

Multistate Demography with R?

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World Population Program - IIASA

Definition

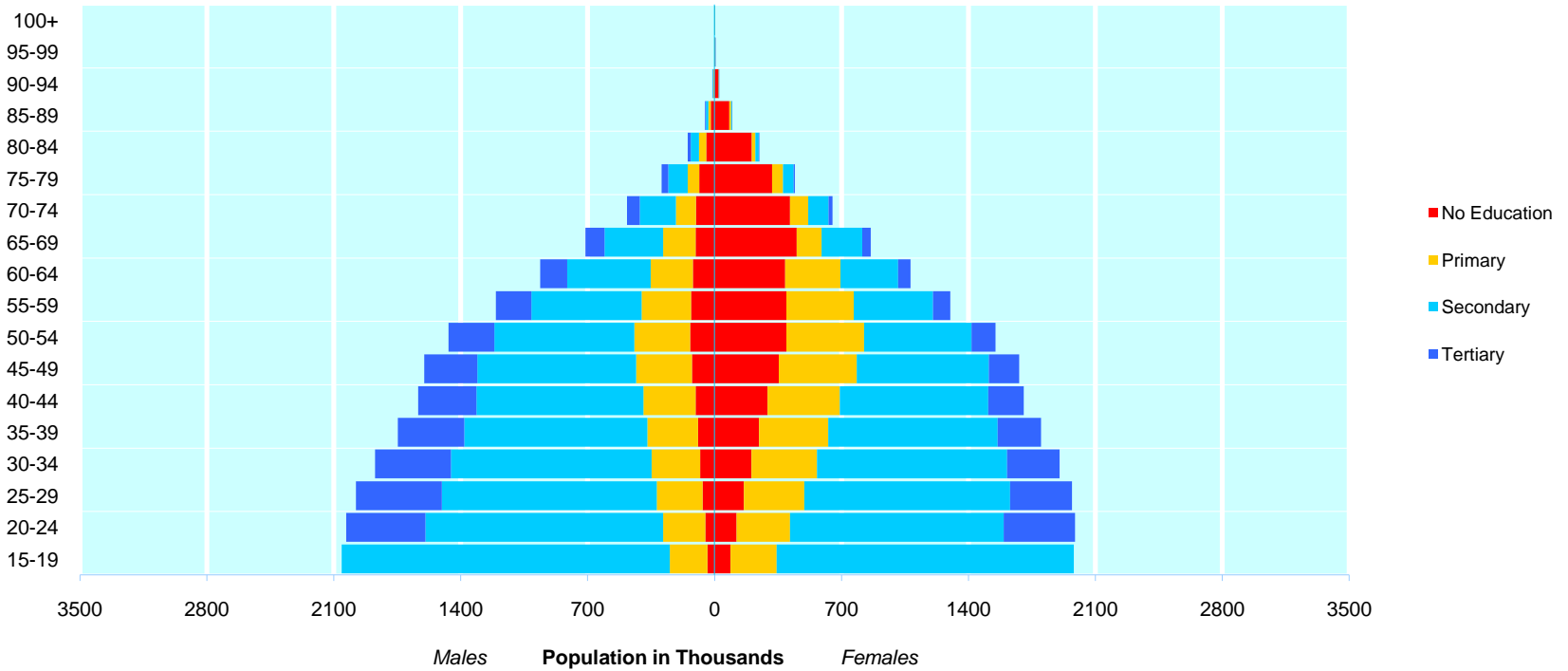
- the study of populations stratified by age, sex, and one or several attributes such as
 - region of residence
 - marital status
 - number of children
 - living arrangement
 - employment status
 - Occupation
 - **Religion**
 - **Educational Attainment**
 - **Health Status / Disease states**

Definition

- A population that is stratified is a multistate population,
- and people who occupy the same state constitute a subpopulation
- the dynamics of multistate populations are governed by
 - differential fertility and mortality (and migration)
 - the transfer of individuals between subpopulations.

Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2045 - Global Education Trend - Scenario



History

- pioneered by **Andrei Rogers** in the **1960s and 1970s (at IIASA)**
 - a **multiregional system** (Demography in 1966) and in book form in 1975.
 - **systems of simultaneous linear equations**, conveniently represented in **matrix notation**.
- broadening of multiregional demography into multistate demography was triggered by **Robert Schoen's**
 - by **marital status** (Schoen 1975).

History

- **Philip Rees** developed an **accounting system for multiregional populations**, pursuing some ideas from Rogers and having been influenced by earlier work of the economist **Richard Stone (1913–1991)**, who initiated economic and social accounting in the early 1960s (Rees and Wilson, 1977).
- **Accounts**—in this case comprising population stocks and flows—have a great advantage: They must balance. **Differences** in data type, inconsistencies, and other data problems are **easily identified**. From their beginning, multistate models followed the accounting tradition prevailing in demography and the actuarial sciences.

History

- Multistate models, and in particular the **multistate life table**, however, could also be viewed as **applications of mathematical statistics**, based in probability theory. Supporters of this perspective—**Jan M. Hoem, Michael T. Hannan**, and others—identified common features of the questions demographers try to answer using the life table and those addressed in the fields of survival analysis and event-history analysis with their focus on **models of duration dependence**. **Age** is viewed as a duration variable. The two distinct traditions persist (see Bogue et al. 1993, Chapters 21-22 for an accessible introduction).

Multistate Model

- At any point in time, an individual occupies a **state**, and
- the distribution of people over the various states determines **the population structure**.
- **State occupancies** change over time as a result of
 - **interstate transitions** people experience and
 - **differential entries** from and **exits** to the rest of the world.

Life Table and Projection Model

- **The multistate life table** describes how the size and composition of a (synthetic) cohort change over time.
- **Multistate projection models** describe how the population structure (**stock**) at a given time depends on the initial population and the transitions people make (**flows**).

Transition Rates and Probabilities

- The **dynamics** of a multistate population—a cohort or an age-graded population—are based on **transition rates** and **transition probabilities**.
- **Rates** relate the number of transitions people make to **the *duration* at risk** of a transition.
- **Probabilities** relate transitions to **the *population* at risk at the beginning** of an interval.

Censoring and Risk Set

- Transition rates and transition probabilities are **estimated** from the data.
- The **estimation of probabilities** directly from the data is complicated in the presence of **censoring** (i.e., if individuals enter or leave the population during the period of observation for a reason unrelated to the transitions being studied).
- In survival analysis, the concept of ***risk set*** has been introduced to distinguish the population at risk of experiencing an event during an interval from the population present at the beginning of that interval.

Converting Rates into Probabilities

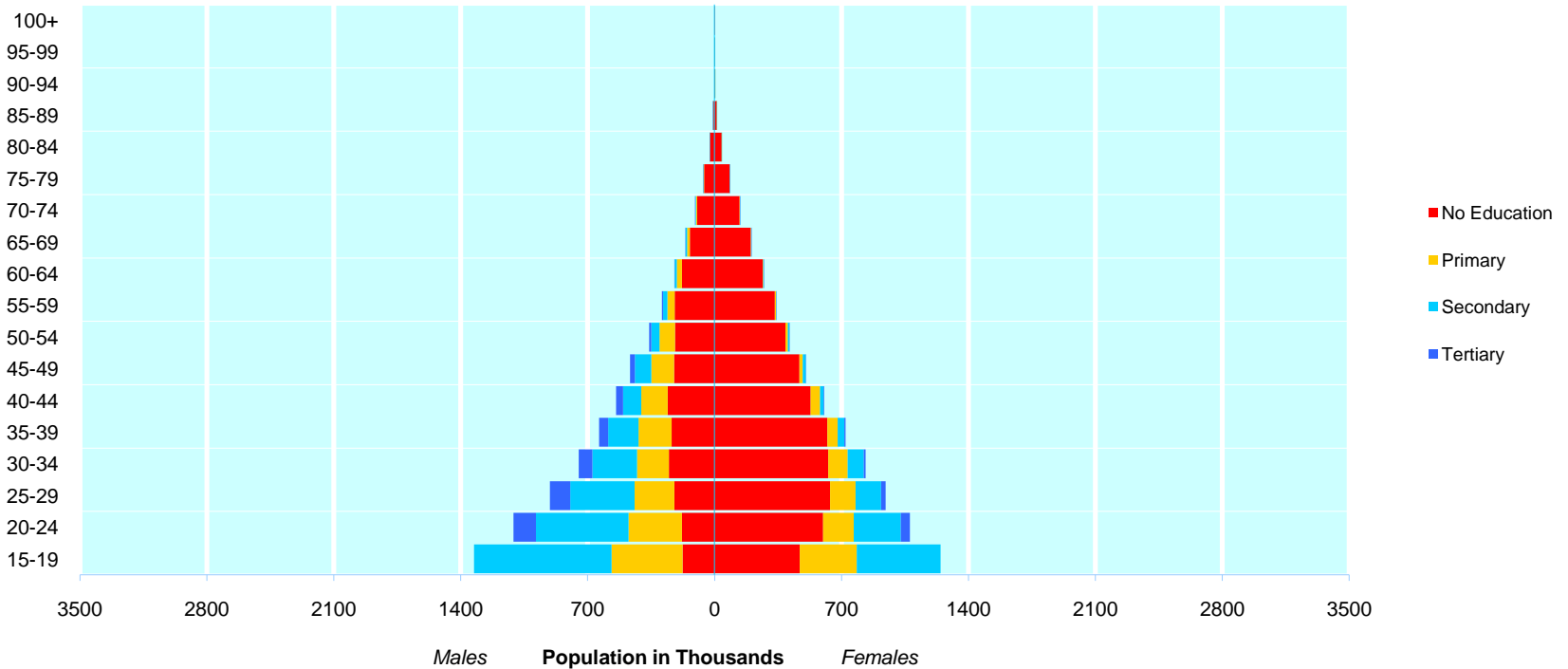
- The estimation of rates does not present that problem since the transitions are related to the time spent in the origin state during the interval.
- In this approach, people may enter and/or leave a state during an interval.
- Transition rates must be **converted** into probabilities.
- The task is straightforward if the rates vary between age intervals but not within age intervals, or when the transitions that occur during an interval are **uniformly distributed**.

Examples:

- Multistate cohort component projection
- By Age, Sex and Education
- By Age, Sex and Religion
- By Age, Sex, Education, Health Status
(ongoing)

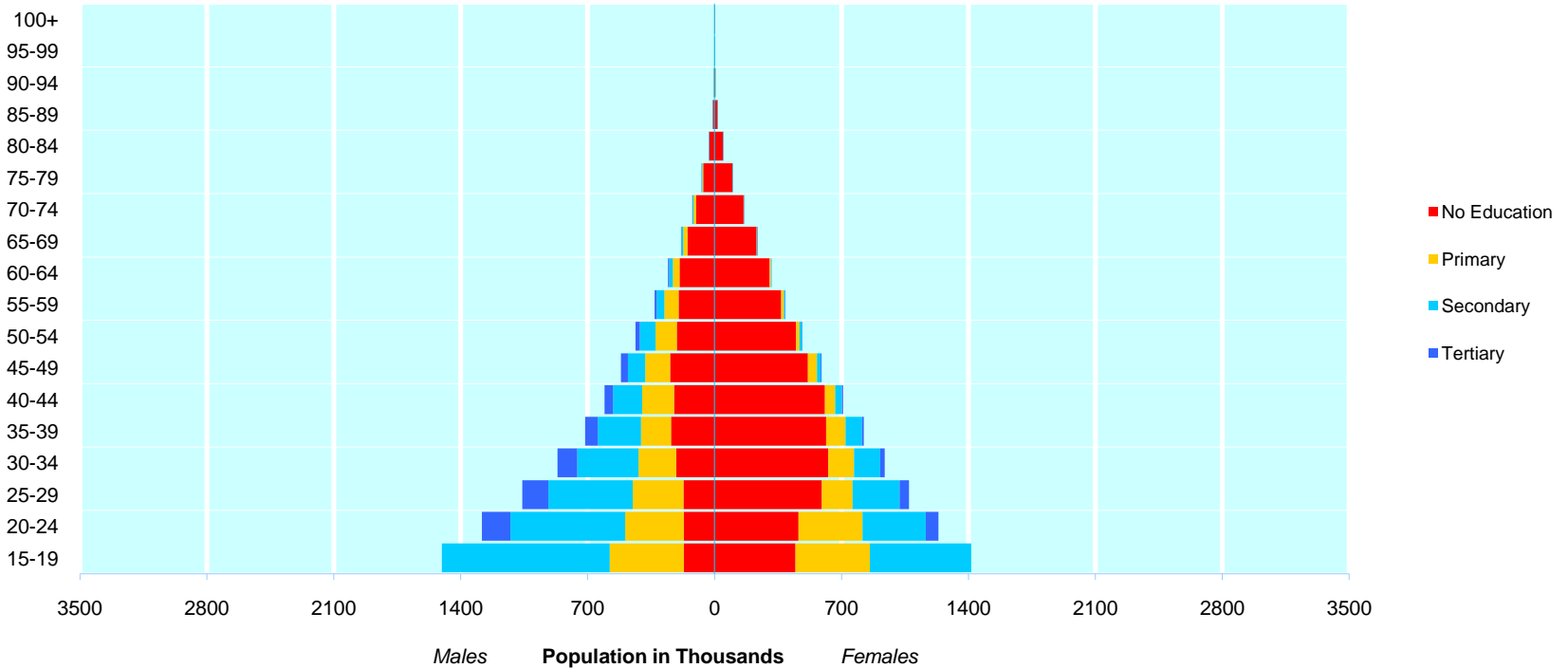
Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2000 - Global Education Trend - Scenario



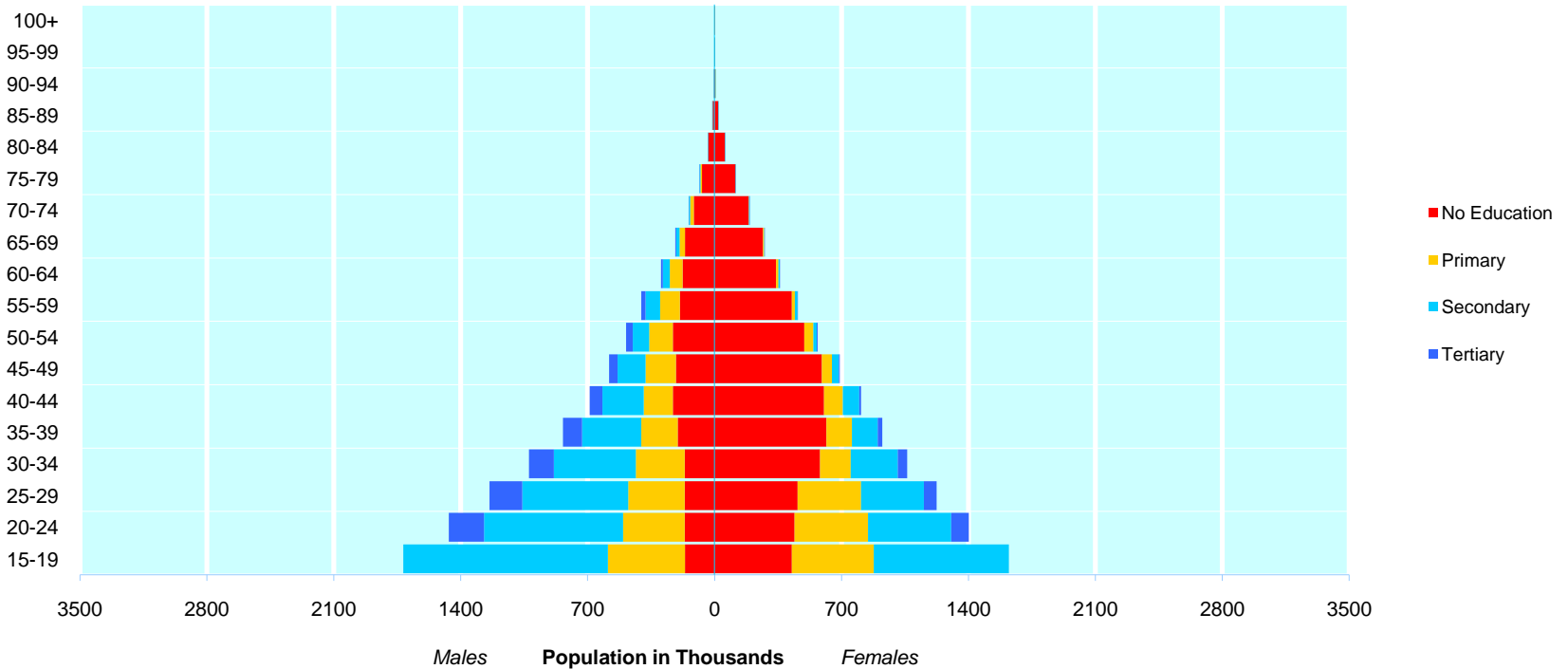
Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2005 - Global Education Trend - Scenario



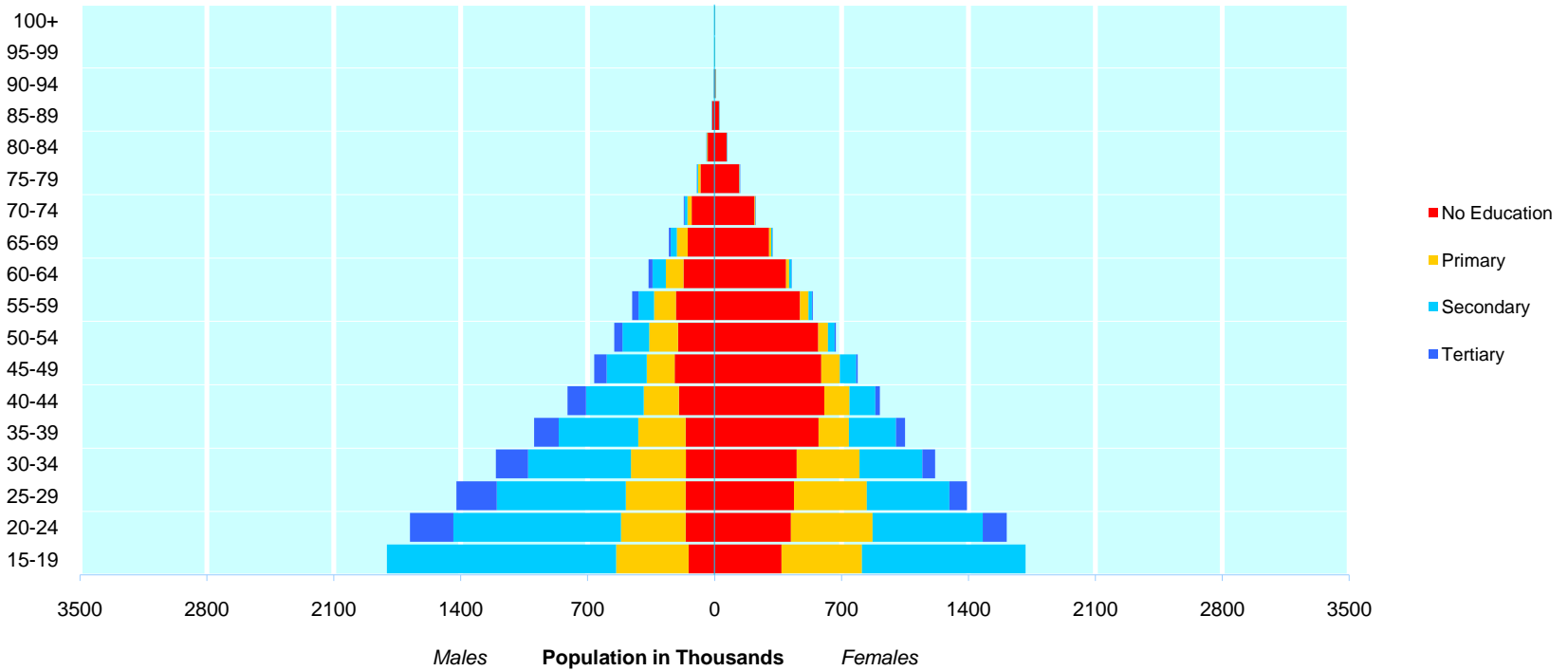
Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2010 - Global Education Trend - Scenario



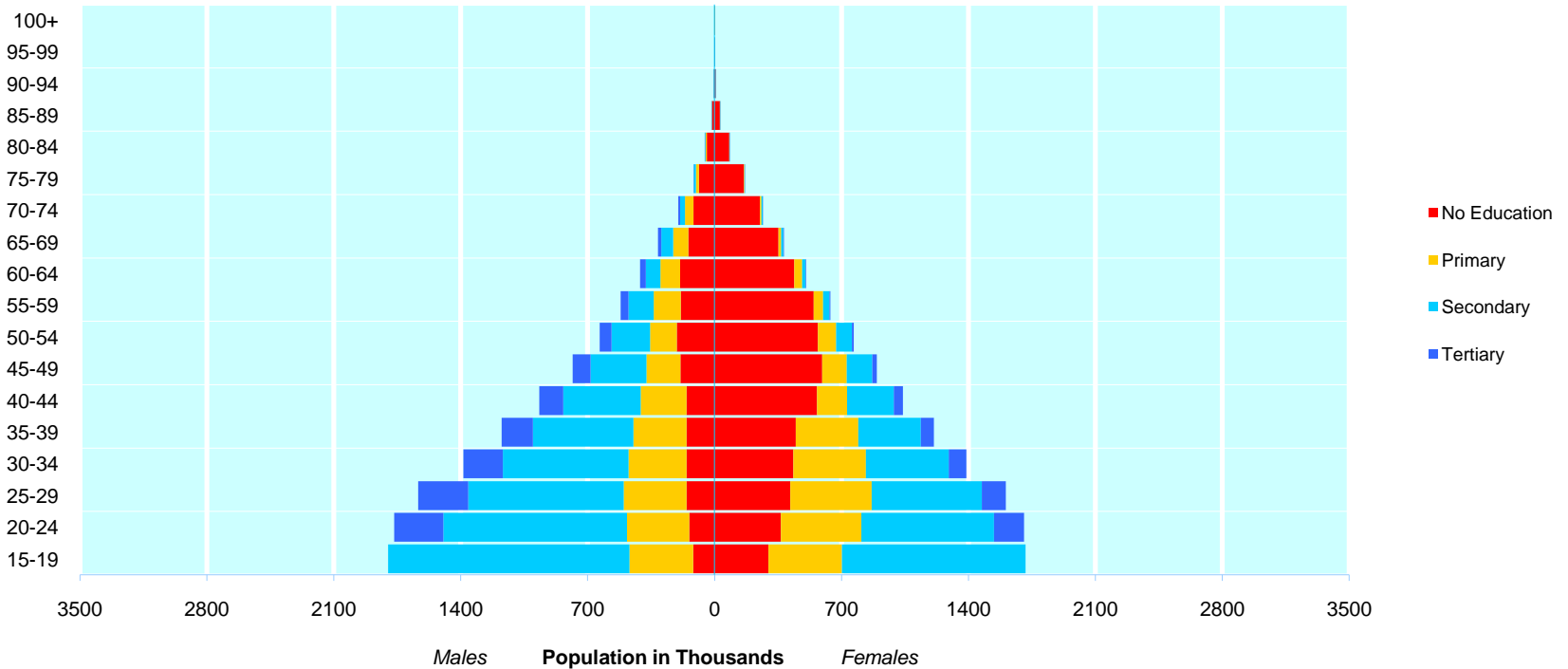
Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2015 - Global Education Trend - Scenario



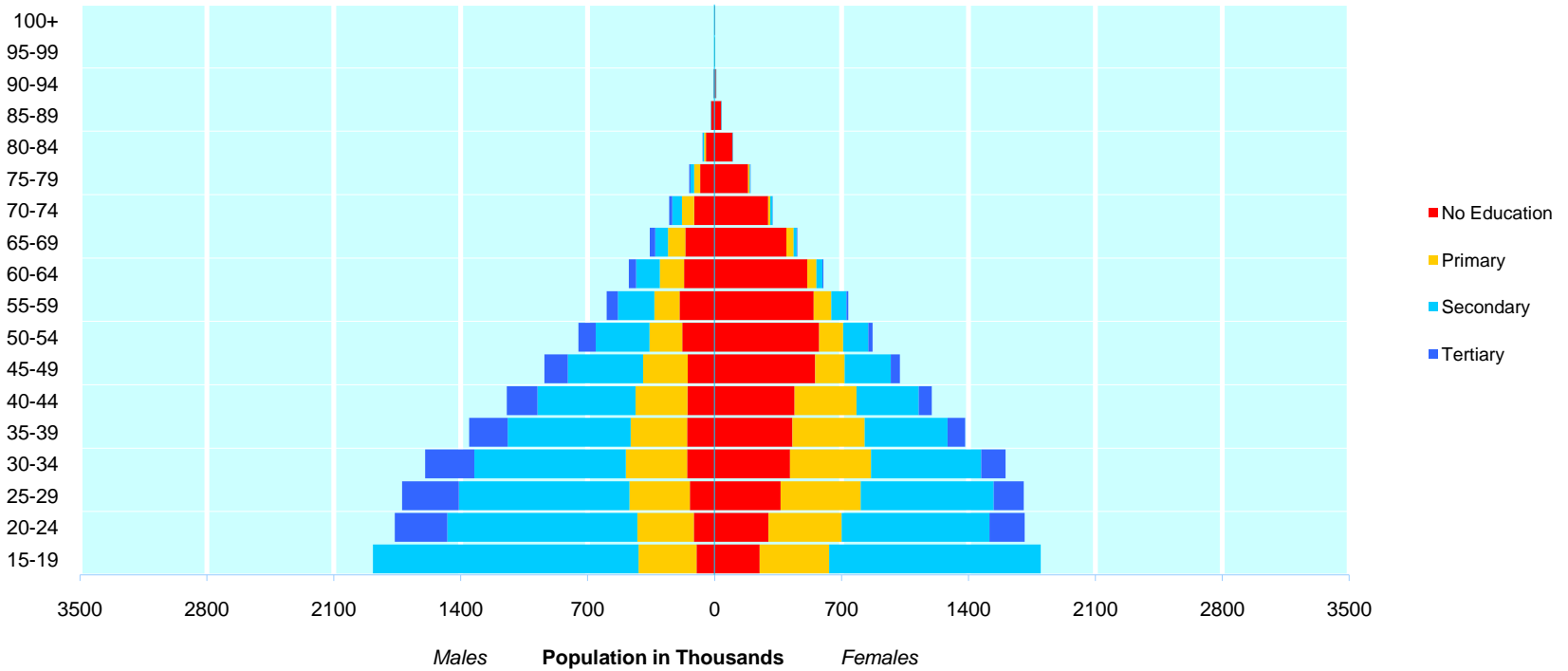
Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2020 - Global Education Trend - Scenario



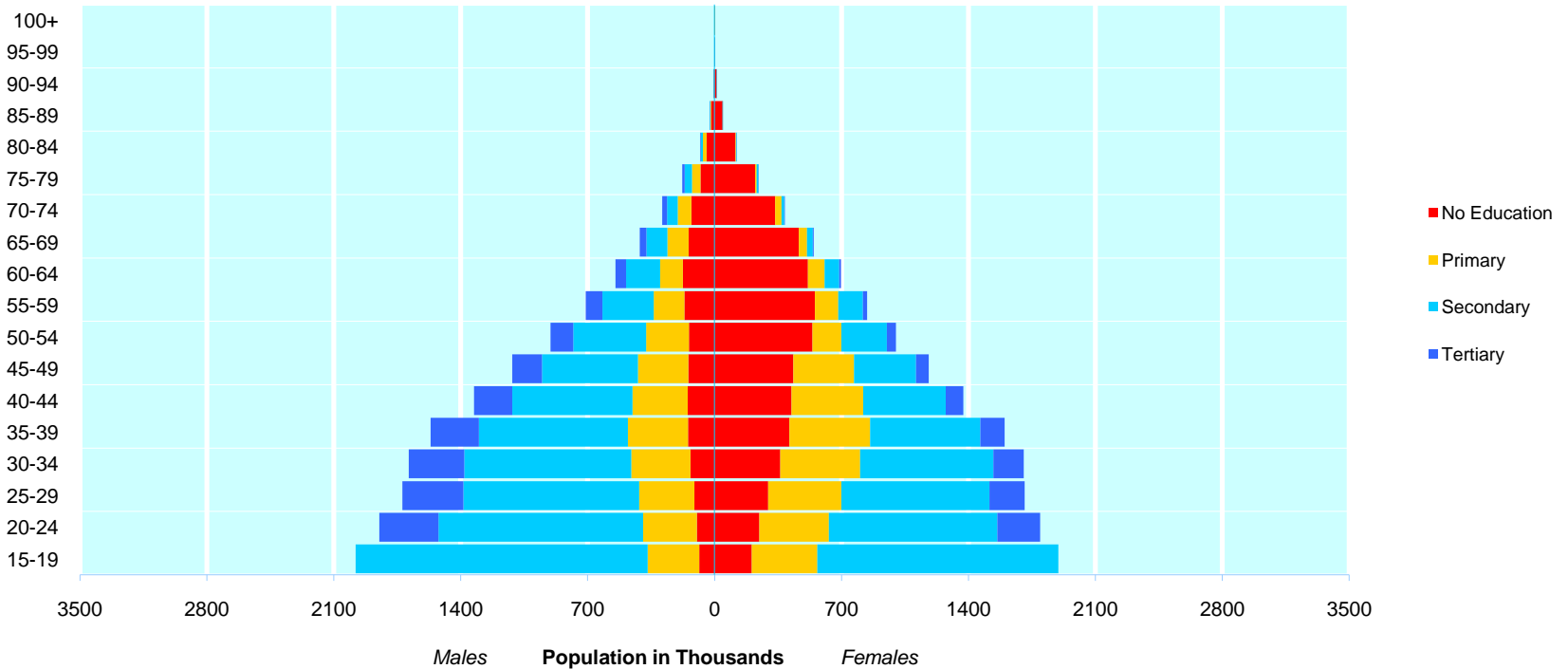
Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2025 - Global Education Trend - Scenario



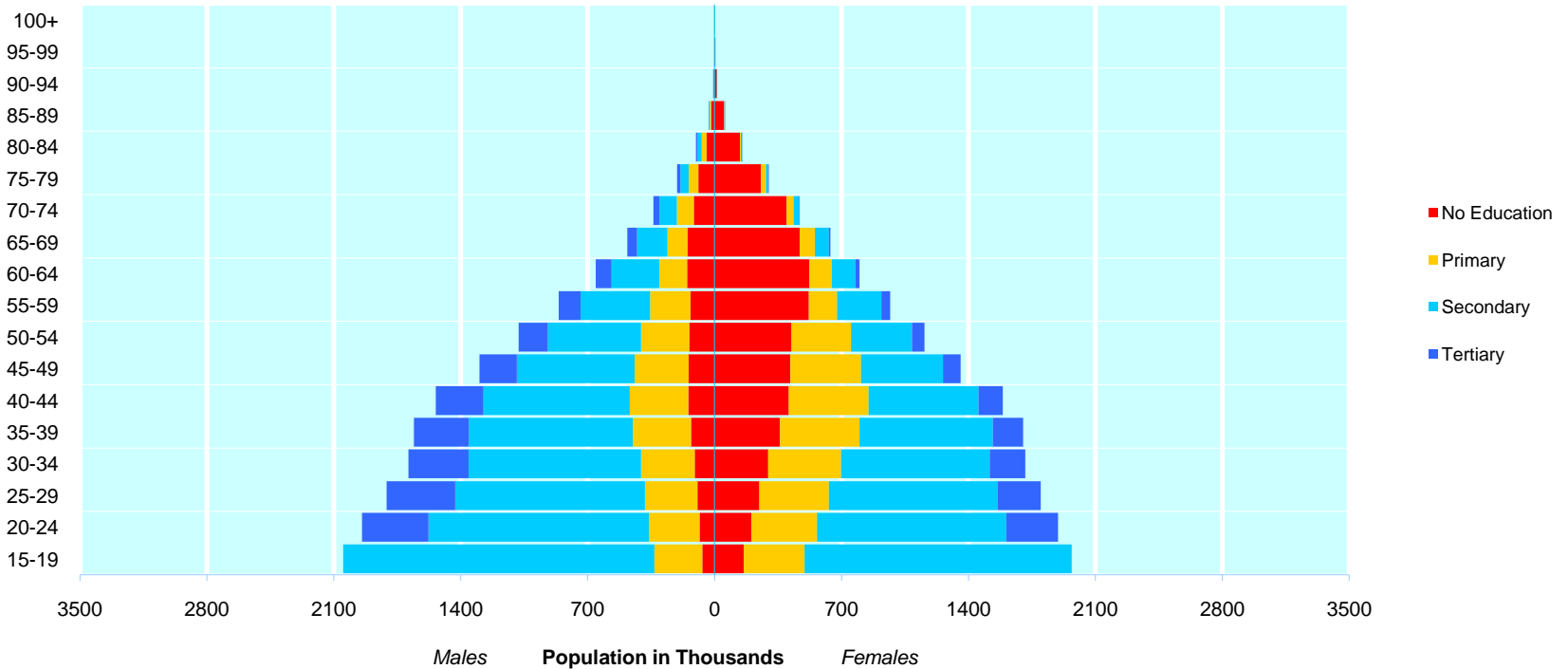
Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2030 - Global Education Trend - Scenario



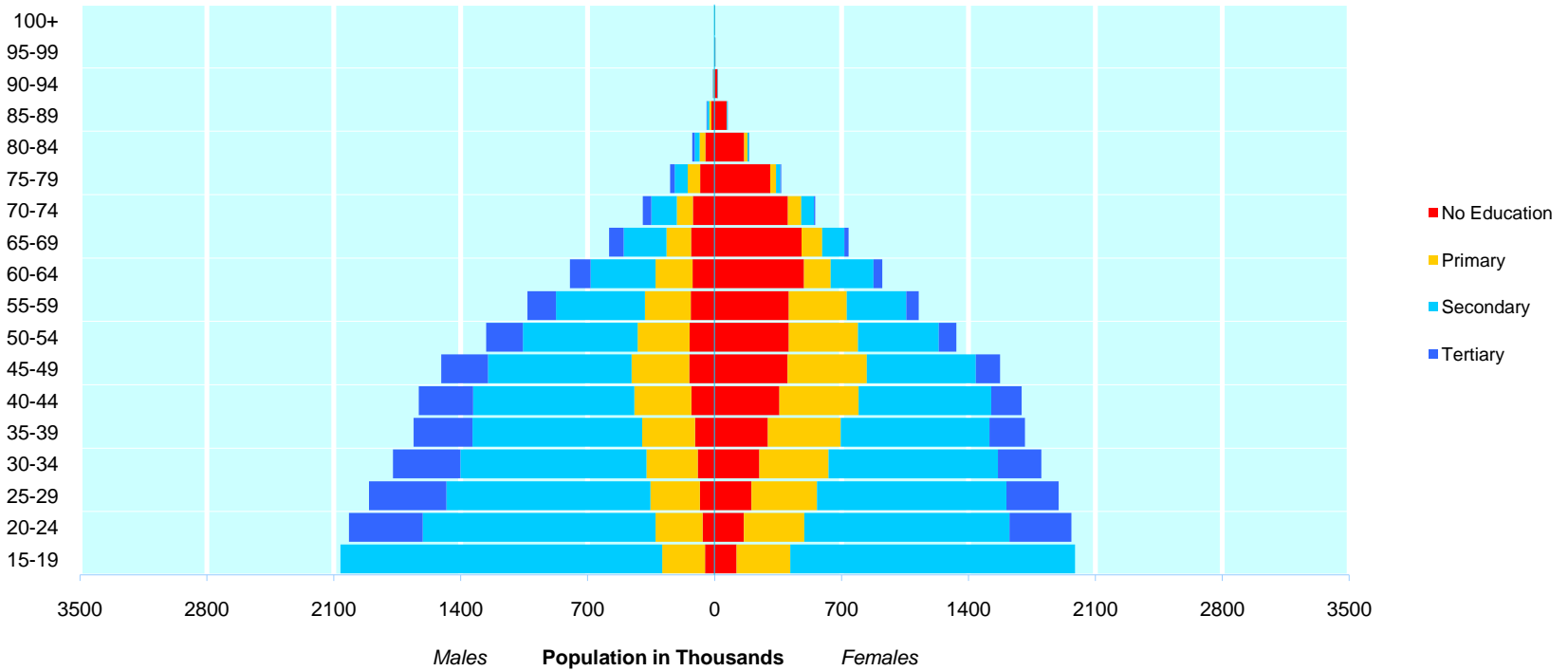
Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2035 - Global Education Trend - Scenario



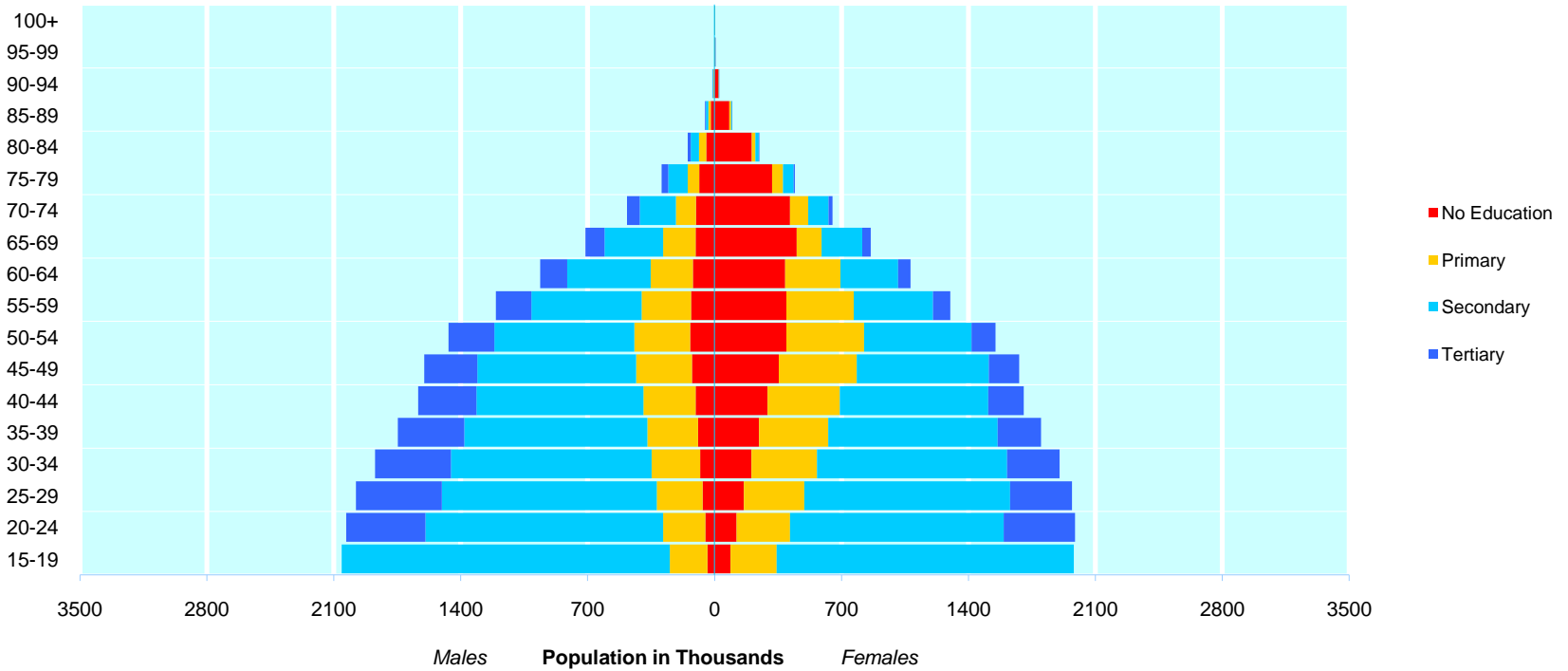
Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2040 - Global Education Trend - Scenario

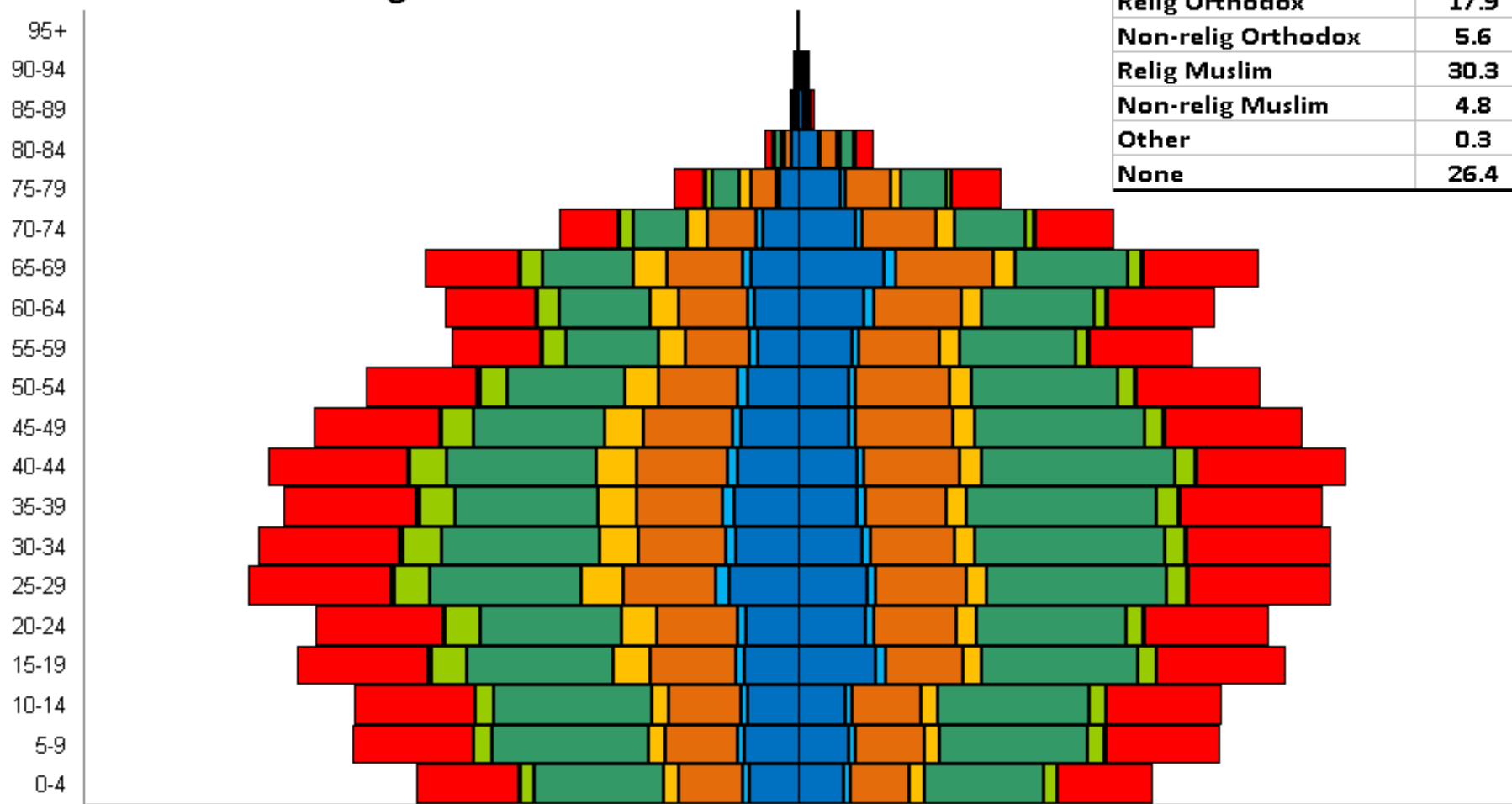


Projection Result

Nepal - Population by Age, Sex and Educational Attainment in 2045 - Global Education Trend - Scenario



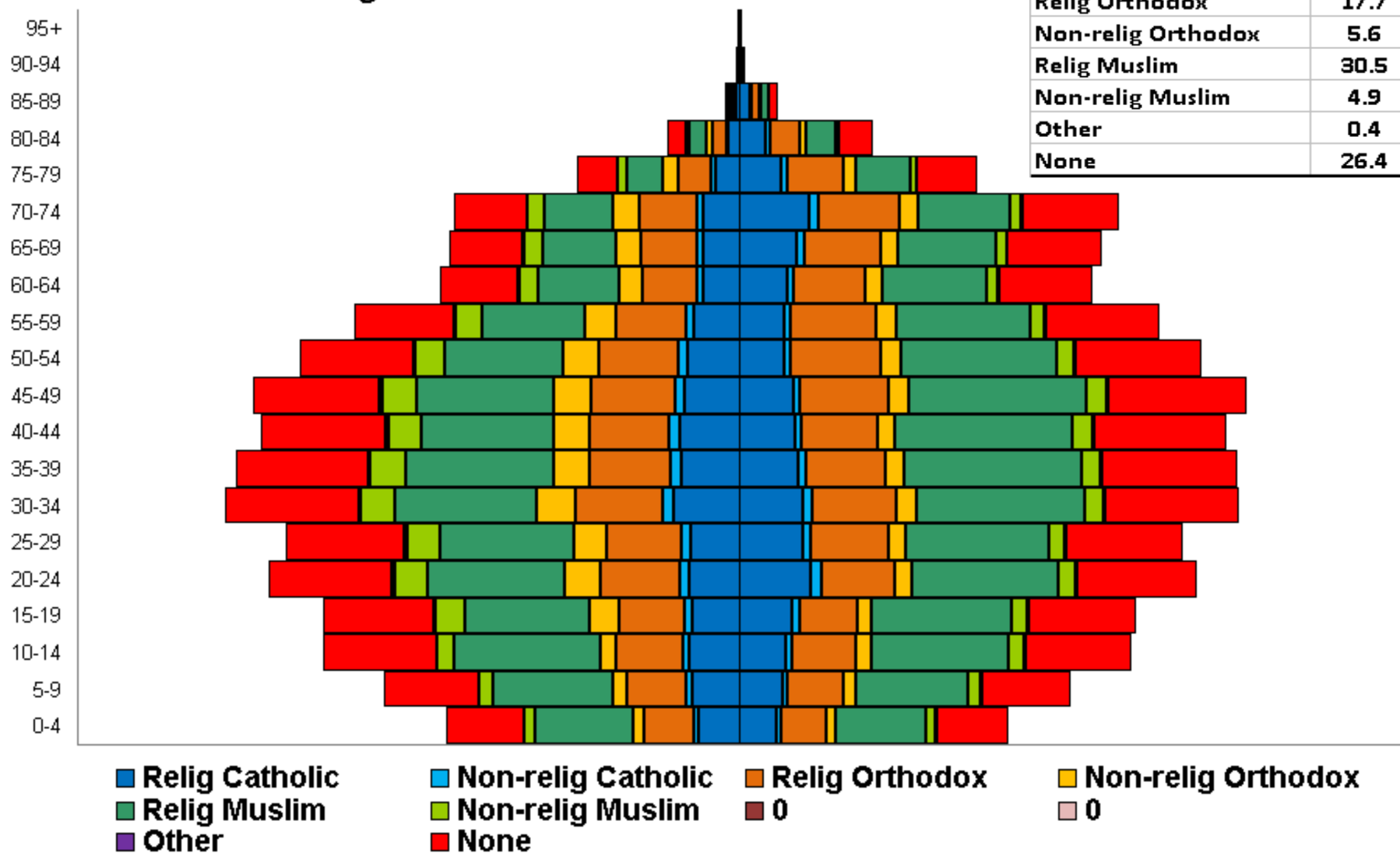
Bosnia and Herzegovina in 2004



Relig Catholic	12.8
Non-relig Catholic	1.9
Relig Orthodox	17.9
Non-relig Orthodox	5.6
Relig Muslim	30.3
Non-relig Muslim	4.8
Other	0.3
None	26.4

- Relig Catholic
- Non-relig Catholic
- Relig Orthodox
- Non-relig Orthodox
- Relig Muslim
- Non-relig Muslim
- 0
- 0
- Other
- None

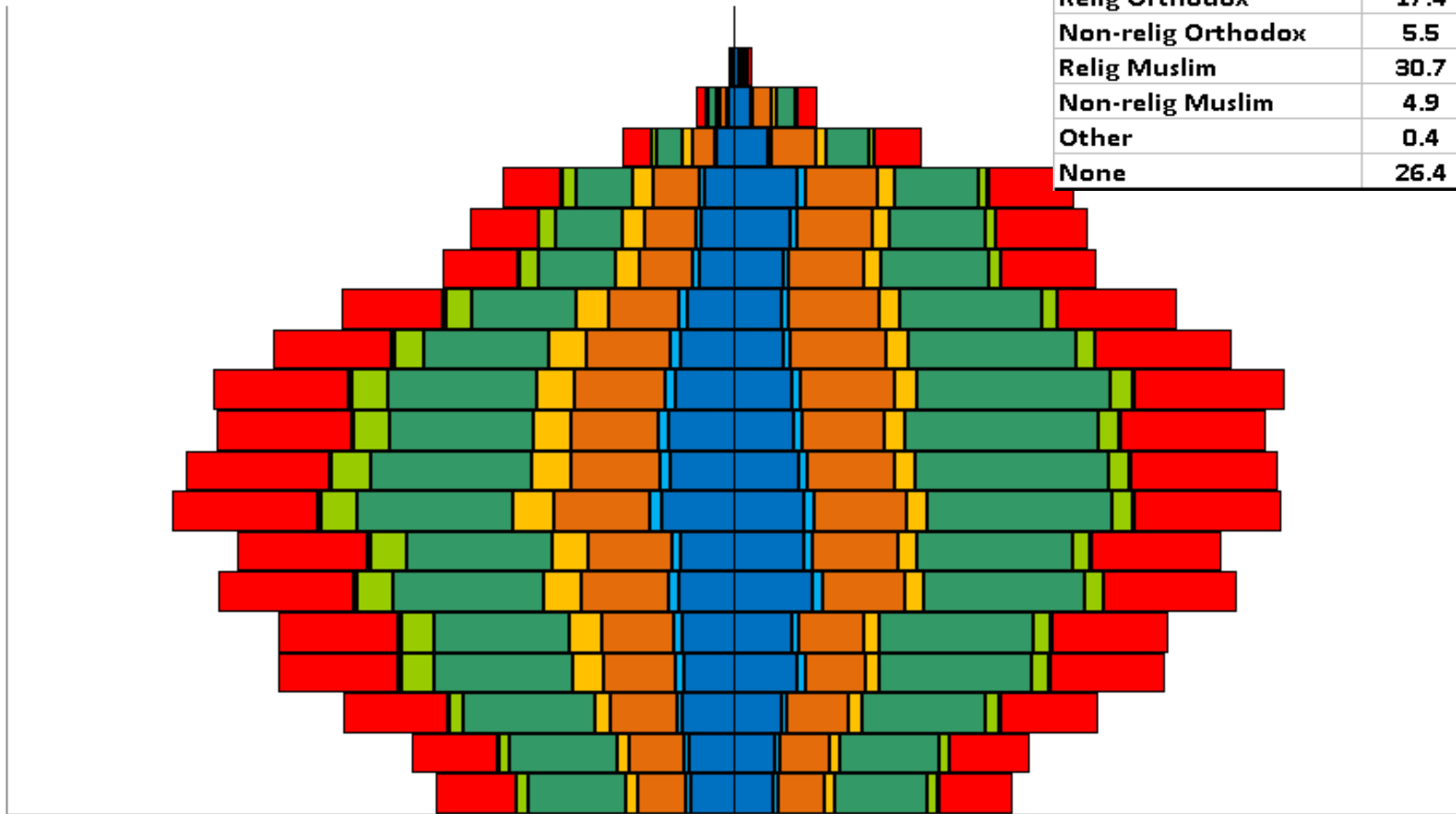
Bosnia and Herzegovina in 2009



Bosnia and Herzegovina in 2014

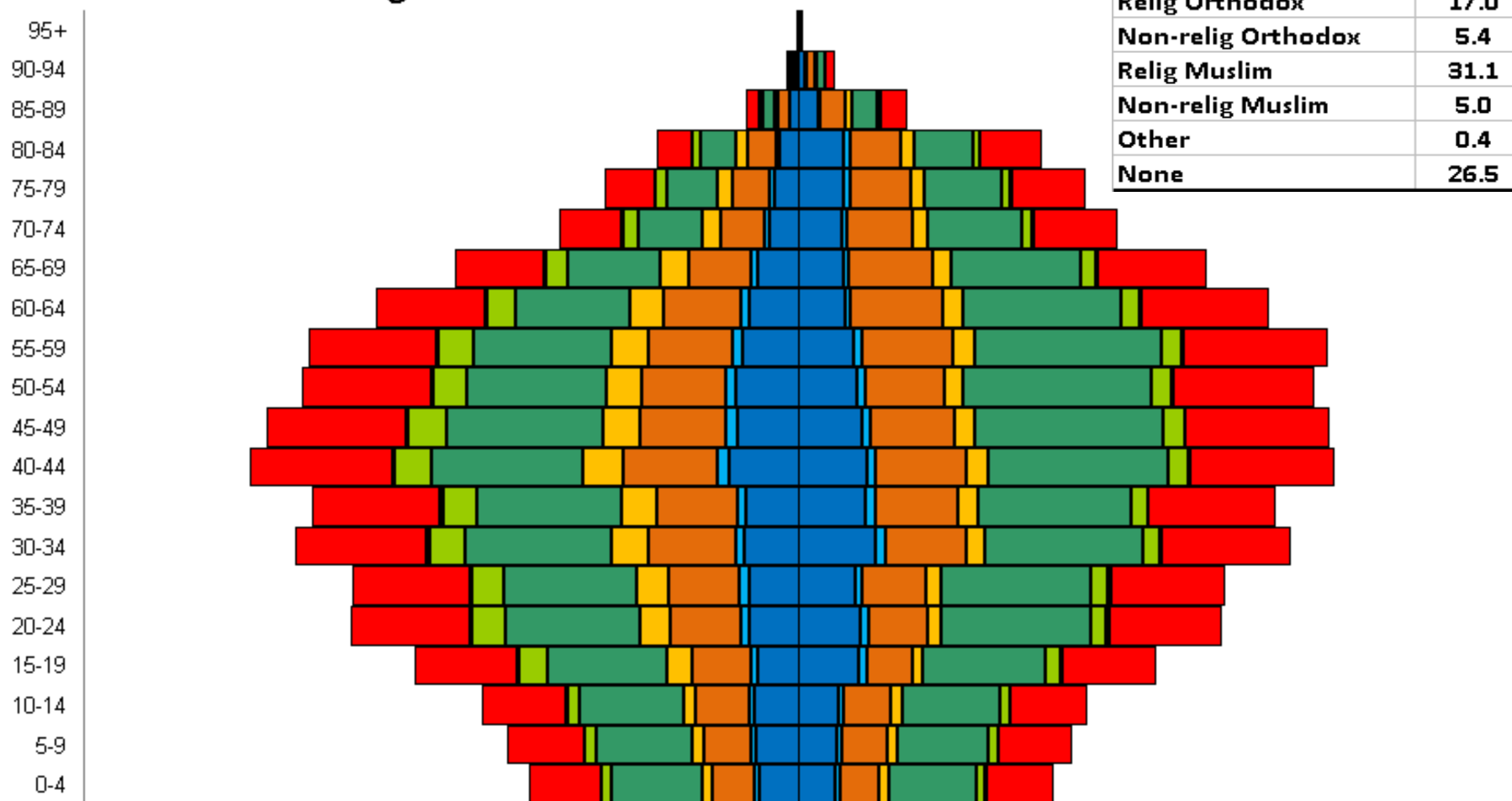
95+
90-94
85-89
80-84
75-79
70-74
65-69
60-64
55-59
50-54
45-49
40-44
35-39
30-34
25-29
20-24
15-19
10-14
5-9
0-4

Relig Catholic	12.7
Non-relig Catholic	1.9
Relig Orthodox	17.4
Non-relig Orthodox	5.5
Relig Muslim	30.7
Non-relig Muslim	4.9
Other	0.4
None	26.4



■ Relig Catholic ■ Non-relig Catholic ■ Relig Orthodox ■ Non-relig Orthodox
■ Relig Muslim ■ Non-relig Muslim ■ 0 ■ 0
■ Other ■ None

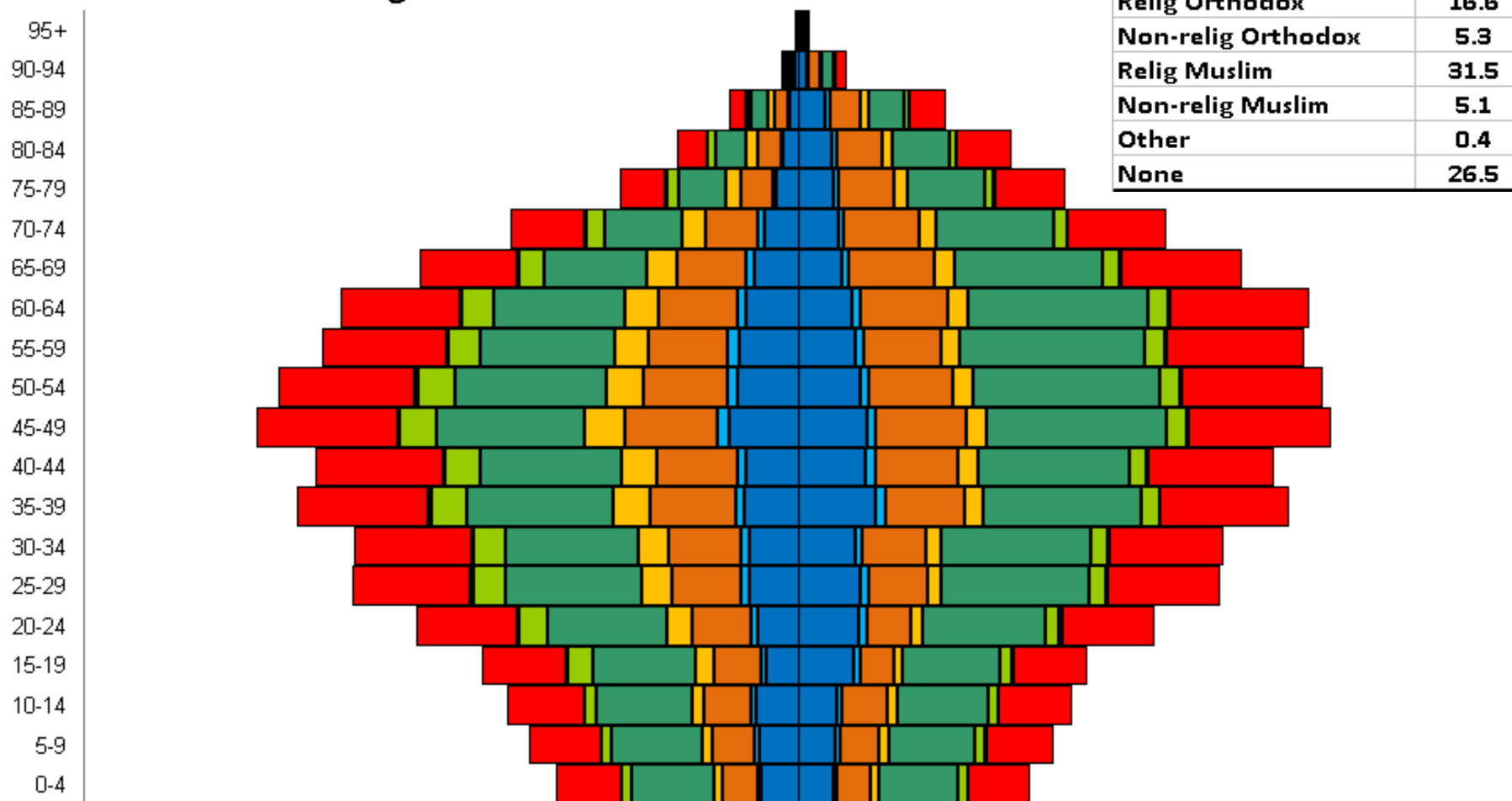
Bosnia and Herzegovina in 2019



Relig Catholic	12.7
Non-relig Catholic	1.9
Relig Orthodox	17.0
Non-relig Orthodox	5.4
Relig Muslim	31.1
Non-relig Muslim	5.0
Other	0.4
None	26.5

- Relig Catholic
- Non-relig Catholic
- Relig Orthodox
- Non-relig Orthodox
- Relig Muslim
- Non-relig Muslim
- 0
- 0
- Other
- None

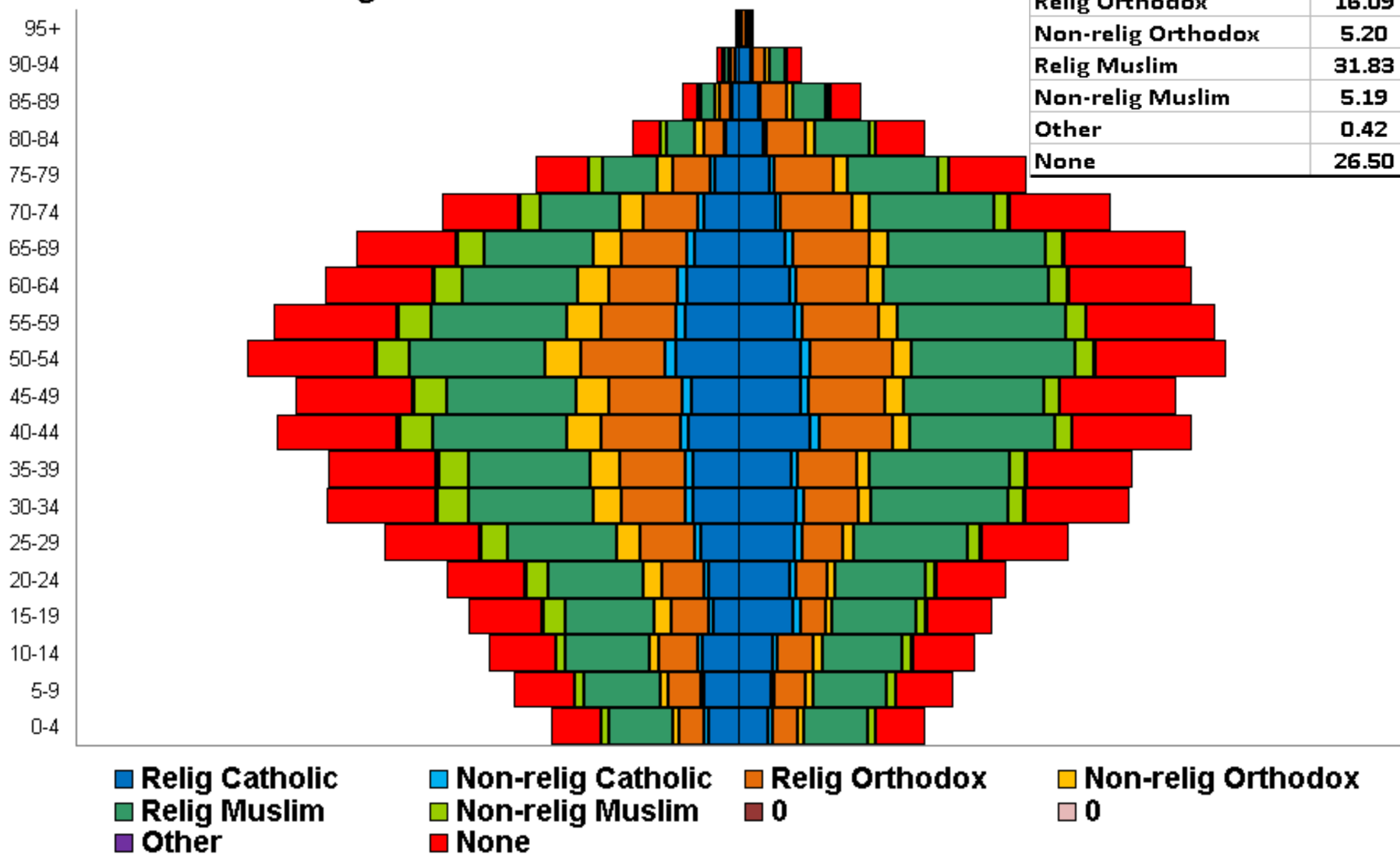
Bosnia and Herzegovina in 2024



Relig Catholic	12.7
Non-relig Catholic	1.9
Relig Orthodox	16.6
Non-relig Orthodox	5.3
Relig Muslim	31.5
Non-relig Muslim	5.1
Other	0.4
None	26.5

- Relig Catholic
- Non-relig Catholic
- Relig Orthodox
- Non-relig Orthodox
- Relig Muslim
- Non-relig Muslim
- 0
- 0
- Other
- None

Bosnia and Herzegovina in 2029



Demographic package in R

- *Demography*
- **Authors:** Rob J Hyndman, Heather Booth, Leonie Tickle, John Maindonald.
- The **demography** package for R contains functions for various demographic analyses.
- It provides facilities for
 - **demographic statistics,**
 - **modelling and forecasting**
- Not a multistate model

DemogR

- Author: James Holland Jones
- **evolutionary demography** and **conservation biology**
- for analyzing age-structured population models
- for the construction and analysis of matrix population models
- classical demography
 - construction of period life tables
 - the generation of model mortality and fertility schedules
- Not a multistate model

Popbio

- Projection matrix models
- Plant demography studies
- Stubben and Milligan, 2007
- Not a multi-state model

msm

- Multistate Markov models
- Christopher H. Jackson
- Fitting general continuous-time Markov and hidden Markov multi-state models
- For longitudinal data
- Covariates can be introduced

Proposed: Multistate Demography? (msdem?)

- **The multistate life table** describes how the size and composition of a (synthetic) cohort change over time.
- **Multistate projection models** describe how the population structure (**stock**) at a given time depends on the initial population and the transitions people make (**flows**).

How to Proceed?

- Demographic
 - Prepare a plan covering all the aspects of multistate demography
 - Reviewing existing literatures / softwares / packages
 - Interview users VID/IIASA
 - Experts – VID/IIASA/NIDI ...
 - A first working draft can be prepared by the mid of next week

R

- Writing a package in R? (WU)
- Dissemination (IIASA / WU)
 - Developing training package
 - First to IIASA/VID researchers
 - IIASA – YSSPers
 - Students (WU?)
 - International (through IIASA and other sources..)
- Continuity..... (IIASA / WU)