# model.py

import modules/libs: Model from mesa.model, MultiGrid from mesa.space, monkeys, environment, humans, land, family\_setting/human\_setting/run\_setting from fnnr\_config\_file, pickle

set up lists: global family IDs, households  # lists all household IDs from Shuang's data

load: vegetation ASCII .txt file (aggregated to ~85 x 100), elevation ASCII .txt file  # aggregated to ~85 x 100, household buffer ASCII .txt file (default 400m; aggregated to ~85 x 100), farm buffer ASCII .txt file (default 300m; aggregated to ~85 x 100), PES buffer ASCII .txt file (default 200m; aggregated to ~85 x 100)

import forest buffer ASCII .txt file  # default 200m; aggregated to ~85 x 100

\*Note: I explain how to generate buffer files of different distances in FNNR-ABM User's Manual.docx, found on Github.

set up masterdict (vegetation types) and resource\_dict (for human resource gathering)

class Movement:  # this is the main model

initiate self ("model"), width, height, continuation/torus property, time (step), step within the current year, number of monkey families (automatically determined by fnnr\_config\_file setting), monkey birth count, monkey death count, monkey ID count, number of humans, model grid type (with or without humans, automatically determined by fnnr\_config\_file setting), model run type (first run to load new settings or normal run, automatically determined by fnnr\_config\_file setting), and human ID count

grid width = 85

grid height = 100

It is possible to change these numbers, but then many other attributes such as vegetation, elevation, and buffer ASCII files, as well as the parameters for how far each monkey travels per step, must also be changed accordingly or else the model will be warped/inaccurate; also, the model will run much more slowly if larger than 85 x 100

empty\_masterdict = {'Outside\_FNNR': [], 'Elevation\_Out\_of\_Bound': [], 'Household': [], 'PES': [], 'Farm': [], 'Forest': [], 'Bamboo': [], 'Coniferous': [], 'Broadleaf': [], 'Mixed': [], 'Lichen': [], 'Deciduous': [], 'Shrublands': [], 'Clouds': [], 'Farmland': []}

These include all of the vegetation types monkeys can step on

# generate land

if model run type == 'first\_run':

self.\_populate()

The coordinates that make up each vegetation category will populate empty\_masterdict.

elif model run type == 'normal\_run':

empty\_masterdict = self.saveLoad()

empty\_masterdict is opened from a saved record instead of being populated by an imported file.

# generate resources

if self.grid\_type == 'with\_humans':

for line in \_readCSV('hh\_survey.csv'):  # hh\_survey.csv contains adapted resource data from Shuang's original data file

resource = Resource(\_readCSV('hh\_survey.csv')) # create agent and add to grid

resource\_dict.setdefault(hh\_id\_math,

self.grid.place\_agent(resource)  # adds resource points to the landscape

# generate land parcel agents

for line in \_readCSV('hh\_land.csv):  # hh\_land.csv contains adapted GTGP/land area data from Shuang's original data file

for i in range(1,6): $ up to 5 land parcels per household

non\_gtgp\_area = float(total\_rice) + float(total\_dry) - float(gtgp\_dry) - float(gtgp\_rice) # calculate non\_gtgp\_area and gtgp\_area; the rest is imported  
gtgp\_area = float(gtgp\_dry) + float(gtgp\_rice)

lp = Land(household ID, GTGP enrollment status, original head of household's age/gender/education, household size, total rice crop, GTGP rice crop, total dry crop, GTGP dry crop, land type (rice or dry), land travel time, plant type (specific crop), non-GTGP output, pre-GTGP output, household size, calculated non-GTGP area, calculated GTGP area)

self.schedule.add(lp)

Repeat for both non-GTGP and GTGP land parcel (since they import different parts of ‘hh\_land.csv’)

# generate human agents

Set self.number\_of\_humans and self.human\_id\_count = 0 # counters that will be increased later

for line in \_readCSV(‘hh\_citizens.csv’):

starting\_position = \_readCSV(‘household.csv’)

resource = random.choice(resource\_dict[hh\_id]) # sets resource that person gathers

age\_category = 1-9 if male depending on age, or 10-19 if female depending on age

if gender == 2 (female):

if marriage == 1 (married) and age < 45:

children = random.randint(0, 4) # existing amount of children so births aren’t inflated

birth\_plan\_chance = random.random()

if birth\_plan\_chance < 0.03125:  
 birth\_plan = 0  
elif 0.03125 <= birth\_plan\_chance < 0.1875:  
 birth\_plan = 1  
elif 0.1875 <= birth\_plan\_chance < 0.5:  
 birth\_plan = 2  
elif 0.5 <= birth\_plan\_chance < 0.8125:  
 birth\_plan = 3  
elif 0.8125 <= birth\_plan\_chance < 0.96875:  
 birth\_plan = 4  
else:  
 birth\_plan = 5

elif gender != 2 (male):

birth\_plan = 0

last\_birth\_time = random.uniform(0, 1) # numbers vary

human\_demographic\_structure\_list[age\_category] += 1 for that person

filter out all humans with a -3 as a value anywhere in Shuang’s data (doesn’t exist)

self.number\_of\_humans += 1

self.human\_id\_count += 1 # unlike number\_of\_humans, human\_id\_count never goes down

human = Human(calculated starting position, household ID, age, resource gathering flag, starting position on grid, chosen resource position on grid, frequency of resource gathering, gender, education, work status, marriage status, past household ID, number of years migrated, migration status, GTGP participation, non-GTGP area, migration network (binary 0 or 1), migration remittances, local off-farm income, last birth time, death rate (set later), age category, number of existing children, birth plan (total number of children))

self.schedule.add(human)

self.grid.place\_agent(human, starting\_position)

# note how agents that change are added to the schedule, and agents that show up in the visualization are added to the grid; in other words, land parcel agents are only added to the schedule, resource agents are only added to the grid, and human and monkey agents are added to both

Note that migrant humans (each household starts with 0 or 1 migrants) are added separately: they have the same attributes as a human in the villages and behave the same once they re-migrate, but their attributes import from different places in ‘hh\_citizens.csv’

# generate monkey family agents

for i in range(self.number\_of\_families): # this is set in fnnr\_config\_file.py

starting\_position = random.choice(startinglist)  
saved\_position = starting\_position # preserve previous position while moving  
from families import Family  
family\_size = random.randint(25, 45) # sets family size for each group--random integer  
family\_id = i  
list\_of\_family\_members = [] # will populate empty list later  
family\_type = 'traditional' # as opposed to an all-male subgroup  
split\_flag = 0 # binary: 1 means its members start migrating out to a new family  
family = Family(Family ID, model, starting position, family size, list of family members, family type—traditional or all-male, saved position, and split\_flag—a family group splits into two groups once it exceeds 45 members)  
self.grid.place\_agent(family, starting\_position)  
self.schedule.add(family)  
global\_family\_id\_list.append(family\_id)

# general individual monkey agents; note that this is nested within family generation

for monkey\_family\_member in range(family\_size):  
 id = self.monkey\_id\_count  
 gender = random.randint(0, 1)  
 if gender == 1: # gender = 1 is female, gender = 0 is male.

# This is different than with humans (1 or 2)  
 female\_list.append(id)  
 last\_birth\_interval = random.uniform(0, 2)  
 else:  
 male\_maingroup\_list.append(id) # as opposed to the all-male subgroup  
 last\_birth\_interval = -9999 # males will never give birth  
 mother = 0 # no parent check for first generation  
 choice = random.random() # 0 - 1 float - age is determined randomly   
 if choice <= 0.11: # 11% of starting monkey population  
 age = random.uniform(0, 1) # are randomly aged befween  
 age\_category = 0 # ages 0-1  
 demographic\_structure\_list[0] += 1  
 elif 0.11 < choice <= 0.27: # 16% of starting monkey population  
 age = random.uniform(1, 3) # are randomly aged befween  
 age\_category = 1 # ages 1-3  
 demographic\_structure\_list[1] += 1  
 elif 0.27 < choice <= 0.42: # 15% of starting monkey population  
 age = random.uniform(3, 7) # are randomly aged between  
 age\_category = 2 # ages 3-7  
 demographic\_structure\_list[2] += 1  
 elif 0.42 < choice <= 0.62: # 11% of starting monkey population  
 age = random.uniform(7, 10) # are randomly aged befween  
 age\_category = 3 # ages 7-10  
 demographic\_structure\_list[3] += 1  
 elif 0.62 < choice <= 0.96: # 34% of starting monkey population  
 age = random.uniform(10, 25) # are randomly aged befween  
 age\_category = 4 # ages 10-25  
 demographic\_structure\_list[4] += 1  
 if gender == 1:  
 if id not in reproductive\_female\_list:  
 reproductive\_female\_list.append(id)  
 # starting representation of male defection/gender ratio  
 structure\_convert = random.random()  
 if gender == 0:  
 if structure\_convert < 0.6:  
 gender = 1  
 last\_birth\_interval = random.uniform(0, 3)  
 if id not in reproductive\_female\_list:  
 reproductive\_female\_list.append(id)  
 elif 0.96 < choice: # 4% of starting monkey population  
 age = random.uniform(25, 30) # are randomly aged between  
 age\_category = 5 # ages 25-30  
 demographic\_structure\_list[5] += 1  
 gender = 1  
 monkey = Monkey(ID, model, gender, age, age category, family ID, last birth interval in years, mother ID)  
 self.number\_of\_monkeys += 1  
 self.monkey\_id\_count += 1  
 list\_of\_family\_members.append(monkey.unique\_id)  
 self.schedule.add(monkey)

def step(self):  
 # necessary; tells model to move forward every step  
 self.time += (1/73)  
 self.step\_in\_year += 1  
 if self.step\_in\_year > 73:  
 self.step\_in\_year = 1 # start new year  
 self.schedule.step()  
  
def \_readASCII() function, which reads in the imported vegetation/elevation/buffer .txt files

define \_populate() function, which places vegetation tiles on the model grid  
  
define saveLoad() function, which pickles objects so they can be loaded from a file instead of re-generated every model run