_mexico_acre_reg / 27899950)
end
```

```
to calcyam
  ;;; POUNDS TO GRAMS - 1 LB = 453.592
  ;;; 118 CALORIES PER 100 GRAMS OF YAM (GOOGLE)
  set meal_predict ((yams_predicted * 453.592) / 100)
  set meal_predicted (meal_predict * 118) ;; total calories
  set meal_predicted (meal_predicted / 2000) ;; total 2000 calorie meals
  set predicated_calyr (meal_predicted / 365)
end
```

```
to seedCost
  set seed_cost ((yams_predicted / 2) * 0.28) ;;; Based on African Yam Seeds
  set predicted_acreage (yams_predicted / 9800) ;;; Calculate This By Spacing
  set seed_spacing 18
  set plants_plotted 4900
end
```

```
;;; YOU COULD CALCULATE THE "YAM" TUTLE TO REPRESENT X POUNDS
;;; THEN PLOTTING IN LANES/ROWS PROPORTIONALLY EITHER ANNUALLY, OR ONE MONTH,
WHATEVER LOOKS RIGHT
```

```
to plotyam
  clear-turtles
  clear-drawing
  ask patches [ set pcolor white ]
  create-turtles 10 ;;; yams_predicted ;;; way too many/need sized down
  ;;; SEED TURTLES (NEED PLANTED)
  ask turtles [
    set size 5
    set shape "seed 1"
    setxy random-xcor random-ycor
  ]

  move

  ask turtles [
```

## FARMING THE UNFARMABLE

```
    set size 8
    set shape "leaf 1"
    setxy random-xcor random-ycor
  ]
move
;;; YAM TURTLES
ask turtles [
  set size 10
  set shape "yam 1"
  setxy random-xcor random-ycor
]
move

set one_yam_turtle 0
set yam_turtles 0
end

;;; SCALE APPROPRIATELY FOR ESTIMATED YAM/POTATO PRODUCTION
to updatedPlot
clear-turtles
clear-drawing
ask patches [ set pcolor white ]
set cx -16
set cy 16
while [ cx < 17 ] [
  while [ cy > -17 ] [
    create-turtles 1
    ask turtles with [ shape = "default" ] [
      set shape "seed 1"
      set size 5
      setxy cx cy
      set heading 0
    ]
    set cy cy - 1
    wait 0.01
  ]
  set cx cx + 1
  set cy 16
]
set nct 0
while [ nct < count turtles ] [
  ask turtle nct [
    set shape "leaf 1"
  ]
  set nct nct + 1
  wait 0.001
]
set nct 0
while [ nct < count turtles ] [
  ask turtle nct [
    set shape "yam 1"
  ]
  set nct nct + 1
  wait 0.001
]
end
```

## FARMING THE UNFARMABLE

```
to move
  set nct 0
  while [nct < 5] [
    ask turtles [
      setxy random-xcor random-ycor
    ]
    wait 0.90
    set nct nct + 1
  ]
end
```

```
;;; REFERENCES
;;; WEATHER API: https://pypi.org/project/python-weather/
;;; AVERAGE TEMPERATURES BY MONTH: GOOGLE/Climates to travel
(https://www.climatestotravel.com/climate/cuba)
;;; AVERAGE HUMIDITY BY MONTH:
https://www.climatestotravel.com/climate/antigua-and-barbuda
;;; YAM PRODUCTION DATASET:
;;; YAM NUTRITION:
;;; SOIL FERTILITY:
;;; ACREAGE:
```