Using Ternary-Balance Schemes to Visualize Family Planning Indicators Jointly for all Countries[1]

Mark C. Wheldon, Philipp Ueffing, Aisha N. Z. Dasgupta, Vladimíra Kantorová
United Nations Population Division, New York, NY
21st March 2019

Background

In response to several global-level initiatives to promote universal access to family planning (Brown et al. 2014; Carr et al. 2012; Peterson et al. 2013), including the *FP2020* initiative (FP2020 2017) and the UN Sustainable Development Goals (United Nations 2015), Alkema et al. (2013), Cahill et al. (2017) and Wheldon et al. (2019) developed hierarchical Bayesian models to jointly estimate and project the prevalence of contraceptive use (CP), unmet need for contraception (UMN), and no-need for contraception, among married and unmarried women aged 15–49. The quantity of interest was a multidimensional compositional vector; a partition of the target population into three exclusive and exhaustive categories. While the statistical model produced a multivariate posterior distribution for the vector, only univariate, marginal indicators were presented in figures and tables in the results. This made interpretation of the relationship between the indicator components across countries more challenging. For example, a user might note a country has low contraceptive prevalence (CP), but it may not be immediately clear whether this is associated with high UMN, high no need, or both. The context of low contraceptive prevalence matters as it has implications for whether there is need for scaled up investments in family planning programmes. In this article we show that indicators of family planning can be reported in true multivariate fashion using the *ternary-balance* scheme of Schöley and Willekens (2017).

Methods

Data

Data were compiled from all nationally representative surveys that provide information on CP, such as Demographic and Health Surveys (DHS), Multiple-Indicator Cluster Surveys (MICS), Performance, Monitoring and Accountability 2020 surveys (PMA), Gender and Generation Surveys (GGS), other international survey programmes and a wealth of national surveys. We obtained 1200 observations across 195 countries for married or in-union women over the period 1950–2018, and 518 observations across 134 countries for unmarried or not-in-a-union women, over the period 1976–2018 (UN Population Division 2018a, 2018b). Where available we used micro data sets, otherwise we used estimates derived from the published tabulations and specially requested tabulations from data collecting institutions. The DHS revised algorithm was used for UMN. Indicators are based on – and their denominators contain - the population of all women of reproductive age, regardless of pregnancy and infecundity status.

Modelling

Bayesian hierarchical models were used to produce probabilistic estimates and projections, jointly, of the compositional vector of contraceptive use categories (see 'Background') for all women of reproductive age, by marital status, at the country level, from 1970–2030 (Alkema et al. 2013; Wheldon et al. 2019). We summarized the joint posterior distribution with posterior quantiles of prevalence of contraceptive use, UMN, and no need for contraception.

Mapping and Plotting Using Ternary-Balance Colour Schemes

Compositions with three components can be represented on a 2-dimensional plane using a ternary-balance colour scheme (Schöley and Willekens 2017). This scheme assigns a basic colour to each of the three components. Compositional vectors can then be represented by colour mixtures in the same proportion as the composition. This gives each vector a single, unique colour. We used these colours to create choropleth maps of family planning compositional vectors of 2008 posterior medians for married women and, separately, unmarried women.

The legend for a ternary-balance plot is a ternary diagram (e.g., Pawlowsky-Glahn et al. 2015) overlaying the colour-scheme. In other words, a triangle coloured in such that the end points are entirely made up of only one of the base colours which

[1] Funding: Grant Nos. OPP1110679 , OPP1183453 Making Family Planning Count from the Bill & Melinda Gates Foundation. The views expressed herein are those of the authors and do not necessarily reflect the views of the United Nations. The designations employed and the presentation of material on any map in this work do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

blend together towards the middle. Individual observations are plotted as points inside this triangle just as they are in the rectangular plotting space of a standard scatter plot. In our case these points are country-level compositional vectors.

Ternary diagrams have been used for this purpose in many fields, including demography (e.g., Kashnitsky and Schöley 2018). The central point of the plot is the vector [1/3, 1/3, 1/3], that is, equal proportions of each component. The vertices are the opposite; 100 percent of one component and none of the others. In our plots, the label of the vertex indicates which component is at 100 percent for points at that vertex. For points in the interior of the triangle, the three component proportions can be derived by reading back to the triangle edges in the direction indicated by the orientation of the number labels on the edge. To improve understanding we followed Kashnitsky and Schöley (2018) and highlighted selected observations in plot legends. The strength of this type of visualization is that the user can better understand the relationships among the three family planning indicators, for all countries at a point in time, within one map.

All computation and visualization was done using *R* (R Core Team 2018) and the packages *tricolore* (Schöley 2018a), *ggtern* (Hamilton 2018), *maptools* (Bivand and Lewin-Koh 2018) and *rgdal* (Bivand et al. 2018).

Results

Ternary-balance choropleth maps of the world showing posterior medians of the three-component vector [CP, UMN, no need for contraception] for women of reproductive age in 2018 are shown for married Figure 1 and unmarried Figure 2 women. The vectors are also plotted in the legends (ternary diagrams).

Among married women, for a substantial proportion of countries, the plot suggests that the dominant component is CP. This is indicated by the abundance of green hues on the map and the large cloud of points congregating near the 'CP corner'. Despite this, CP varies widely, from above 80 percent (e.g., China, Finland) to less than 10 percent (e.g., Chad, South Sudan). The lowest levels of CP are in Eastern, Middle, and Western Africa, and some parts of Western and Southern Asia and Oceania. This range can be seen immediately in the legend as plotted points stretch from the 'CP corner' right down to the opposite edge. For countries with relatively low CP among married women, the dominant component is no need, similarly indicated by blue on the map and points near the 'No need corner'. Levels of UMN are low on the 0–100 percent scale; only three countries have UMN greater than 33 percent (Samoa, Haiti, Angola).

For unmarried women, CP is much lower compared to married women and the variation across countries is much lower; the cloud of points does not stretch right into the 'CP corner' for this group. Relatively high CP is seen in a similar set of countries as for married women (Europe, Northern America, Latin America and the Caribbean, Southern Africa). The belt of low CP countries stretches from Northern Africa through South-Eastern Asia indicating countries where sexual-activity of unmarried women is not common and which are, therefore, concentrated in the 'no need corner'. UMN is also much lower. Again, this is immediately obvious from the legend in which all points are very close to the bottom edge far away from the 'UMN corner', and the map in which there is a near absence of pink hues.

The ternary diagrams clearly show that there is a highly non-uniform distribution across the space of compositions, and that these are different for married and unmarried women. In other words, rather than being evenly spread across the triangle, there are distinct patterns in the scatter of plotted points. Among married women, lower CP is associated with higher no need and higher UMN (albeit to a lesser extent). In contrast, among unmarried women, lower CP is much more strongly associated with no need.

Discussion

We have showed that the ternary-balance scheme of Schöley and Willekens (2017) can be used to plot indicators of family planning jointly. The resulting ternary-balance choropleth maps allowed a vivid comparison of the two main marital groups at the country-level, and they highlighted regions where the estimated level of one of the components was high. Uniquely, though, it illustrates the full joint distributions for the three components, respecting the constraint that they sum to 1, and helps the user to understand the relationships among three family planning indicators simultaneously, at a point in time, across all countries. This is seen in the plot for married women where low and medium CP can be seen to be associated to a different degree with UMN or no need, respectively. Among unmarried women, low CP was associated almost entirely with high no need, albeit with exceptions in Western and Middle Africa where unmet need was above 10%.

An adequate consideration of the joint relationships could be useful for policy development and programming that are responding to low CP. Areas where CP is low due to significant UMN would require different policies to those where it is due to high no need.

The observation that UMN appeared low on the 0–100 scale does not mean that it is unimportant. Rather, it indicates that typical values are lower, and their range narrower, than for CP and no need. Twenty percent (or even 10 % among unmarried women) should be regarded as 'very high' for UMN (recall that our indicators were calculated for all women of reproductive age regardless of sexual activity status).

A consequence of this narrower range for UMN for unmarried women is that only a small subset of the colour palette was used in the map showing a useful comparison to married women map. The . This is not a limitation, however; if comparisons of relative UMN are desired the colour scale can be adjusted. Some examples are given by Schöley (2018b).

References

Alkema, L., Kantorova, V., Menozzi, C., & Biddlecom, A. (2013). National, regional, and global rates and trends in contraceptive prevalence and unmet need for family planning between 1990 and 2015: a systematic and comprehensive analysis. *The Lancet*, *381*(9878), 1642–1652.

Bivand, R., Keitt, T., & Rowlingson, B. (2018). *rgdal: Bindings for the "Geospatial" Data Abstraction Library*. https://CRAN.R-project.org/package=rgdal

Bivand, R., & Lewin-Koh, N. (2018). *maptools: Tools for Reading and Handling Spatial Objects*. https://CRAN.R-project.org/package=maptools

Brown, W., Druce, N., Bunting, J., Radloff, S., Koroma, D., Gupta, S., et al. (2014). Developing the "120 by 20" Goal for the Global FP2020 Initiative. *Studies in Family Planning*, *45*(1), 73–84. doi:10.1111/j.1728-4465.2014.00377.x

Cahill, N., Sonneveldt, E., Stover, J., Weinberger, M., Williamson, J., Wei, C., et al. (2017). Modern contraceptive use, unmet need, and demand satisfied among women of reproductive age who are married or in a union in the focus countries of the Family Planning 2020 initiative: a systematic analysis using the Family Planning Estimation Tool. *The Lancet*, *391*(10123), 870–882. doi:10.1016/S0140-6736(17)33104-5

Carr, B., Gates, M. F., Mitchell, A., & Shah, R. (2012). Giving women the power to plan their families. *The Lancet*, *380*(9837), 80–82. doi:10.1016/S0140-6736(12)60905-2

FP2020. (2017). Family Planning Summit, July 11, 2017, London, UK. http://summit2017.familyplanning2020.org/? Accessed 13 September 2018

Hamilton, N. (2018). *ggtern: An Extension to "ggplot2", for the Creation of Ternary Diagrams*. https://CRAN.R-project.org/package=ggtern

Kashnitsky, I., & Schöley, J. (2018). Regional population structures at a glance. *The Lancet*, *392*(10143), 209–210.

Pawlowsky-Glahn, V., Egozcue, J. J., & Tolosana-Delgado, R. (2015). *Modeling and Analysis of Compositional Data: Modeling and Analysis of Compositional Data*. New York, NY: John Wiley & Sons, Incorporated. http://ebookcentral.proquest.com/lib/unhq-ebooks/detail.action?docID=1895896. Accessed 12 September 2018

Peterson, H. B., Darmstadt, G. L., & Bongaarts, J. (2013). Meeting the unmet need for family planning: now is the time. *The Lancet*, *381*(9879), 1696–1699. doi:10.1016/S0140-6736(13)60999-X

R Core Team. (2018). *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/

Schöley, J. (2018a). *tricolore: A Flexible Color Scale for Ternary Compositions*. https://CRAN.R-project.org/package=tricolore

Schöley, J. (2018b, January 14). Experimenting with different approaches to construct mean-centered and variance-scaled ternary color scales. Such scales are needed to plot unbalanced and narrow compositions. @ikashnitsky Which version of the legend do you prefer? Visualized with http://github.com/jschoeley/tricolore … #ggternpic.twitter.com/cZX2OTEf4q. *@jschoeley*. Tweet. https://twitter.com/jschoeley/status/952660875986505728. Accessed 12 September 2018

Schöley, J., & Willekens, F. (2017). Visualizing compositional data on the Lexis surface. *Demographic Research*, *36*(21), 627–658. doi:10.4054/DemRes.2017.36.21

UN Population Division. (2018a). *World Contraceptive Use 2018* (Data set No. POP/DB/CP/Rev2018). New York, NY: United Nations, Department of Economic and Social Affairs, Population Division. http://www.un.org/en/development/desa/population/publications/dataset/contraception/wcu2016.shtml. Accessed 10 September 2018

UN Population Division. (2018b). *World Contraceptive Use by Marital Status and Age 2018* (Data set). New York, NY: United Nations, Department of Economic and Social Affairs, Population Division. http://www.un.org/en/development/desa/population/publications/dataset/contraception/wcu2016.shtml. Accessed 10 September 2018

United Nations. (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development* (Draft Resolution Referred to the United Nations Summit for the Adoption of the Post-2015 Development Agenda by the General Assembly at its Sixty-Ninth Session No. A/70/L.1). New York, NY: United Nations General Assembly.

Wheldon, M. C., Kantorová, V., Ueffing, P., & Dasgupta, A. N. Z. (2019). *Methods for estimating and projecting key family planning indicators among all women of reproductive age* (Technical Paper No. 2018/2). New York: United Nations, Department of Economic and Social Affairs, Population Division. https://www.un.org/en/development/desa/population/publications/pdf/technical/TP2018-2.pdf. Accessed 8 January 2019

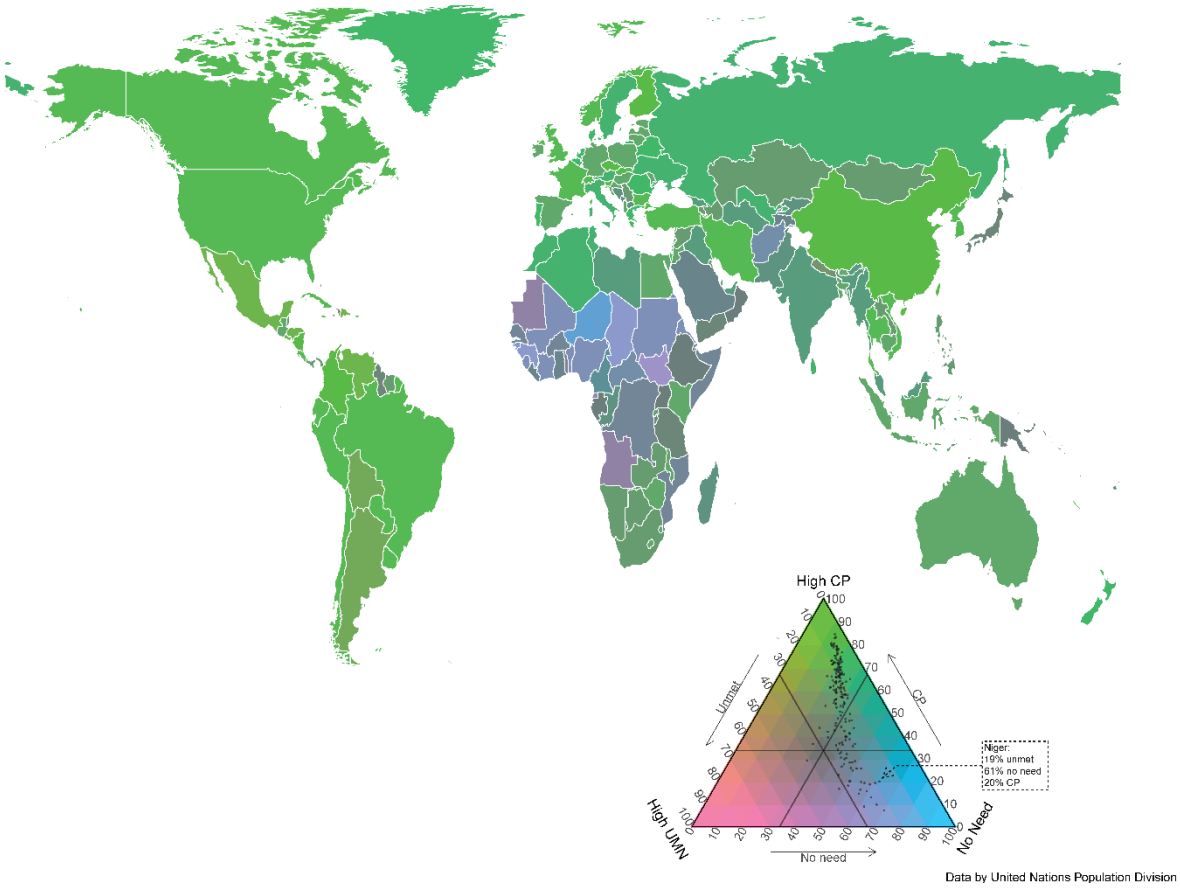

Figure 2. Ternary colour map of contraceptive prevalence (CP), unmet need for family planning, and no need for family planning, for married women aged 15—49, 2018. Model-based estimates (posterior medians) plotted; source data UN Population Division (2018a).

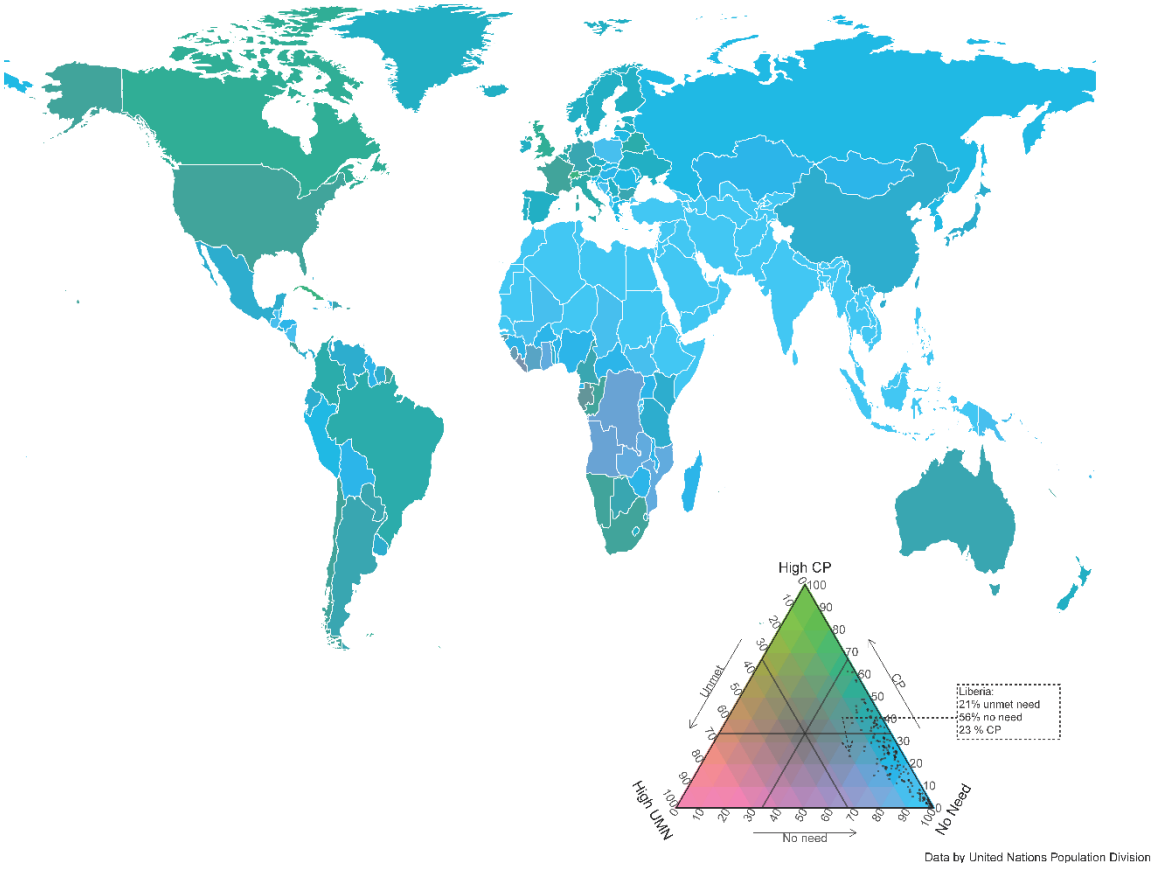

Figure 1. Ternary colour map of contraceptive prevalence (CP), unmet need for family planning, and no need for family planning, for unmarried women aged 15—49, 2018. Model-based estimates (posterior medians) plotted; source data UN Population Division (2018b).