

2022 Subcounty Population Projections for Pima County Jurisdictions

Pima Association of Governments

1. Background

Executive Order 2011-04 designated the Arizona Office of Economic Opportunity (AOEO) as the state agency responsible for developing official population estimates and projections for the State of Arizona. Regional Councils of Governments (COGs) are requested to assist AOEO in preparing the projection series. COGs, in accordance with AOEO policy, also have the option to produce subcounty population projections to incorporate with the series from AOEO. As a COG, Pima Association of Governments (PAG) signed a petition on February 21, 2023, to generate the 2022 subcounty population projection series for incorporated jurisdictions and the unincorporated balance of Pima County.

2. Subcounty Population Projections in Pima County

2.1 Assumptions

Subcounty population projections of all municipalities and unincorporated Pima County are developed based on the 2022 boundaries of each municipality as of July 1, 2022. These boundaries remain unchanged throughout the projection horizon. Future annexations or de-annexations cannot be predicted and are therefore not considered by this methodology.

Using the established geographical boundaries, PAG estimated the population growth capacity of each jurisdiction. This calculated capacity was held constant across the forecast horizon to ensure that the projected population of each municipality can be absorbed by current planning standards. PAG examined future land use plans and American Community Survey (ACS) 5-year estimates to establish a population growth cap for each jurisdiction based on the availability of developable land at current population densities. These constraints were defined by analysis of metrics such as total buildable land and the maximum number of permitted dwelling units on vacant, infill, and redevelopable land. When a

municipality reaches the limit of its growth capacity, its population will plateau. PAG assumes these constraints are stable and fixed within each jurisdiction's boundary for the entirety of the projection period.

In 2022, the AOEO produced 2022-2060 population projections for Pima County. The subcounty population PAG has developed adopts the Pima County control total established by the AOEO.

2.2 Methodologies

Following jurisdictional stakeholder discussion and recommendations, PAG developed three population projections. These are:

1. The time series method
2. The 2019 county population share growth method
3. The average of the time series and the 2019 county population growth share methods with the City of South Tucson held constant

PAG's jurisdictional members reached consensus to recommend the average of the time series and the 2019 county population growth share methods. These two methodologies are discussed in detail below.

2.2.1 Time Series Method

The time series method uses historical population estimates to project a time series trend for the future growth of each municipality. As input for the time series, PAG used July 1 state population estimates by jurisdiction from 1980 to 2022, with exceptions for the Town of Sahuarita (1995 to 2022 only) and the City of South Tucson (2000 to 2022 only).

The time series method relies principally on a historical trend to forecast growth potential into the future. In order to avoid annexation bias, it is important to count the historic population using a consistent municipal boundary across the entire time series. Controlling for jurisdictional annexations, PAG adjusted annual historical subcounty population estimates based on 2022 jurisdictional boundaries in combination with 2010-2022 annexation data from AOEO. Population projection series were then set to proceed from the fixed 2022 boundaries. Unincorporated Pima County's original historical population trend (in blue) shows a recent significant drop by out-annexation (Figure 1(a)). Without any historical trend adjustment to account for annexation, a jurisdiction such as unincorporated Pima County could show negative growth

despite increasing population. In this case, the out-annexed population was reduced sequentially and accumulatively over the 2010-2022 period to rectify the impact of this bias on the historical population trend. The orange trend line in Figure 1(a) represents the adjusted population growth. The orange trend line of Figure 1(b), by contrast, shows the population gained by the City of Tucson through annexation applied sequentially and accumulatively from 2010-2022. This adjustment corrects for the sudden increase in population caused by recent City annexations that could, uncorrected, overestimate the forecasted growth trend line.

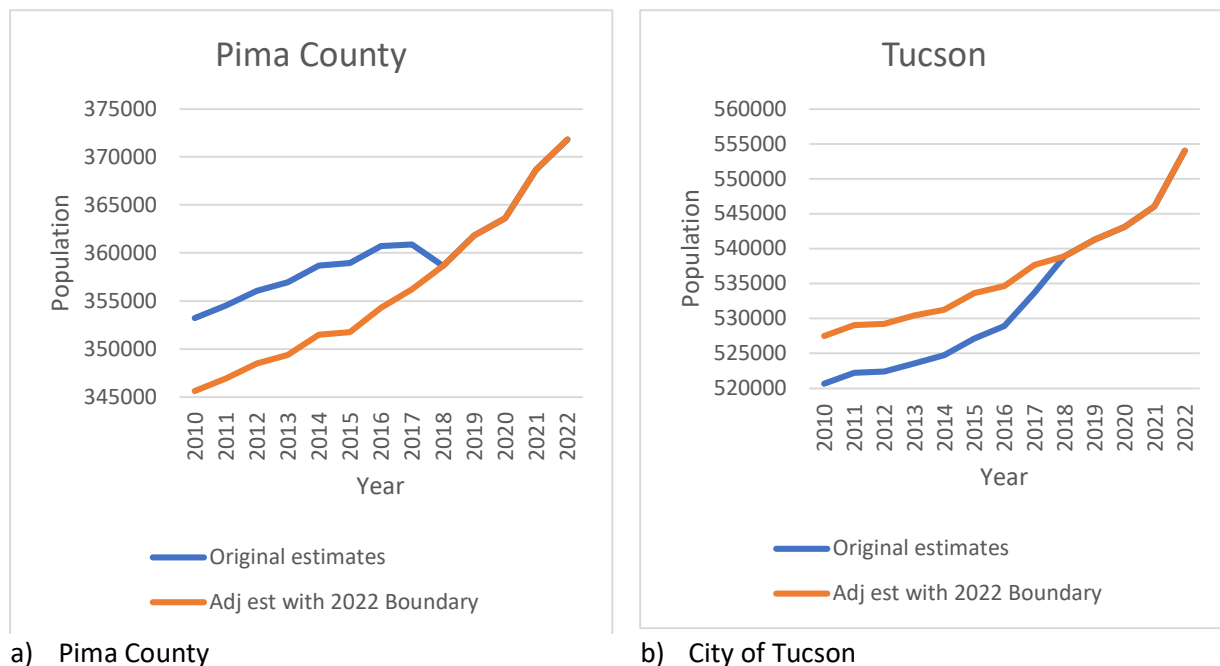


Figure 1. Historical Population Adjustment

After the adjustment for annexation, PAG estimated a time-series population projection using the Auto-Regressive Integrated Moving Average (ARIMA) (0,2,1) time series model for the City of South Tucson and for other jurisdictional time series using Brown's simple exponential smoothing model¹. The ARIMA (0,2,1) model uses two differences related to error terms shown in Equation (1).

¹<https://people.duke.edu/~rnau/411avg.htm#:~:text=The%20simplest%20time-varying%20trend,line%20through%20the%20two%20centers.>

$$\widehat{Y}_t = 2Y_{t-1} - Y_{t-2} - \theta_1 e_{t-1} - \theta_2 e_{t-2} \quad (1)$$

Where,

\widehat{Y}_t : the estimated population in year t,

Y_t : observed population in year t, e_t : error in year t, and

θ_1, θ_2 : coefficients.

The library `auto.arima()` in R was utilized to compute the solution². Brown's simple exponential smoothing model implements an exponentially weighted moving average as shown in Equation (2).

$$\widehat{Y}_t = \alpha[Y_{t-1} + (1 - \alpha)Y_{t-2} + (1 - \alpha)^2 Y_{t-3} + (1 - \alpha)^3 Y_{t-4} + \dots] \quad (2)$$

Where,

Y_t : observed population in year t,

\widehat{Y}_t : estimated population in year t, and

α : a constant smoothing factor between 0 and 1.

To find the optimal α of Brown's exponential smoothing model, PAG utilized Excel's "What if Analysis" to generate values minimizing the sum of squared errors (SSE). The smallest SSE values represent those forecast values closest to real observations. The value of Y is computed recursively from its own previous value, while $(1-\alpha)$ becomes a discount factor exponentially weighing the previous value. In another words, the model gradually gives more weight to more recent observations.

The statistical results of the proposed models are shown in Table 1.

² <https://www.rdocumentation.org/packages/forecast/versions/8.21/topics/auto.arima>

Table 1. Time-Series Model Statistics

Jurisdiction	Model Type	R-Squared	MAPE	RMSE
Marana	Brown	0.9989	5.60%	624.81
Oro Valley	Brown	0.9969	4.43%	951.97
Sahuarita	Brown	0.9975	4.41%	600.62
South Tucson	ARIMA (0,2,1)	0.9714	0.85%	73.33
Tucson	Brown	0.9899	0.99%	6508.92
Unincorporated Pima	Brown	0.9908	1.64%	5647.24

In the table, the mean absolute percentage error (MAPE) is the average difference between the actual observations and the forecasted values, and it measures the prediction accuracy of the model. The root mean square error (RMSE) is the measurement of the average difference between the model-predicted values and the actual values. The R-squared represents the difference between total variation and the explained variation proportionate to total variation. It also measures the goodness of fit of the forecast equation. The R-squared, RMSE and MAPE scores shown in this table suggests the model equation has a close fit to the observations.

The pandemic impacted Census 2020 data collection efforts during Census 2020. PAG and its jurisdictional partners have concerns over the coverage and the accuracy of the 2020 Census enumerations. The Census 2020 report for the City of South Tucson showed a significant drop in population from 2010 which may indicate a pandemic-related undercount. A time series model in this context will therefore exaggerate population decline for the City of South Tucson, a result that is unrealistic given local knowledge. Consultation with jurisdictional stakeholders indicated that South Tucson is not expected to have significant population growth during the projected period. The suggested course of action was to hold constant the City's 2022 population estimate through 2060.

As discussed in Section 2.1, growth capacity was calculated and applied to each jurisdiction. The Town of Oro Valley reaches its maximum growth capacity in 2033 as shown in Figure 2. Final adjustments were made to match growth of all jurisdictions to the 2022 Pima County control total.

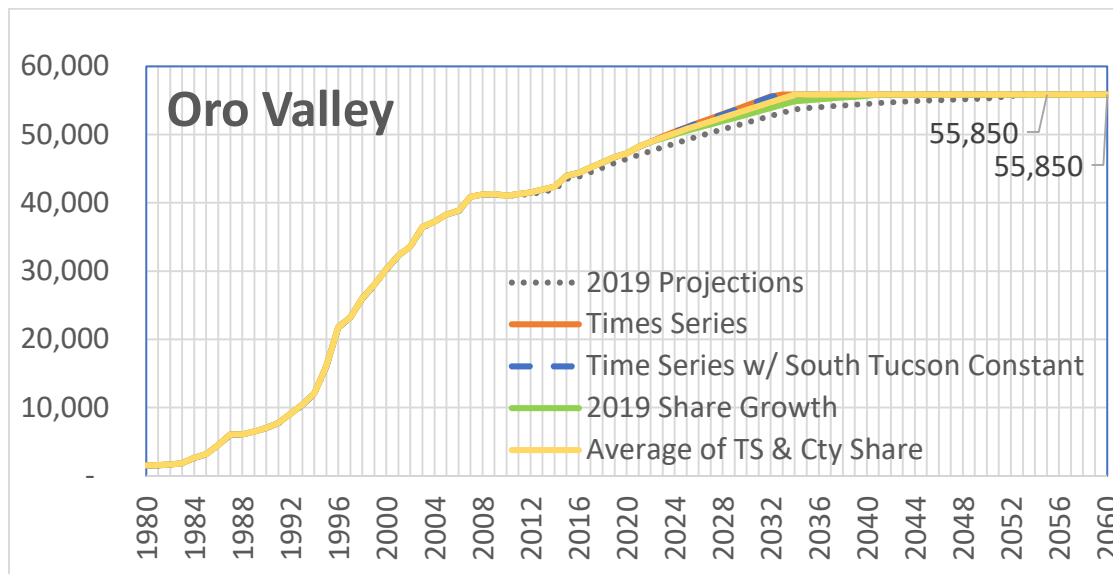


Figure 2. The Town of Oro Valley Population Projections from Different Forecast Methods

2.2.2 2019 Population Share Growth Method

In 2019, PAG generated subcounty population projections for AOEO with two methods:

1. Subcounty time series model based on the 2019 county population projection series.
2. 2016 population share method applying the 2016 subcounty share to 2019 county population projections.

The final recommended method for the 2019 subcounty projections took the average of the above two methods.

PAG's 2019 population share growth method applied each jurisdiction's 2019 approved population share ratio (jurisdiction population-to-county total population) to the new 2022 county control total with the new annexation adjustments. With the new 2022 boundaries, the county shares of each jurisdiction are corrected from the original 2019 shares. The Town of Oro Valley reaches its maximum growth capacity in 2041 and population remains constant afterward (See Figure 2). Final adjustments were made to match the 2022 Pima County control total.

2.2.3 Average of Time Series with South Tucson constant and 2019 Population Share Method

Each forecast method stresses factors that impact future growth in different aspects. The time series method focuses on recent population trends. The 2019 population share growth method, by contrast, places emphasis on jurisdiction growth relative to the county total. Jurisdictional stakeholders discussed the associated tradeoffs of adopting the time-series versus the 2019 population share growth method. The jurisdictions reached a consensus to average the two methods while holding constant the 2022 population for the City of South Tucson. The averaging method has the advantage of balancing the influence of all factors in the equation.

3. Results

Members of PAG's population technical subcommittee, PopTech, approved a proposal to recommend final 2023 subcounty population projections using the averaging method on April 21, 2023. Table 2 shows the jurisdictional subcounty projections. The technical recommendation by PAG's jurisdictional stakeholders was approved by the PAG Regional Council on May 25, 2023.

Table 2. Average of Time Series with South Tucson Constant and 2019 Population Share Growth Method

	MAR	OV	SAH	STUC	TUC	PC	TOTAL
2022 Population	56,758	48,906	36,179	4,599	554,021	371,835	1,072,298
2030 Population	70,024	53,573	41,837	4,599	571,827	387,554	1,129,414
2040 Population	86,235	55,751	47,833	4,599	594,332	406,320	1,195,070
2050 Population	101,359	55,850	52,531	4,599	612,203	423,286	1,249,828
2060 Population	116,239	55,850	57,156	4,599	631,112	440,256	1,305,212
Growth (22-60)	59,481	6,944	20,977	-	77,091	68,421	232,914
Annual Growth	1,565	183	552	-	2,029	1,801	6,129
Annual Growth Rate	2.76%	0.37%	1.53%	0.00%	0.37%	0.48%	0.57%

Annual Growth Rate (10-22)	5.15%	1.60%	3.21%	-1.54%	0.42%	0.63%	0.78%
Share of County Growth	25.54%	2.98%	9.01%	0.00%	33.10%	29.38%	100.00%
Share of County Growth (10-22)	23.76%	8.63%	11.02%	-1.14%	29.03%	28.70%	100.00%
2022 County Share	5.29%	4.56%	3.37%	0.43%	51.67%	34.68%	100.00%
2060 County Share	8.91%	4.28%	4.38%	0.35%	48.35%	33.73%	100.00%

The population projection series in Table 2 meets the requirement that it matches the county population projection control total from AOEO. The projection series from this method shows the Town of Marana to be the fastest growing jurisdiction, averaging 2.76% annual growth until 2060, followed by the Town of Sahuarita with 1.53% annual growth. The City of Tucson remains the largest jurisdiction with a 48.35% share of total county population in 2060. Unincorporated Pima County is projected to have 0.48% annual growth, but the Town of Oro Valley is projected to have slower growth at the end of the series having maxed out its growth capacity. As discussed earlier, no additional population growth was applied to South Tucson.

Figures 3 and 4 show each jurisdiction's growth rate and the change of its relative share of county population, combining 2010-2022 adjusted population estimates and the 2023-2060 population forecast. The Town of Marana is projected to maintain the highest rate of growth. Going forward, the Town of Sahuarita, by contrast, is projected to have slower growth than in the previous two decades. Figure 4 shows both Marana and Sahuarita will continuously increase their relative share of county population over the next 38 years.

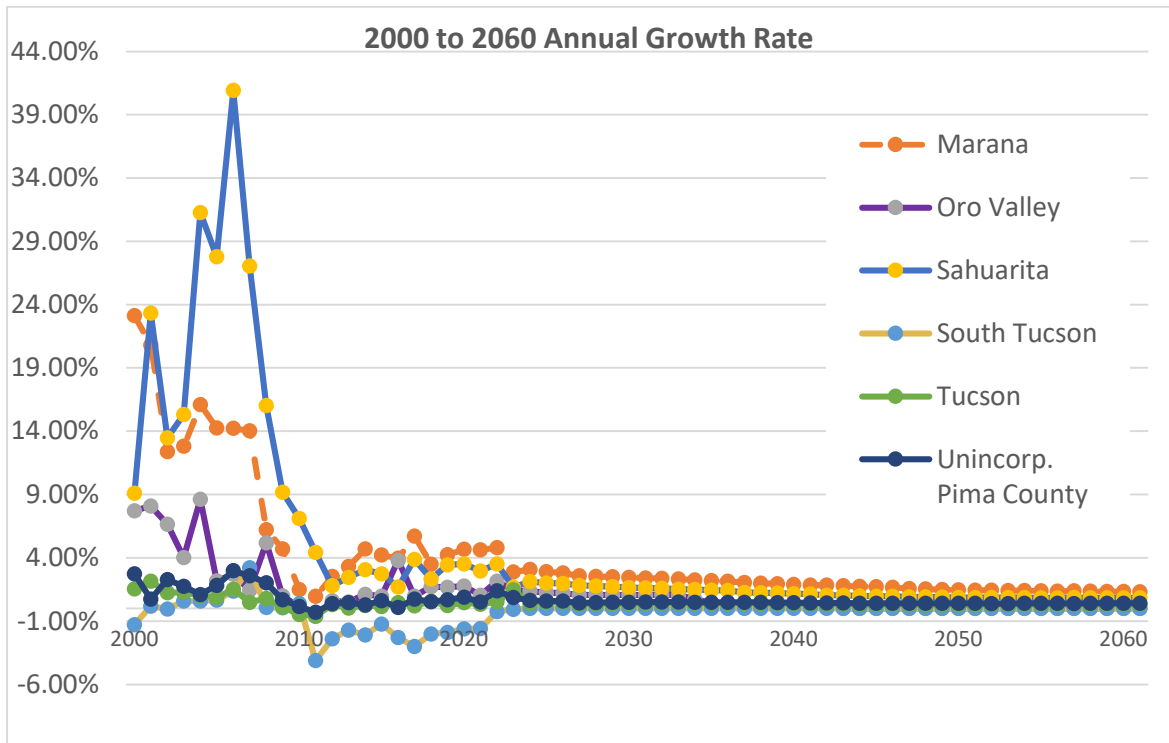


Figure 3. Growth Rate of County Total and Jurisdictions

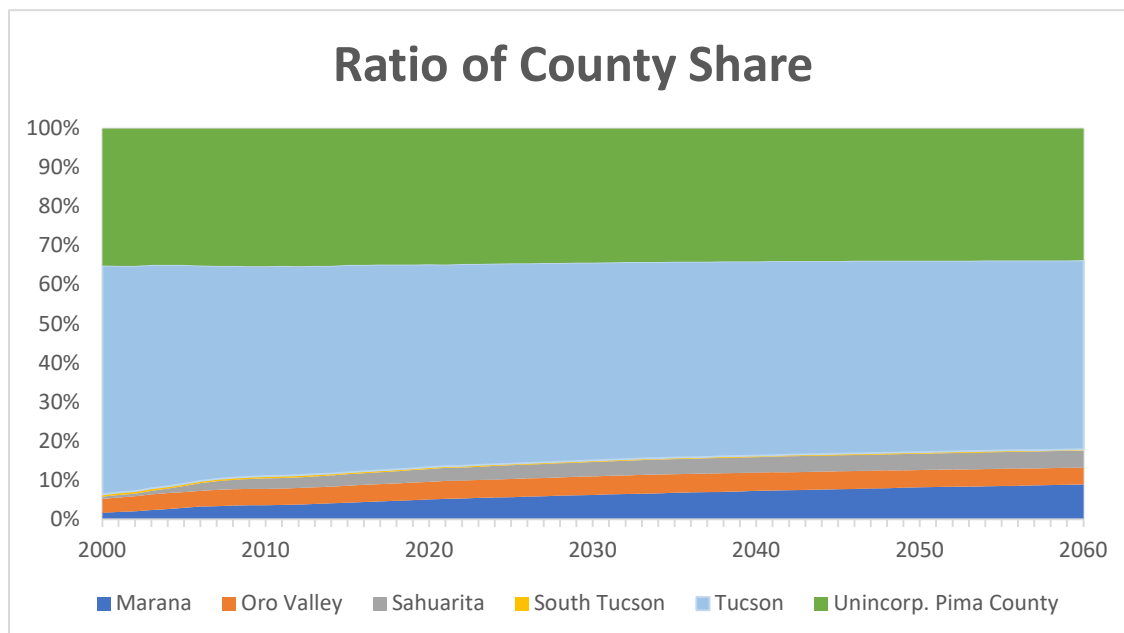


Figure 4. Jurisdictions Population Share of County