

An Agent-based Model of the Western Chitwan Valley, Nepal

Michigan State University
August 20, 2009

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Outline

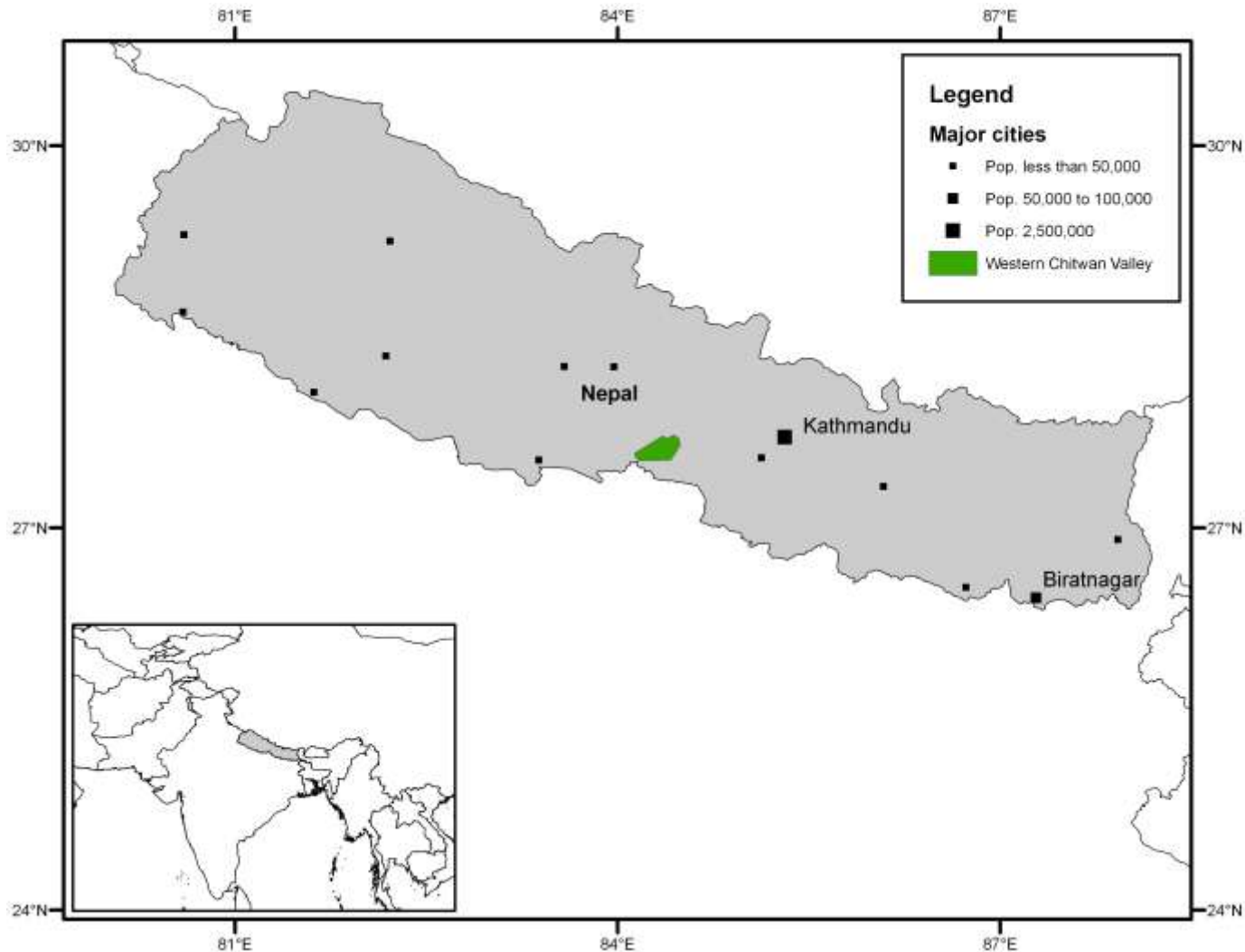
- Introduction to PIRE project & Chitwan site
- Model overview
 - Structure
 - Code verification
 - Experiment
- Discussion

INTRODUCTION

Introduction - PIRE

- Goal: To make comparative studies on two field sites in Nepal and China
 - Western Chitwan Valley, Nepal
 - Wolong Nature Reserve, China
- Today:
 - Focus on an agent-based model of the Western Chitwan Valley, Nepal

The Western Chitwan Valley, Nepal



The Western Chitwan Valley, Nepal



0 5 10 20 km



The Chitwan Valley data

- Survey first carried out in 1996
- Detailed survey every 5 years
- Monthly household surveys (births, marriages, deaths)
- Neighborhood-level LULC every 5 years

THE MODEL

Model objectives

- Investigate the connection between micro-scale demographic variability and macro-scale environmental change
- Include significant feedbacks between environmental and demographic change

The “ChitwanABM”

- The agents (borrowing from the CVFS)
 - People (9640)
 - Households (1773)
 - Neighborhoods (171)
 - Regions (1)
- Agents are drawn from the CVFS data
 - There is a one-one relation between persons, neighborhoods, and households in the data, and agents in the model

Person

- Attributes
 - Sex
 - Age
 - Ethnicity
 - Mother (and her attributes)
 - Father (and his attributes)
 - Family size preference
 - Contraceptive use history

Person (cont)

- Derived attributes
 - Number of living children
- Each person is a member of a
 - Household, Neighborhood, and **REGION**

Household

- Attributes
 - Use of any non-wood fuel
 - Land ownership (house plot, any land)
- Derived attributes
 - Household size

Neighborhood

- Each household is a member of a neighborhood
- Attributes
 - Non family services
 - Availability of electricity
 - Land-use / land-cover (more later)
- Derived attributes
 - Number of households members

Neighborhoods – LULC

- LULC classes are defined as in Axinn and Ghimire (2007):
 - Agricultural vegetation
 - Non-agricultural vegetation
 - Private buildings
 - Public infrastructure
 - Other (ponds, silted riverbanks, etc.)

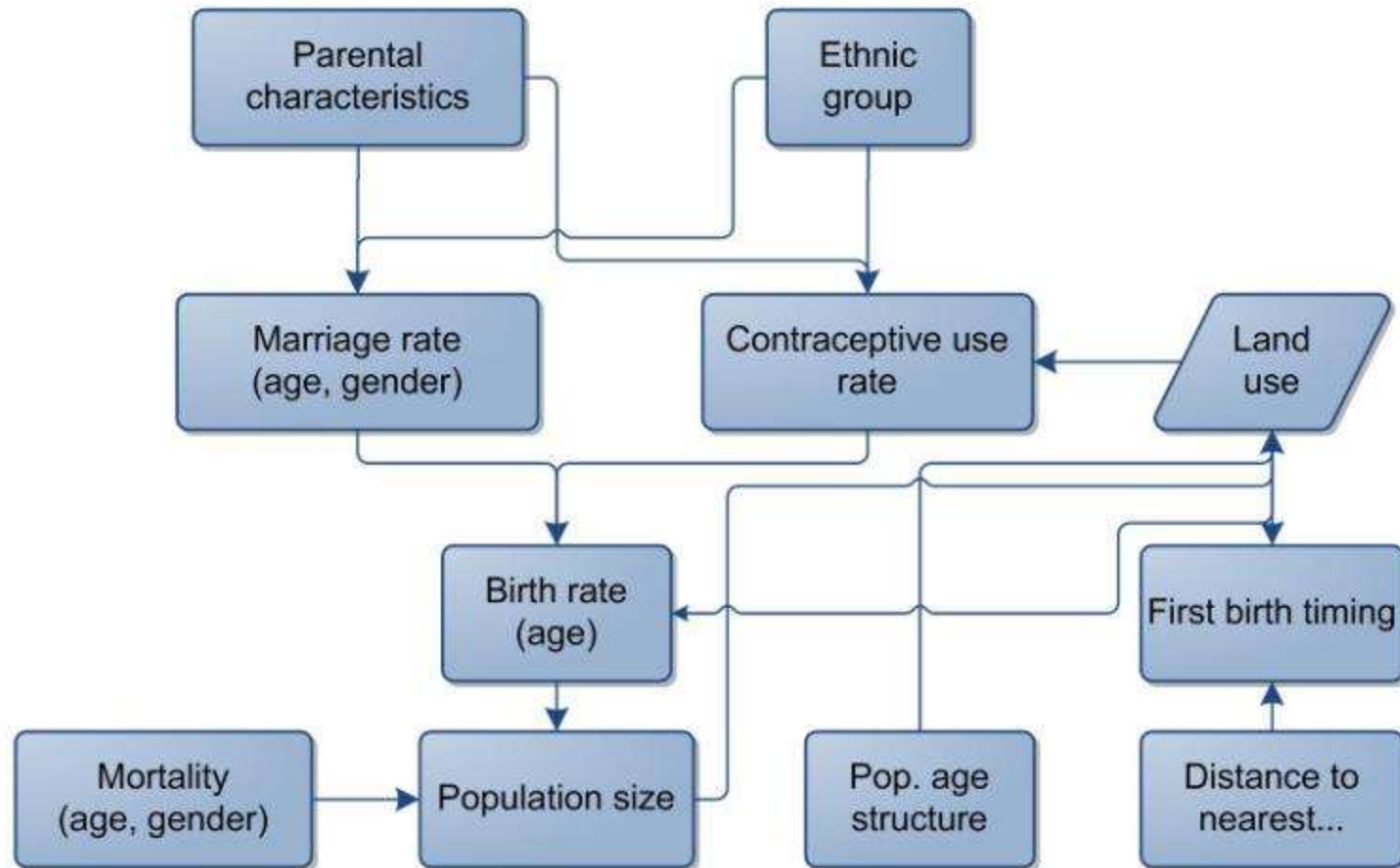
Region

- Each neighborhood is a member of a region
- Only one region in the model
- Future:
 - Multiple regions could allow variation in parameters/processes between groups of neighborhoods
 - Don't have to be spatially contiguous

The processes

- Fertility
- Marriage
- Death
- Land use change
- Household fission (still preliminary)
- Migration (still preliminary)

Conceptual model



Fertility

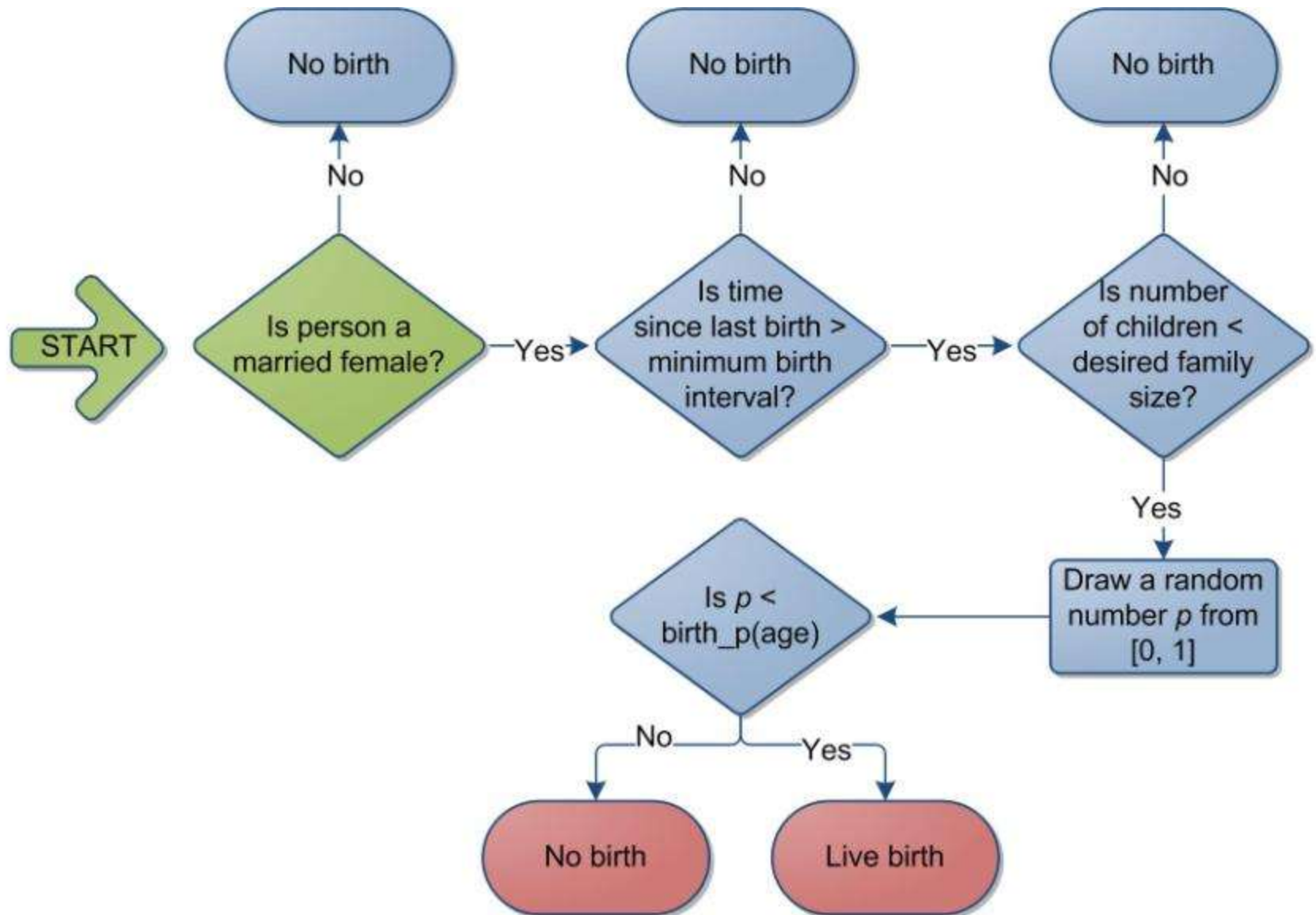
- Probability of birth calculated dependent on
 - Age
 - Ethnicity
 - Parents contraceptive use
- Each person has an intended fertility rate (taken from the CVFS data)
- Intended fertility rate is taken as an upper limit on number of children

Fertility (cont)

- Birth probability calculated over several bins:
0, 15, 16, 18, 20, 23, 26, 30, 35, 40, 45
- Probability of birth in a given bin is calculated as

$$P_{m,n} = \frac{\textit{num births}}{\textit{num psn months}}$$

- Where *num psn months* is only calculated over women > 9 months from their last birth



Marriage

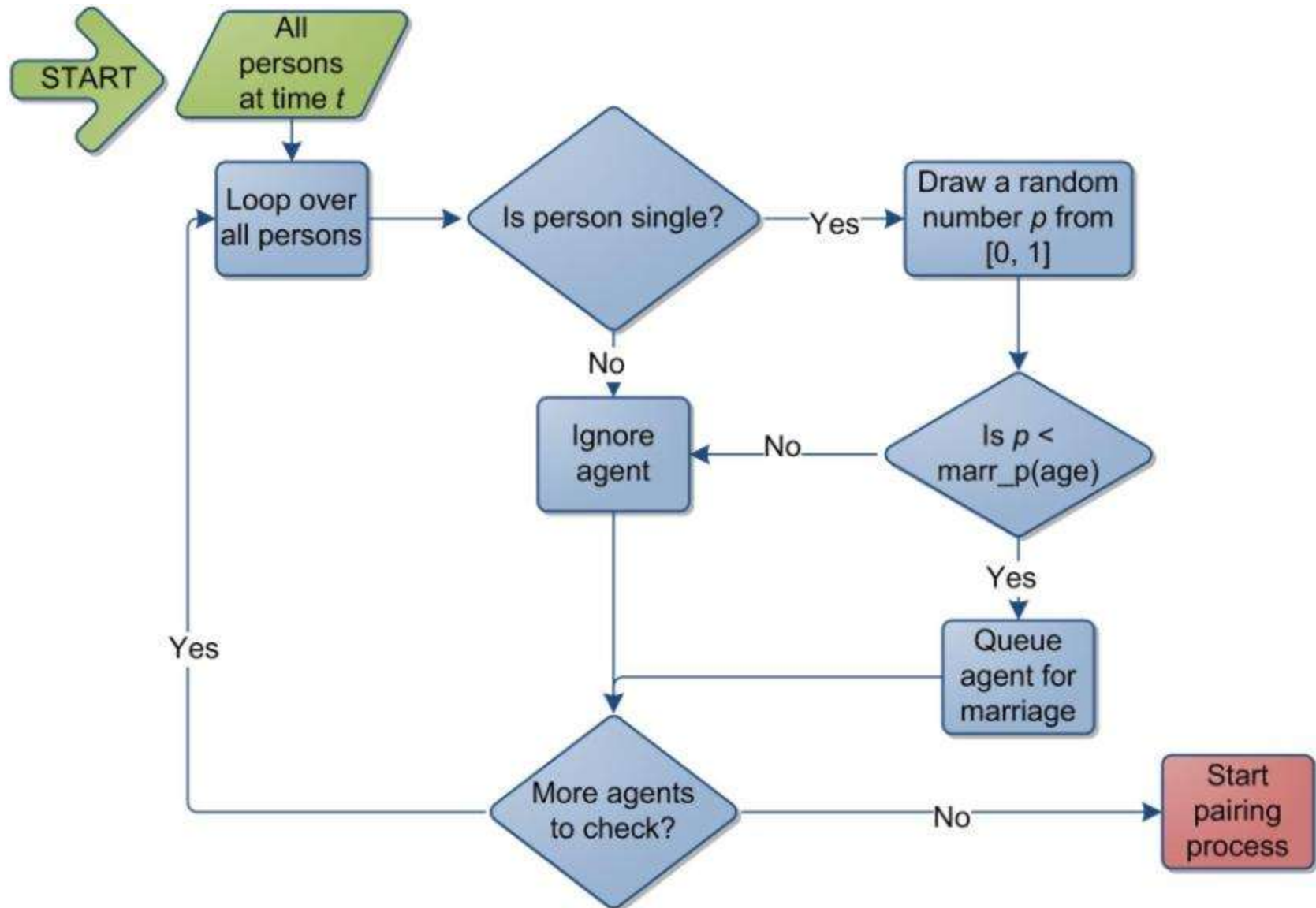
- Marriage occurs with probability based on
 - Age
 - Sex
- Marriage rate calculated over 8 bins of those eligible for marriage (all single individuals)
 - Lower limits:

0, 10, 14, 18, 22, 30, 40, 60

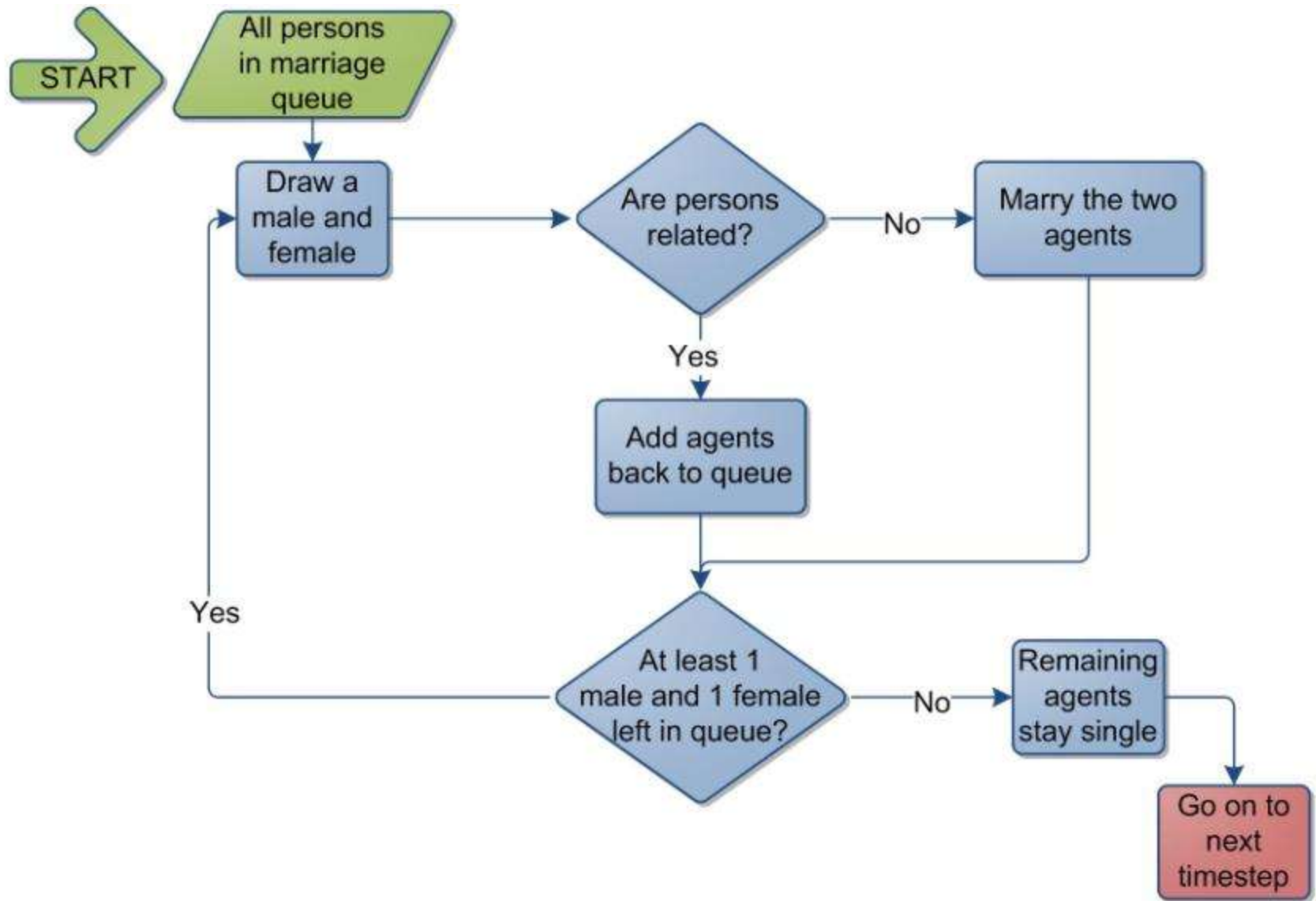
- Marriage rate is calculated for each bin as:

$$p_{m,n} = \frac{\text{num marriages}}{\text{num psn months}}$$

Marriage process (1)



Marriage process (2)



Marriage – future work

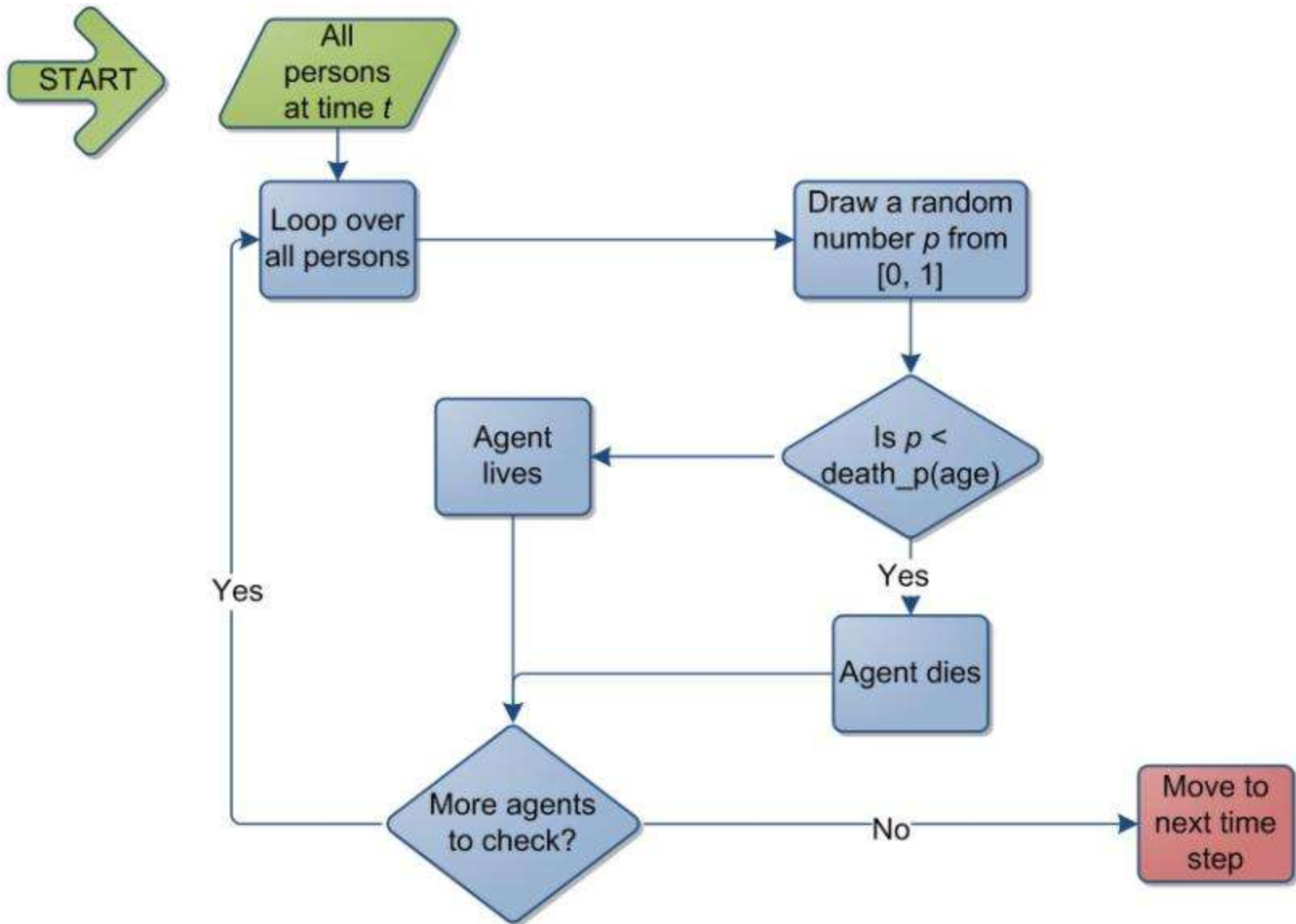
- Incorporate work of Yabiku (2006a, 2006b)
 - Tie marriage rates to:
 - Age
 - Sex
 - Ethnicity
 - Neighborhood agricultural land
 - Environmental perceptions?
 - Other controls?

Mortality

- Death occurs with a probability based on
 - Age
 - Sex
- Mortality rate calculated over 10 bins
 - Lower limits:
0, 3, 6, 12, 20, 40, 60, 80
- Probability of death per month is calculated for each bin n as:

$$p_{d,n} = \frac{\textit{num deaths}}{\textit{num psn months}}$$

Mortality process



Household fission

- Currently:
 - New households form when marriage occurs
 - Households locate (at random) within either spouse's neighborhood
- **This biases model towards smaller HH sizes**
- More work needed

Land use change

- Land use is tracked at the *neighborhood* level
- New households
 - → increase in private buildings
 - → decrease in non-agricultural vegetation
 - → decrease in agricultural vegetation

Migration

- Still preliminary
- Code exists for distant migration, but parameterization is incomplete
- Referring to Massey, Axinn and Ghimire (2007)

A POSSIBLE EXPERIMENT

A possible experiment

- Feedbacks between land-use change and fertility
 - Biddlecom, Axinn, and Barber (2005)
 - Axinn and Ghimire (2007)
 - Ghimire and Hoelter (2007)

Feedbacks: Population → LULC

- From Axinn and Ghimire (2007)
 - ↑ Younger population age structure →
 - ↑ private buildings
 - ↓ vegetation (both agricultural and non-agricultural)
 - ↑ Crude birth rate →
 - ↑ private buildings
 - ↓ vegetation (both agricultural and non-agricultural)

Feedbacks: LULC → population

- From Ghimire and Hoelter (2007)
 - ↓ Agricultural land →
 - ↑ Hazard of first birth
- From Biddlecom, Axinn, Barber (2005)
 - ↑ Dependence on public lands →
 - ↑ Family size preferences
 - ↑ Fodder collection times →
 - ↑ Family size preferences

“Verification”

- Models are never “true” (Turner)
- Model verification
 - Does code mean what I think it means?
 - Do agent attributes reflect the data?
- Future
 - Use a “jackknife” approach with HH registry data

Running the model

```
azvoleff@azvoleff-laptop: ~/Code/Python/ChitwanABM
File Edit View Terminal Help
~ $ cd ~/Code/Python/ChitwanABM/
~/Code/Python/ChitwanABM $ ./runmodel.py
No rc file found. Using parameters from rcparams.default.

*****
08/18/2009 09:59:34 PM: started model run number 20090818-215932.
*****

1996-1 | P: 9652 | TMa: 2189 | HH: 1775 | Ma: 2 | B: 20 | D: 7 | Mi: 118
1996-2 | P: 9657 | TMa: 2187 | HH: 1776 | Ma: 1 | B: 11 | D: 6 | Mi: 99
1996-3 | P: 9668 | TMa: 2185 | HH: 1778 | Ma: 2 | B: 15 | D: 4 | Mi: 104
1996-4 | P: 9678 | TMa: 2184 | HH: 1779 | Ma: 1 | B: 20 | D: 10 | Mi: 127
1996-5 | P: 9690 | TMa: 2185 | HH: 1781 | Ma: 2 | B: 13 | D: 1 | Mi: 111
1996-6 | P: 9703 | TMa: 2185 | HH: 1782 | Ma: 1 | B: 20 | D: 7 | Mi: 129
1996-7 | P: 9715 | TMa: 2185 | HH: 1785 | Ma: 3 | B: 16 | D: 4 | Mi: 118
1996-8 | P: 9721 | TMa: 2183 | HH: 1787 | Ma: 2 | B: 12 | D: 6 | Mi: 125
1996-9 | P: 9729 | TMa: 2185 | HH: 1789 | Ma: 2 | B: 11 | D: 3 | Mi: 100
1996-10 | P: 9736 | TMa: 2187 | HH: 1792 | Ma: 3 | B: 10 | D: 3 | Mi: 117
1996-11 | P: 9747 | TMa: 2188 | HH: 1795 | Ma: 3 | B: 14 | D: 3 | Mi: 121
1996-12 | P: 9758 | TMa: 2191 | HH: 1798 | Ma: 3 | B: 12 | D: 1 | Mi: 118
      TOTAL | New Ma: 22 | B: 162 | D: 54 | Mi: 1269
                        Elapsed time: 0h 0m 5s
1997-1 | P: 9767 | TMa: 2190 | HH: 1800 | Ma: 2 | B: 12 | D: 3 | Mi: 110
1997-2 | P: 9780 | TMa: 2188 | HH: 1800 | Ma: 0 | B: 16 | D: 3 | Mi: 107
1997-3 | P: 9792 | TMa: 2189 | HH: 1802 | Ma: 2 | B: 14 | D: 2 | Mi: 124
1997-4 | P: 9805 | TMa: 2190 | HH: 1805 | Ma: 3 | B: 18 | D: 5 | Mi: 109
1997-5 | P: 9821 | TMa: 2191 | HH: 1806 | Ma: 1 | B: 17 | D: 1 | Mi: 93
1997-6 | P: 9826 | TMa: 2192 | HH: 1808 | Ma: 2 | B: 8 | D: 3 | Mi: 120
1997-7 | P: 9845 | TMa: 2189 | HH: 1808 | Ma: 0 | B: 23 | D: 4 | Mi: 107
```

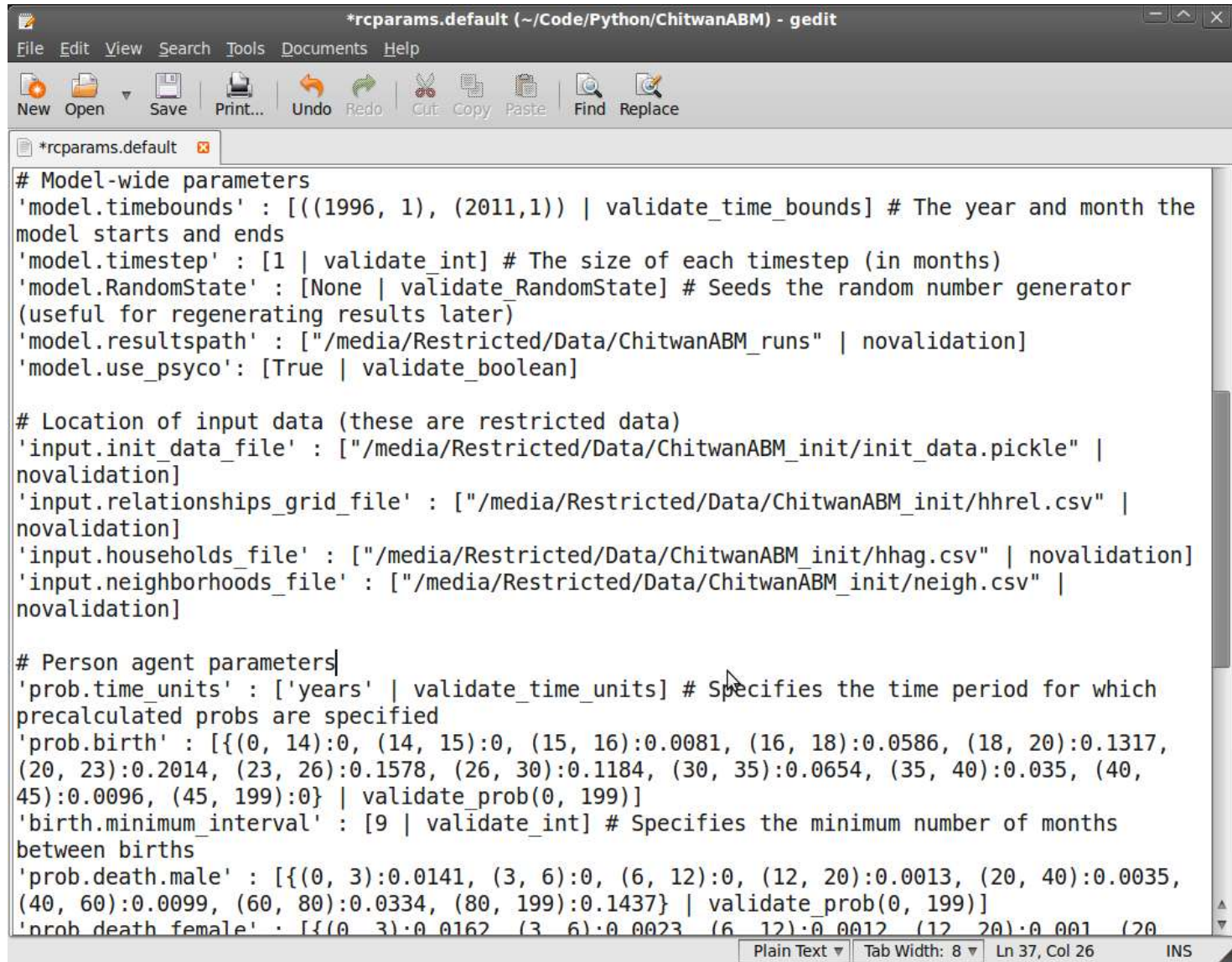
Running the model

```
azvoleff@azvoleff-laptop: ~/Code/Python/ChitwanABM
File Edit View Terminal Help
2009-5 | P: 10226 | TMa: 2236 | HH: 2344 | Ma: 6 | B: 14 | D: 5 | Mi: 150
2009-6 | P: 10227 | TMa: 2234 | HH: 2347 | Ma: 3 | B: 8 | D: 7 | Mi: 117
2009-7 | P: 10231 | TMa: 2233 | HH: 2349 | Ma: 2 | B: 9 | D: 5 | Mi: 126
2009-8 | P: 10238 | TMa: 2233 | HH: 2353 | Ma: 4 | B: 12 | D: 5 | Mi: 131
2009-9 | P: 10238 | TMa: 2234 | HH: 2359 | Ma: 6 | B: 6 | D: 6 | Mi: 135
2009-10 | P: 10241 | TMa: 2235 | HH: 2364 | Ma: 5 | B: 8 | D: 5 | Mi: 137
2009-11 | P: 10242 | TMa: 2240 | HH: 2370 | Ma: 6 | B: 3 | D: 2 | Mi: 138
2009-12 | P: 10239 | TMa: 2237 | HH: 2375 | Ma: 5 | B: 9 | D: 12 | Mi: 123
      TOTAL | New Ma: 54 | B: 90 | D: 71 | Mi: 1603
                        Elapsed time: 0h 1m 29s
2010-1 | P: 10240 | TMa: 2238 | HH: 2380 | Ma: 5 | B: 6 | D: 5 | Mi: 129
2010-2 | P: 10243 | TMa: 2240 | HH: 2384 | Ma: 4 | B: 8 | D: 5 | Mi: 117
2010-3 | P: 10250 | TMa: 2245 | HH: 2393 | Ma: 9 | B: 11 | D: 4 | Mi: 122
2010-4 | P: 10251 | TMa: 2248 | HH: 2402 | Ma: 9 | B: 8 | D: 7 | Mi: 133
2010-5 | P: 10251 | TMa: 2248 | HH: 2406 | Ma: 4 | B: 6 | D: 6 | Mi: 142
2010-6 | P: 10251 | TMa: 2251 | HH: 2412 | Ma: 6 | B: 5 | D: 5 | Mi: 144
2010-7 | P: 10246 | TMa: 2253 | HH: 2419 | Ma: 7 | B: 4 | D: 9 | Mi: 120
2010-8 | P: 10246 | TMa: 2255 | HH: 2422 | Ma: 3 | B: 4 | D: 4 | Mi: 151
2010-9 | P: 10243 | TMa: 2257 | HH: 2429 | Ma: 7 | B: 6 | D: 9 | Mi: 122
2010-10 | P: 10241 | TMa: 2255 | HH: 2431 | Ma: 2 | B: 5 | D: 7 | Mi: 124
2010-11 | P: 10240 | TMa: 2253 | HH: 2436 | Ma: 5 | B: 8 | D: 9 | Mi: 123
2010-12 | P: 10231 | TMa: 2247 | HH: 2441 | Ma: 5 | B: 9 | D: 18 | Mi: 141

*****
08/18/2009 10:01:11 PM: finished model run number 20090818-215932.
*****

Saving results... done.
~/Code/Python/ChitwanABM $
```

Running the model

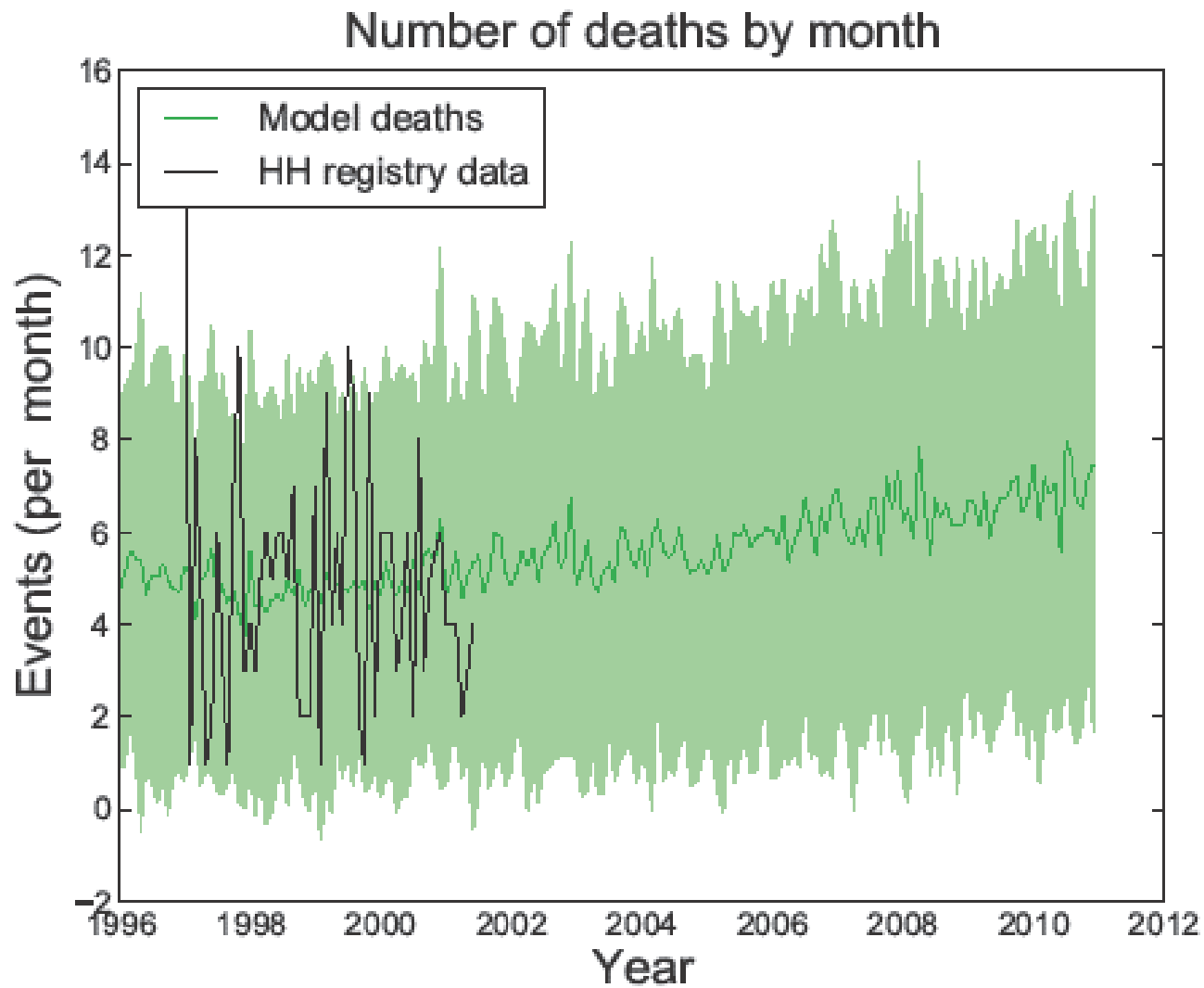


The screenshot shows a Gedit window titled '*rcparams.default (~/Code/Python/ChitwanABM) - gedit'. The window contains a Python dictionary of model parameters. The parameters are organized into sections: Model-wide parameters, Location of input data, and Person agent parameters. The Model-wide parameters section includes 'model.timebounds', 'model.timestep', 'model.RandomState', 'model.resultspath', and 'model.use_psyco'. The Location of input data section includes 'input.init_data_file', 'input.relationships_grid_file', 'input.households_file', and 'input.neighborhoods_file'. The Person agent parameters section includes 'prob.time_units', 'prob.birth', 'birth.minimum_interval', 'prob.death.male', and 'prob.death.female'. The parameters are defined as lists of tuples representing time intervals and probabilities, with some parameters having validation functions like 'validate_time_bounds', 'validate_int', 'validate_prob', and 'validate_boolean'.

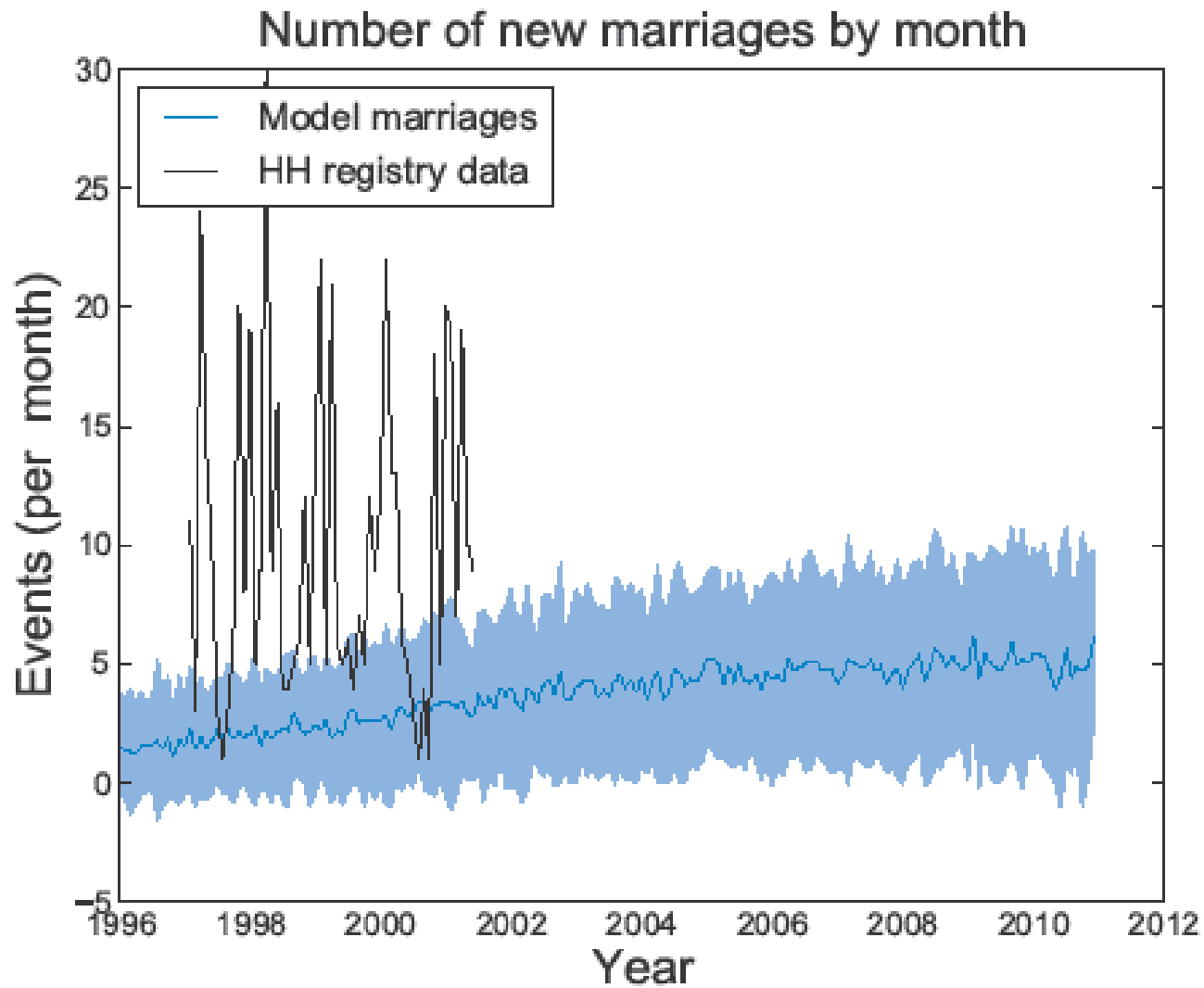
```
# Model-wide parameters
'model.timebounds' : [((1996, 1), (2011,1)) | validate_time_bounds] # The year and month the
model starts and ends
'model.timestep' : [1 | validate_int] # The size of each timestep (in months)
'model.RandomState' : [None | validate_RandomState] # Seeds the random number generator
(useful for regenerating results later)
'model.resultspath' : ["/media/Restricted/Data/ChitwanABM_runs" | novalidation]
'model.use_psyco': [True | validate_boolean]

# Location of input data (these are restricted data)
'input.init_data_file' : ["/media/Restricted/Data/ChitwanABM_init/init_data.pickle" |
novalidation]
'input.relationships_grid_file' : ["/media/Restricted/Data/ChitwanABM_init/hhrel.csv" |
novalidation]
'input.households_file' : ["/media/Restricted/Data/ChitwanABM_init/hhag.csv" | novalidation]
'input.neighborhoods_file' : ["/media/Restricted/Data/ChitwanABM_init/neigh.csv" |
novalidation]

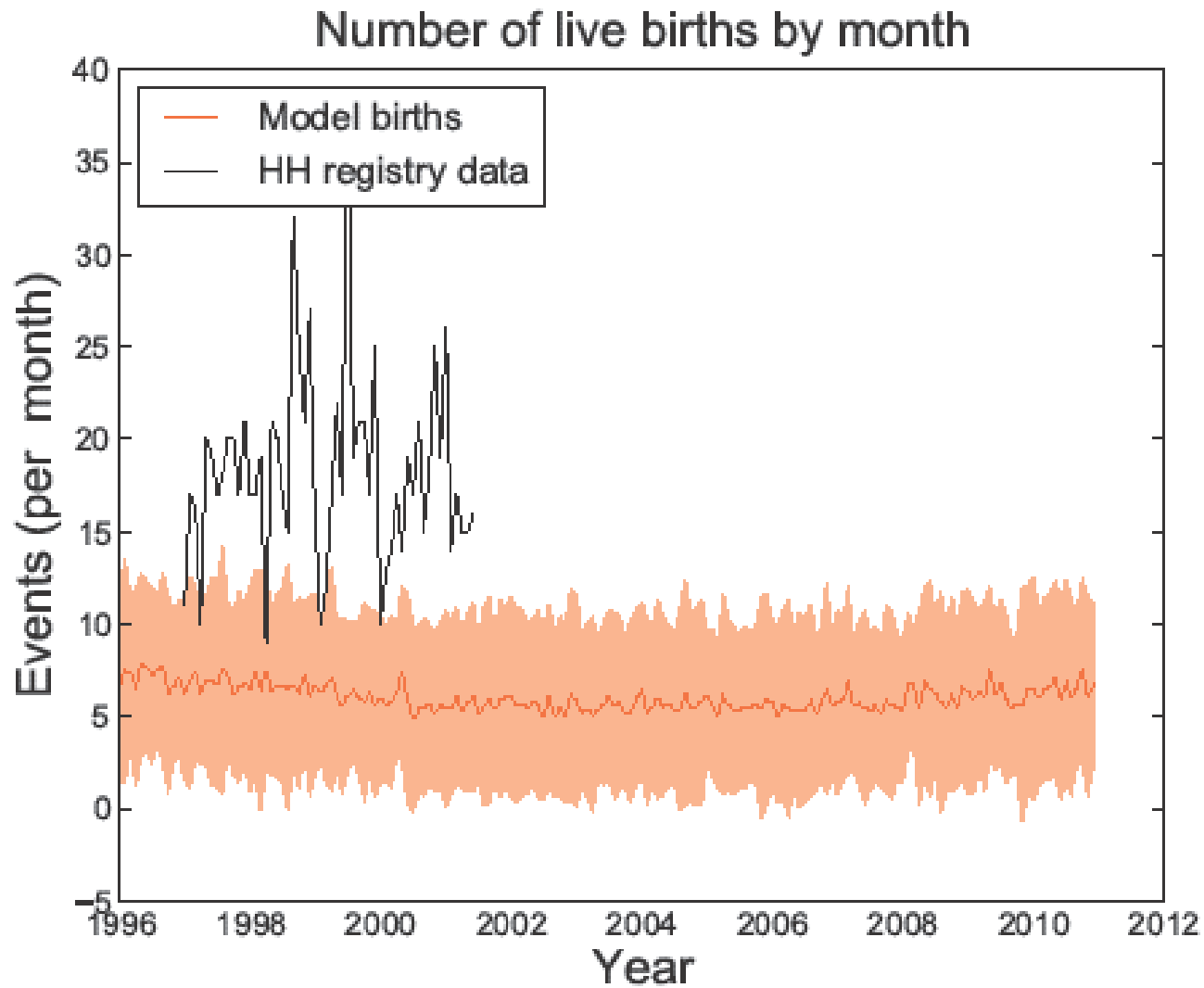
# Person agent parameters
'prob.time_units' : ['years' | validate_time_units] # Specifies the time period for which
precalculated probs are specified
'prob.birth' : [{(0, 14):0, (14, 15):0, (15, 16):0.0081, (16, 18):0.0586, (18, 20):0.1317,
(20, 23):0.2014, (23, 26):0.1578, (26, 30):0.1184, (30, 35):0.0654, (35, 40):0.035, (40,
45):0.0096, (45, 199):0} | validate_prob(0, 199)]
'birth.minimum_interval' : [9 | validate_int] # Specifies the minimum number of months
between births
'prob.death.male' : [{(0, 3):0.0141, (3, 6):0, (6, 12):0, (12, 20):0.0013, (20, 40):0.0035,
(40, 60):0.0099, (60, 80):0.0334, (80, 199):0.1437} | validate_prob(0, 199)]
'prob.death.female' : [{(0, 3):0.0162, (3, 6):0.0023, (6, 12):0.0012, (12, 20):0.001, (20,
```



Running the model - output



Running the model - output



Technical notes

- Model is coded in Python
- Requires no special software to run
- Changing parameters is simple
- Shapefile output possible
- Available online:
 - <http://rohan.sdsu.edu/~zvoleff>
- Data confidentiality?

Thank you.

LUNCH!

CONTROLS – WHAT TO INCLUDE?

Selection of controls

- Fertility
 - First birth timing
 - Family size preferences
- Marriage age
 - Yabiku (2006, 2007), Pierce (2000)
- New household formation

Fertility: first birth timing + environment

Possible controls

(Ghimire and Hoelter, 2007; Ghimire and Axinn, 2008)

- Land use under agriculture
- Non family services
- Parental characteristics
 - Number of children
 - Education
 - Work
 - Contraceptive use
- Ethnicity
- Marriage duration
- Schooling
- Media exposure
- Contraceptive use

Fertility: family size preference

Possible controls (Biddlecom, Axinn and Barber, 2005)

- Environmental measures
 - Time to coll. wood
 - Time to coll. wood has inc. (+)
 - Time to coll. fodder
 - Time to coll. fodder has inc.
 - Wood is from public land (*)
 - Fodder is from public land
- Indiv. level controls
 - Age group (***)
 - Age at first marriage
 - Yrs of school before marr. (**)
 - Ever used contraception (**)
 - Num. of living male child. (**)
- Household level controls
 - Own home (*)

+P<.10, *P<.05, **P<.01, ***P<.001

Marriage timing

Possible controls (Yabiku, 2006)

- Neighborhood ag. Land
 - Wage labor**
- Distance to NFOs
 - Years schooling completed
 - Enrolled in school**
- School
- Health post
- Bus stop
- Market
- Employer
- % opp. sex single in neigh.
- Born in current neigh?
- Sex**
- Ethnicity
- Age**
- Age-squared**
- Non family activities
 - Salaried job
 - Family owned business

*P<.05, **P<.01, ***P<.001, two tailed tests

Migration

Possible controls (Massey, Axinn, and Ghimire, 2007) (19)

- Age
- Sex (sep. models)
- Distant vs. local moves
- Environmental conditions
 - Perceived prod. decline
 - Share of neighborhood green
 - Time to collect firewood
- Human capital
 - Years of schooling
 - Currently have a wage job
 - Currently have a salaried job
- Social capital
 - Household network tie
 - Neighborhood prevalence
- Age (birth cohort)
- Physical capital
 - Farmland
 - Livestock
 - House plot owned
 - Home quality
- Ethnicity
- Time

All $P < .05$ in *at least one* model

Household fission

Possible controls (no previous work?)

- Any ideas from Monday 8/19 discussion led by Lisa Pierce?

References

- Axinn, W. G. & Ghimire, D. (2007), 'Social Organization, Population, and Land Use'(07-617), Technical report, University of Michigan.
- Biddlecom, A. E.; Axinn, W. G. & Barber, J. S. (2005), 'Environmental Effects on Family Size Preferences and Subsequent Reproductive Behavior in Nepal', *Population & Environment* **26**(3), 583--621.
- Ghimire, D. J. & Axinn, W. G. (2008), 'Social Organization, Land Use, and First Birth', Technical report, University of Michigan.
- Massey, D.; Axinn, W. & Ghimire, D. (2007), 'Environmental Change and Out-Migration: Evidence from Nepal'(07-615), Technical report, University of Michigan.
- Yabiku, S. (2006), 'Land Use and Marriage Timing in Nepal', *Population & Environment* **27**(5), 445--461.
- Yabiku, S. (2006), 'Neighbors and neighborhoods: effects on marriage timing', *Population Research and Policy Review* **25**(4), 305--327.

Acknowledgement

- San Diego State University
- Institute of Social Research, University of Michigan
- NSF PIRE Grant

Thank you! Questions?