Results Appendix for: The Economic Origins of Government

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October 2022

For online publication only

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1 Additional figures

1.1 Rainfall patterns

In Figure RA1, we relate changes in rainfall in Turkey to river shifts in southern Iraq. The x-axis measures time, and the y-axis measures the first difference of the fifty year standard deviation of yearly rainfall. The source and construction of these data are described in the Data Appendix, section 3. Vertical lines indicate river shifts in Iraq, and the continuous line measures the time-series of rainfall. The idea of this graph is to provide intuition for the assertion by historians that river flow levels (see section 4 of the paper), the primary driver of river shifts in Iraq, are in turn driven by rainfall patterns in Turkey.

Figure RA1 provides graphical intuition for this assertion. The first river shift occurs coincidentally with increases in the volatility of rainfall in Turkey. For subsequent river shifts, there is variation in the certainty with which we know the years, and for some river shifts we use the variation in rainfall in Turkey to precisely date the river shift. We provide all detail in section 3 of the Data Appendix. Although it is impossible with the available data to provide a causal link between rainfall changes in Turkey and river shifts in Iraq, the available data support the take of historians on the ultimate - exogenous - source of changes in river flow level, and river shifts. We provide further supporting evidence for the exogeneity of river shifts in Table 2 in the paper.

2 Additional tables

This section provides several additional results, showing the robustness of the main results in our paper. There are two subsections. In the first, we estimate a cross-sectional model at the level of the grid cell. In this model, the independent variable of interest is an indicator equal to one if a grid cell ever experienced a river shift. This model allows us to study correlates of river shifts. In the second part, we estimate our stacked difference-in-differences model introduced in the paper.

2.1 Cross-sectional results

In this section we estimate a cross sectional model, with an indicator if a grid cell ever experienced a river shift as the variable of interest. These regressions show whether places that are in the center of the plain, where river shifts are concentrated, are different from places where no shifts take place. Note that for our main empirical analyses, we include a full set of grid cell fixed effects, accounting for such cross-sectional, time-invariant differences.

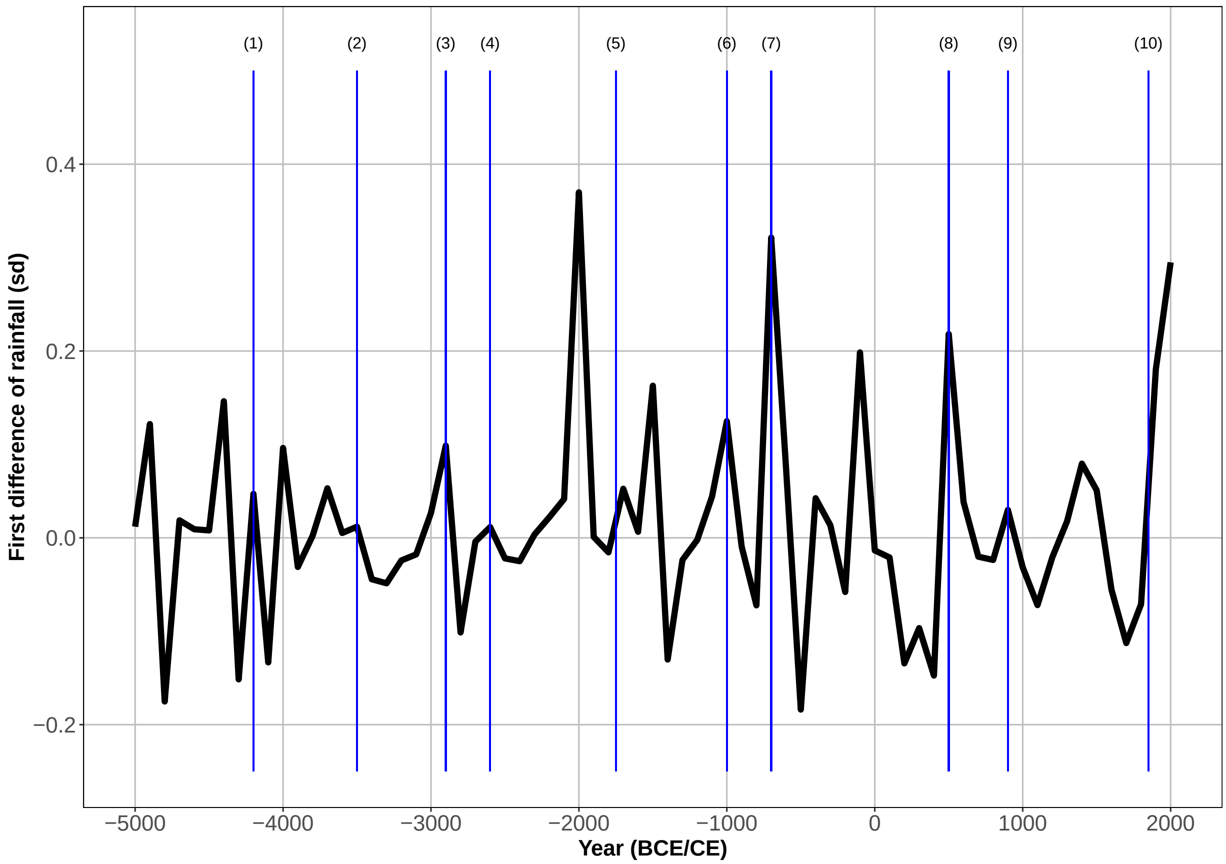
Formally, we estimate the following equation, using OLS:

$$Y_c = \alpha + \beta \times rivershift_c + \varepsilon_c \tag{1}$$

In this model, Y_c is an outcome of interest for grid cell c. $rivershift_c$ is an indicator equal to one if grid cell c ever experienced a river shift. ε_c is a heteroskedasticity robust standard error.

In table RA1 we show that river shifts are not concentrated in places that are inhabited today. This is important because we may expect density of archeological remains to be lower in urban areas or areas that are otherwise occupied. If occupation correlates with river shifts, we may be less likely to recover archeological remains. We study this issue by using data from the mid-twentieth century - before the main archeological excavations that we use in this paper had started. In column (1) the outcome variable is an indicator equal to one if a grid cell is on a canal in 1952. Since agricultural activity is concentrated near canals, we use this variable as a proxy for cultivated land, which may be harder to excavate if permission is given at all. In column (2) we use an indicator equal to one if a grid cell was indicated as 'cultivated' in 2000 by the Food and Agricultural Organization. We study these outcomes in a cross-section where we measure for each grid cell whether it ever experienced a river shift. Comparing cells that ever experienced a river shift to cells that never experienced a shift allows us to test whether river shifts happened

Figure RA1: RAINFALL AND RIVER SHIFTS



Notes: this graph relates changes in the 50 year standard deviation of rainfall in Turkey to changes in river courses in southern Iraq. These changes are numbered, and the numbers correspond to those in Table DA3 in the Data Appendix, which contain a description for each change. Six out of the ten changes in this graph are river shifts, other are changes in relative importance of river branches. The third change in the river course is the river shift that defines our main study period. The coincidence of increases in rainfall volatility and changing river courses supports the claim that river shifts ultimately result from increases in flow level brought on by increases in upstream rainfall.

disproportionally in places that today are cultivated. We find that cultivation today is not more likely to take place where rivers historically shifted, and we therefore do not think that differential success at discovering archeological artifacts due to present day cultivation is driving our results.

In table RA2 we study the geographical patterns of rainfall, temperature and soil productivity across our sample area. Columns present different dependent variables, and the first row presents estimates of β in equation 1. Columns 1 and 2 show that, on average, the center of the sample area experiences lower rainfall and higher temperatures. Column 3 shows that when relying only on rainfall, the center of the sample area is less suitable for growing barley (the main local staple crop). In other words, the part of our sample area where treatment is concentrated is less productive and more arid. However, column (4) provides evidence that when irrigated the center of the plain is more productive. This last result is in line with our historical data that show that when rivers move away, settlement tends to stay in the center of the plain, rather than to move with the rivers. Taken together, the results in this table show that there is a productivity differential that is realized when irrigating the center of the plain.

Table RA1: River shifts and contemporary outcomes (cross-section)

Dependent variable:	On canal 1952 (yes/no)	Bare land (yes/no)	Nearest city not excavated (yes/no)
	(1)	(2)	(3)
[1em] River shift (yes/no)	0.00	0.02	-0.01
	(0.02)	(0.02)	(0.02)
Mean dep. var.	0.23	0.16	0.08
Observations	1374	1374	1374

Notes: All regressions are estimated using OLS. On canal 1952 (yes/no) is an indicator equal to one if a grid cell was within 5km from an irrigation canal in 1952. Bare land (yes/no) is an indicator equal to one if a grid cell was bare (uncultivated and no tree cover) around 2000. Nearest city not excavated (yes/no) is an indicator equal to one if the nearest city to has not been excavated. River shift (yes/no) is an indicator equal to one if a grid cell ever experienced a river shift, across all river shifts in our dataset. A river shift in period t is defined as an indicator equal to one if the distance to the nearest river in period t-1 is different from the distance to the nearest river in period t. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA2: River shifts and geography (cross-section)

Dependent variable:	Average rainfall (mm)	Average temperature (C)	Barley suitability difference, (kg/ha)
	(1)	(2)	(3)
[1em] River shift (yes/no)	-1.96***	0.04**	545.75***
	(0.13)	(0.02)	(35.47)
Mean dep. var.	11.93	23.14	3307.61
Observations	1374	1374	1374

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. Average rainfall (mm) is rainfall in millimeters averaged over a grid cell. Average temperature (C) is the average temperature (Celsius) in a grid cell. Barley suitability difference (kg/ha) is the difference in suitability of the soil for growing barley when irrigated and when not irrigated, measured in kilograms per hectare of attainable production. River shift (yes/no) is an indicator equal to one if a grid cell ever experienced a river shift, across all river shifts in our dataset. A river shift in period t is defined as an indicator equal to one if the distance to the nearest river in period t-1 is different from the distance to the nearest river in period t. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

2.2 Main results: Robustness

In this section we present several robustness checks for the results in our main paper. These checks form two groups. First, we present additional results for the main finding of our paper, the effect of a river shift on state formation. Second, we present additional results for the other results in our paper. We will briefly discuss each robustness check in turn.

In Table RA3 we repeat Table 3 from our paper, reporting pre-period coefficients. All pre-period coefficients are small and insignificant. This suggests that one identifying assumption, the parallel trends assumption, is likely satisfied.

In Tables RA4 and RA5 we study the effect of the inclusion of fixed effects in our main specification. In our main specification we include unit fixed effects, time fixed effects, and several trends in covariates. In Table RA4 we remove all fixed effects. Our point estimate of interest is the treatment effect in the treatment period, coefficient *river shift (yes/no)*. If the treatment effect only appears when including fixed effect we would worry that the result is driven by our choice of regression specification. We find that this is not the case, the treatment effects without fixed effects are qualitatively similar to those with fixed effects in our paper. In Table RA5 we include only unit and period fixed effects, omitting other covariates. We similarly find that the treatment effects in the treatment period are similar. The exception is column (2) where the treatment effect disappears. This is due to a differential trend between the north and the south of our panel. The north was on a downward trend in terms of building, and the south on an upward trend. We capture these trends with our trends in the archeological survey areas, and we discuss these areas in the Data Appendix section 1.2. When we account for these trends in the main results table in our paper, we recover the treatment effect. Note that in both RA3 and RA4 we sometimes observe significant pre-period coefficients. These are always small relative to the treatment period coefficients and do not show a trend. Our main specification accounts for these differences through the inclusion of covariates.

In Table RA6 we re-estimate the main results from Table 3 in our paper using De Chaisemartin and d'Haultfoeuille (2020)'s estimator. This estimator accounts for potentially heterogeneous unit specific treatment effects. As treatment happens at the same time for all units, is discrete, and absorbing, we do not expect that using this estimator should make a big difference. We find similar treatment effects throughout.

In Table RA7 we vary the unit of observation from a five kilometer grid cell to a 10 kilometer grid cell. We adjust the definition of treatment accordingly: Grid cell c is treated if it had a river within 10 kilometers before the shift and farther than 10 kilometers after the shift. We find that all results are robust to changing the size of our artificial units of observation, but that they are estimated with less precision which is to be expected considering the reduction in the number of observations.

In Tables RA8 to RA12 we vary which sample of 5x5 kilometer grid cells we use. In the sample we use in the paper we impose two restrictions. We drop cells that saw a new river branch move closer to them (rather than farther away) and grid cells for which our archeological base data indicated that a particular stretch of the plain was not "sweep" surveyed owing to time constraints or physical obstacles, although being in principle within the scope of the project. In Table RA8 we keep the cells removed by these two procedures, thus recovering our full sample area of 1,374 cells within the scope of the series of "sweep" surveys described in section 1.2 of the Data Appendix. In Table RA9, we only exclude "treated closer" grid cells but keep the rest of the sample area. In Table RA10, we include "treated closer" grid cells but exclude unsurveyed areas. In other words, we report all possible combinations of our baseline sample restrictions. The results do not change. In Tables RA11 and RA12, we use more restrictive samples compared to the baseline sample in the main paper. In Table RA11, we exclude those small areas of the plain that the base archeological survey maps mark as "limited survey", which is to say surveyed with less precision. This change does not alter the results. In Table RA12 we change the sample more drastically to include only cells that are within 10 kilometers from the river before treatment. This means that the control group is now no longer all cells that did not experience a river shift, but all cells that did not experience a river shift and were close to a river before. Naturally, this reduces the sample size. We find qualitatively similar but slightly smaller, noisier, treatment effects, as we would expect.

In Tables RA13 through **??** we vary the definition of treatment. In the paper, a grid cell is treated if before a river shift the nearest river was within five kilometers of its centroid, and after treatment it is further than five kilometers. In Table RA13 we change the after-treatment cutoff to two kilometers. We then in steps move to 3.5, 7.5 and 10 kilometers (note that 5km is the main treatment) in Tables RA14, RA15, and RA16. For 2 kilometers, relatively few grid cells are treated and we get similar, but noisier results. For 3.5 and 7.5, results are similar to our main results. For 10 kilometers, we do not find significant results anymore. This is to be expected as 10 kilometers is typically too far away to directly irrigate from the river and we are therefore mismeasuring treatment when using this cutoff.

In the paper, we discuss the definition of our main outcome variable, our indicator equal to one if a grid cell is part of state. This indicator is constructed from two inputs, whether there is a government building in the nearest city (or within the boundaries of a state) and whether a grid cell is located within the borders of a state. In the paper we report robustness to the use of only the building information, omitting the information on boundaries. Here we vary which buildings we include. In the paper we include palaces, ziggurats and temples. In Table RA17 we just use palaces and ziggurats, the more prominent types of administrative buildings, for the definition of our outcome variable. We find that the main results are robust to this change, except for new cities where we do not have enough variation to estimate.

In Tables RA18, RA19 and RA20 we study another aspect of the definition of our outcome variable: The construction of boundaries in the pre-treatment periods. Before our treatment period, no states controlled territory beyond a small area around a city. Based on the historical literature, we choose a cutoff for this hinterland of six kilometers. Here we vary this cutoff. In Table RA18 we use 8 kilometers, in RA19 we use 12 kilometers and in Table RA20 we use 15 kilometers. We observe that treatment effects in the treatment period are stable and significant. As we increase the range, some of the pre-period coefficients become significant, although the estimated effects remain small relative to the treatment effect in the treatment period and between periods there is no trend. The significance is driven by the fact that all cities in pre-periods are next to a river and, therefore, with wider bandwidths, more of their adjacent cells are too. Since treatment means that a river moves, mechanically there will be more treated cells under a state as we increase the number of grid cells around a city (and next to a river). For inference, the important observation is the absence of a pre-trend.

In Table RA21 we show that we can include non-excavated cities in the sample. We assign these cities zero buildings. There are four unexcavated cities from our main study period which we discuss in the Data Appendix: Akshak, Bad Tibira, Kesh and Larak. The difference with the main sample is that grid cells that are nearest to a non-excavated city are now not under a state (since the nearest city has zero buildings) rather than missing from the sample. Results are virtually identical.

In Table RA22 we address potential spatial autocorrelation of the error term by double clustering the standard errors at a larger 10 kilometers grid cell level. The coarser clustering does not threaten inference. In Table RA23 we study robustness to the cutoff of the Conley standard errors we use to account for spatial correlation. We vary the cutoff from 484 kilometers (encompassing the entire sample area), to 242, to 121 and 66 kilometers, which is 1/2, 1/4, and 1/8 of the distance we use in the paper, respectively. We find that the standard errors are either identical or smaller than the ones computed with the largest cutoff distance. In addition, we report double clustered standard errors at the level of the grid cell and the city by period in parentheses. Our main conclusions are robust to using these alternative standard errors. In Table RA24, we further test robustness to spatial autocorrelation by running a Spatial Durbin model that incorporates both the spatial lags of the outcome(s) and those of the regressors. The spatial lags are computed through an inverse distance matrix. Explicitly modeling for potential spatial autocorrelation does not significantly alter our main results.[1]

In Table RA25 we perform a placebo check. Rather than studying a river shifting away, we study a river shifting closer. We define treatment analogously to a river shifting away: A river shifted closer if the centroid of a grid cell used to be further than 5 kilometers away from a grid cell and, after the shit, is within 5 kilometers. Table RA25 otherwise repeats the same structure of the main table so far. We find a consistently negative effect of a river shifting closer. This result is driven by the absence of states before and after treatment where rivers shift to, and the formation of states where the river shifted away. Since cells that are part of a state that formed as a result of a river shifting away are more likely to be in the control group of a river shifting closer, we find a negative treatment effect.

[1]Results are here estimated using OLS. Maximum Likelihood estimation does not change the results significantly.

Our last table in this section is not a robustness check but studies an alternative interpretation of the effect a river shifting away may have. Rivers and canals were used for transportation, and a river shift away may therefore alter trade patterns. Trade patterns, in turn, have been linked to the formation of states in ancient Iraq (Algaze, 2008). We measure trade (potential) in two ways. We first follow Harris (1954) and measure market potential. Let d_{ct} be the population density of grid cell c in period t and let d_{-ct} be the spatial lag of population density, as defined in section 7 of the main paper, of grid cell c in period t. We construct the time-varying market potential of grid cell c as $2d_{ct} + d_{-ct}$. In addition, we measure trade by archeological finds of cylinder seals in the nearest city to grid cell c. Long-distance trade containers were marked by imprinting a seal on traded goods. These 'cylinder seals' are found in archeological excavations, and we record an indicator equal to one if a cylinder seal was found in the nearest city to grid cell c. We report results in Table RA26 we provide results. We find a small and insignificant effect for both outcomes suggesting that changing trade patterns are not driving our main results.

Table RA3: REPORTING: ALL PRE-PERIOD COEFFICIENTS

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.00	0.00	-0.00	-0.00
	(0.00)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.00	0.00	0.00	-0.00
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no) t-2	0.00	0.01	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no)	0.14***	0.16***	0.11***	0.02
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4631	4424	4631	4631
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA4: FIXED EFFECTS: OMITTING ALL FIXED EFFECTS

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	-0.05***	-0.12***	-0.02***	-0.03***
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no) t-3	-0.05***	-0.12***	-0.02***	-0.03***
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no) t-2	-0.05***	-0.12***	-0.02***	-0.03***
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no)	0.31***	0.40***	0.29***	0.02
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4631	4424	4631	4631
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	N	N	N	N
Period x rainfall	N	N	N	N
Period x temperature	N	N	N	N
Period x urban	N	N	N	N

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA5: TRENDS: NO GROUP-SPECIFIC TIME-TRENDS

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.02***	0.01**	0.01	0.01**
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no) t-3	0.02***	0.01**	0.01***	0.01**
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no) t-2	0.01***	0.01**	0.01	0.01**
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no)	0.18***	-0.06	0.23***	-0.05**
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4631	4424	4631	4631
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	N	N	N	N
Period x rainfall	N	N	N	N
Period x temperature	N	N	N	N
Period x urban	N	N	N	N

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA6: ESTIMATOR: DE CHAISEMARTIN AND D'HAULTFOEUILLE (2020) ESTIMATOR

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
Placebo t-3	0.00	-0.01	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
Placebo t-2	0.00	-0.00	-0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
Placebo t-1	-0.01	-0.02*	-0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
Effect t-0	0.16***	0.13**	0.12***	0.04*
	(0.03)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	3699	3475	3699	3699
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using the estimator proposed by De Chaisemartin and d'Haultfoeuille (2020). The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. Distance to nearest capital (km) is the distance to the nearest capital city in kilometers. A capital city is a city that dominates at least one other city (see the data appendix). Distance is measured from a grid cell's centroid. Admin building area capital city (m2) is the total area in square meters of all palaces and ziggurats in the capital city that governs the nearest city. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). For each regression using distance to nearest capital as the outcome variable, we include an indicator equal to one if the nearest city is a capital city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA7: UNIT OF OBSERVATION: 10KM GRID CELLS

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.01	0.01	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)
river shift (yes/no) t-3	0.01	0.01	0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.01)
river shift (yes/no) t-2	0.01	0.01	0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.01)
river shift (yes/no)	0.17***	0.27***	0.12*	0.03
	(0.06)	(0.08)	(0.06)	(0.04)
Mean dep. var.	0.07	0.14	0.04	0.03
Observations	1335	1291	1335	1335
Clusters	268	268	268	268
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 10x10 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA8: SAMPLE: INCLUDE UNSURVEYED AREAS AND GRID CELLS WHERE THE RIVER SHIFTED TO

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no) t-3	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no) t-2	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no)	0.13***	0.15***	0.10***	0.03
	(0.03)	(0.04)	(0.03)	(0.02)
Mean dep. var.	0.06	0.11	0.03	0.03
Observations	6830	6411	6830	6830
Clusters	1374	1374	1374	1374
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA9: SAMPLE: INCLUDE UNSURVEYED AREAS

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.00*	0.00	-0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no) t-3	0.00*	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no) t-2	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no)	0.13***	0.14***	0.10***	0.03
	(0.03)	(0.04)	(0.03)	(0.02)
Mean dep. var.	0.06	0.12	0.04	0.03
Observations	5971	5596	5971	5971
Clusters	1200	1200	1200	1200
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA10: Sample: Include grid cells where the river shifted to

Dependent variable:	Under city state (yes/no)		New state (yes/no)	Existing state (yes/no)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.00	0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no) t-3	0.00	0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no) t-2	0.00	0.01	0.01	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no)	0.14***	0.17***	0.12***	0.02
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.05	0.12	0.03	0.03
Observations	5430	5193	5430	5430
Clusters	1094	1094	1094	1094
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA11: SAMPLE: EXCLUDE LIMITED SURVEY AREAS

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.00	0.00	-0.00	-0.00
	(0.00)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.00	0.00	0.00	-0.00
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no) t-2	0.00	0.01	0.01	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no)	0.11***	0.16***	0.08**	0.02
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.06	0.13	0.03	0.03
Observations	4386	4261	4386	4386
Clusters	883	883	883	883
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA12: SAMPLE: ONLY GRID CELLS ADJACENT TO A RIVER

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.01	0.01	0.00	-0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.01	0.01	0.01*	-0.00
	(0.01)	(0.01)	(0.00)	(0.00)
river shift (yes/no) t-2	0.01*	0.01	0.01*	-0.00
	(0.00)	(0.01)	(0.01)	(0.00)
river shift (yes/no)	0.08**	0.12**	0.05	0.02
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.07	0.12	0.05	0.03
Observations	2660	2565	2660	2660
Clusters	532	532	532	532
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA13: TREATMENT: TREATED IF RIVER WAS < 2KM BEFORE THE SHIFT

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	-0.00	-0.00	-0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	-0.00	-0.00	-0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-2	-0.00	-0.00	-0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no)	0.08*	0.10*	0.07*	0.01
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4631	4424	4631	4631
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 2 kilometers in period t-1 and is further than 2 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA14: TREATMENT: TREATED IF RIVER WAS < 3,5KM BEFORE THE SHIFT

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.01	0.01	-0.00	0.00
	(0.00)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.01	0.01	0.01	0.00
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no) t-2	0.01	0.01	0.01	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no)	0.15***	0.21***	0.10**	0.05**
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4631	4424	4631	4631
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 10 kilometers in period t-1 and is further than 10 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA15: TREATMENT: TREATED IF RIVER WAS < 7.5KM BEFORE THE SHIFT

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.01	0.01	-0.00	0.00
	(0.00)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.01	0.01	0.01	0.00
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no) t-2	0.01	0.01	0.01	0.00
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no)	0.06*	0.11**	0.06	0.00
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4631	4424	4631	4631
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 10 kilometers in period t-1 and is further than 10 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA16: TREATMENT: TREATED IF RIVER WAS < 10KM BEFORE THE SHIFT

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.01	0.01	-0.00	0.00
	(0.00)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.01	0.01	0.01	0.00
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no) t-2	0.00	0.01*	0.00	0.00
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no)	0.03	0.06	0.05	-0.02
	(0.04)	(0.06)	(0.04)	(0.01)
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4631	4424	4631	4631
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 10 kilometers in period t-1 and is further than 10 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA17: State definition: Using only palaces and ziggurats

Dependent variable:	Under city state (yes/no)		New state (yes/no)	Existing state (yes/no)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.01*	0.00	-0.00	NA
	(0.00)	(0.00)	(0.01)	
river shift (yes/no) t-3	0.01*	0.00	0.01*	NA
	(0.00)	(0.00)	(0.00)	
river shift (yes/no) t-2	0.00	-0.00	0.00	NA
	(0.00)	(0.01)	(0.00)	
river shift (yes/no)	0.13***	0.12***	0.11***	NA
	(0.04)	(0.04)	(0.04)	
Mean dep. var.	0.03	0.03	0.03	0.01
Observations	4631	4424	4631	4660
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA18: STATE DEFINITION: USE 8KM FOR CITY HINTERLAND

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.01**	0.01*	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.01**	0.01*	0.01**	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-2	0.01**	0.01**	0.01*	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no)	0.14***	0.16***	0.12***	0.02
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.06	0.13	0.03	0.03
Observations	4628	4424	4628	4628
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA19: STATE DEFINITION: USE 12KM FOR CITY HINTERLAND

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.03***	0.03***	0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.03***	0.03***	0.02***	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-2	0.02***	0.03***	0.02***	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no)	0.15***	0.18***	0.13***	0.02
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.08	0.15	0.04	0.04
Observations	4622	4424	4622	4622
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA20: State definition: Use 15km for city hinterland

Dependent variable:	Under city state (yes/no)		New state (yes/no)	Existing state (yes/no)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.03***	0.04***	0.01	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.03***	0.04***	0.03***	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-2	0.03***	0.04***	0.02***	0.00
	(0.01)	(0.01)	(0.01)	(0.00)
river shift (yes/no)	0.15***	0.18***	0.14***	0.02
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.09	0.15	0.04	0.05
Observations	4619	4424	4619	4619
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA21: STATE DEFINITION: SET TO ZERO IF NEAREST CITY IS NOT EXCAVATED

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.00	0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.01)	(0.00)
river shift (yes/no) t-3	0.00	0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no) t-2	0.00	0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no)	0.13***	0.16***	0.11***	0.02
	(0.04)	(0.05)	(0.04)	(0.02)
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4655	4660	4655	4655
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA22: INFERENCE: CLUSTER AT 10KM GRID CELL LEVEL

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	0.00	0.00	-0.00	-0.00
	(0.00)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.00	0.00	0.00	-0.00
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no) t-2	0.00	0.01	0.00	-0.00
	(0.00)	(0.01)	(0.00)	(0.00)
river shift (yes/no)	0.14***	0.16***	0.11**	0.02
	(0.05)	(0.06)	(0.05)	(0.02)
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4631	4424	4631	4631
Clusters 1	932	932	932	932
Clusters 2	297	297	297	297
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the a 10 by 10 kilometer grid are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA23: INFERENCE: CONLEY CUTOFFS AND DOUBLE CLUSTERING CITY X PERIOD

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no)	0.14**	0.16**	0.11*	0.02
	(0.06)	(0.07)	(0.06)	(0.02)
P-value pre-trend	0.81	0.66	0.81	0.69
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4631	4424	4631	4631
Clusters 1 - Grid cells	932	932	932	932
Clusters 2 - City x period	70	63	70	70
Conley SE 66 km	0.06	0.05	0.06	0.02
Conley SE 121 km	0.06	0.05	0.06	0.02
Conley SE 242 km	0.04	0.05	0.05	0.01
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Each column reports several standard errors. First, Conley (1999) standard errors with different cutoffs. In parentheses, we report double clustered standard errors at the grid cell level and at the city x period level. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA24: SPATIAL CORRELATION: DURBIN MODEL

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
river shift (yes/no)	0.09***	0.11***	0.10***	-0.01
	(0.03)	(0.04)	(0.02)	(0.02)
P-value pre-trend	0.14	0.74	0.12	0.64
Mean dep. var.	0.06	0.12	0.03	0.03
Observations	4631	4424	4631	4631
Clusters	932	932	932	932
Using reconstructed borders	Y	N	Y	Y
Outcome's spatial lag	Y	Y	Y	Y
Regressors' spatial lag	Y	Y	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. Each column includes the spatial lag of the outcome variable as well as the spatial lags of river shift (yes/no). The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA25: PLACEBO: SHIFTING CLOSER

Dependent variable:	UNDER CITY STATE (YES/NO)		NEW STATE (YES/NO)	EXISTING STATE (YES/NO)
	(1)	(2)	(3)	(4)
[1em] river shift closer (yes/no) t-4	0.02*	0.01	0.00	0.01**
	(0.01)	(0.01)	(0.01)	(0.00)
river shift closer (yes/no) t-3	0.02*	0.01	0.01	0.01**
	(0.01)	(0.01)	(0.01)	(0.00)
river shift closer (yes/no) t-2	0.01	0.00	-0.00	0.01**
	(0.01)	(0.01)	(0.01)	(0.00)
river shift closer (yes/no)	-0.03	-0.09**	-0.00	-0.03
	(0.03)	(0.04)	(0.02)	(0.02)
Mean dep. var.	0.05	0.12	0.02	0.03
Observations	4790	4603	4790	4790
Clusters	966	966	966	966
Using reconstructed borders	Y	N	Y	Y
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. New state (yes/no) is an indicator equal to one if the grid cell is part of a state that did not exist in the previous period. Existing state (yes/no) is an indicator equal to one if the grid cell is part of a state that existed in the previous period. River shift closer (yes/no) is an indicator equal to one if the nearest river was further than 5 kilometers in period t-1 and is within 5 kilometers in period t (distances measured from the cell centroid). Using reconstructed borders indicates whether we use reconstructions of historical state borders to define whether a grid cell was part of a state. If this is not the case, we only use information on building activity in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA26: INTERPRETATION: TRADE

Dependent variable:	Market Potential	Seal (yes/no)
	(1)	(2)
river shift (yes/no)	-26.36	0.05
	(273.43)	(0.04)
P-value pre-trend	0.80	0.25
Mean dep. var.	14036.90	0.06
Observations	4320	4388
Clusters	932	932
Conley SE	279.67	0.03
Period x archeological excavation	Y	Y
Period x rainfall	Y	Y
Period x temperature	Y	Y
Period x urban	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Market potential is market potential following Harris (1954). We introduce the construction of this variable in the discussion at the start of this appendix. Seal (yes/no) is an indicator equal to one if a cylinder seal was found in the nearest city. All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

2.3 Additional results: Robustness

In this section we discuss several robustness and additional results for Tables 4 to 6 in our paper, as well as several validation exercises for our use of cuneiform tablets as a source of information about government.

In Table RA27 we report all lag coefficients for Table 4, to study pre-trends. We find no evidence for pre-trends in any outcome. In Table RA28, we report double clustered standard errors for our results in Table 4. All outcomes in this table, save our indicator for whether a grid cell is on a canal, vary at the level of the nearest city. We therefore double cluster at the level of the grid-cell and the city-period. We find that the effect of a river shift on being on a canal is unaffected, as we expect, and that treatment effects on the other outcomes become less precisely estimated. P-values are around the 10% level.

In Table 4 in our paper, we use an indicator equal to one if we have record of tribute being paid in the city nearest to a grid cell. We find that a river shifting away increases the probability of such a tablet being found. In Table RA29 we study the robustness of this finding to several ways of measuring the presence of tribute payments from cuneiform tablets. The consensus is that the majority of surviving tablets from our main study period report economic transactions that were recorded for tribute payment or redistribution: "Overall, the available evidence suggests that there was more administrative concern with the distribution of goods than with their production. Texts record goods issued and received; [...] The administrative concern with the exchange in contrast with the apparent lack of interest in production suggests that elites may have been content to allow producers to raise animals, grow crops, and manufacture products in whatever way they chose as long as tribute demands were met." (Pollock, 1999, pp.112-3).[2] We therefore start out by simply using an indicator equal to one if any tablet survives from the city nearest to a grid cell. When we use this as the dependent variable in our standard panel difference-in-differences model we find a positive and significant effect of a river shifting away on the presence of a tablet. A river shifting away is associated with a doubling of the probability of observing a tablet in the nearest city. Our source for these tablets, the Cuneiform Digital Library initiative, has classified into categories based on experts' opinions. Examples of categories are lexical, religious, or administrative. We code an indicator equal to one if at least one tablet in the nearest city has been classified as administrative and use this indicator as our outcome variable in column (2). We find that a river shifting away increase the probability of having an admin tablet by about 50% relative to the sample mean. In columns 3 and 4 we use the content of the tablets to zoom in further. In the Data Appendix, section 8.2, we show how we use the fact that many tablets have been transliterated from Sumerian cuneiform signs a transliterated text in the Latin alphabet. We also provide a list of tribute related keywords. With these keywords, we code an indicator equal to one if at least one tablets in the city nearest to a grid cell has a tablet that mentions tribute. We find that a river shifting away is associated with a large increase in the probability of having a tablet that mentions tribute (sample mean: 0.04. Point estimate: 0.10 (s.e. 0.04)). Note, however, that before our treatment period no tablets mention tribute. Many tablets that are ostensibly records of tribute payment do not actually mention tribute but are simply itemized lists of items paid as tribute that were likely implicitly understood as records of transactions. We record the most common items and code an indicator if there is either a mention of such items or of tribute on a tablet found in the nearest city. We find a large increase in the probability of finding such a tablet in the nearest city when a river shifts away (sample mean: 0.18. Point estimate: 0.10 (s.e. 0.05)).

In Table RA30 we report all lag coefficients for Table 5 in the main paper. We do not find any pre-trends.

In our paper, we report results on the functioning of government as bar graphs, in Figure 6. Here, instead, we report regression results. We start by coding an indicator equal to one if we observe the term 'lugal' being used in a tablet. 'Lugal' refers to the head of a ruling lineage. We also search for the term 'gal', which is a generic term indicating seniority, often used in the sense of "chief". In addition we code indicators for the presence of tax words (like above) and words for canal. In the Data Appendix, section 8.2, we discuss the coding procedure for these variables. We use these indicators to compute the fraction of tablets mentioning a certain term over the total number of excavated tablets in a given city and period. We report results in Table RA31. We find a positive treatment effect of a river shifting away on all outcome

[2] See also Englund (2011) and Nissen (1993, 1986) on the interpretation of early cuneiform writing exclusively as an accounting device employed to record economic transactions. Section 8 of the Data Appendix provides a more extensive discussion of this issue.

variables. We probe this conclusion further by re-estimating the same regressions, as in Table RA31, this time including an additional indicator equal to one if any tablet has been found in the nearest city to a grid cell. We report this result in Table RA32. The most instructive exercise in this table is to compare the sizes of point estimates across columns relative to their respective means. When we do this we find that the results for 'lugal' and canals are the strongest. The reason why we do not show this Table in the paper is that a lot of the cross-sectional (within period) variation comes from having a tablet in the first place (the extensive margin) than just from talking about specific topics more frequently. For this reason, we show the before-after comparison in the paper.

In Tables RA33 and RA34 we study the robustness of Table 6 in our paper to changing the estimator. In our paper we use a standard two way fixed effect model. Such models may produce misleading results in the presence of heterogeneous effects across periods and units De Chaisemartin and d'Haultfoeuille (2020). We present two alternative models, one that separates each river shifts and stacks the individual results into an aggregate result, and the model proposed by De Chaisemartin and d'Haultfoeuille (2020). In Table RA33 we estimate a stacked panel difference-in-differences model. Intuitively, for each period t, we construct a short-run panel covering four periods before treatment and one after. This results in 26, 5-period panels.[3] We then stack each of these experiments into a larger panel. Formally, the equation we estimate has the following form:

$$Y_{ctk} = \gamma_{ct} + \sum_{k=-4}^{0} \beta_{tk} \times \mathbb{1}(period_{tk}) + \sum_{k=-4}^{0} \beta_{tk}^{treatment} \times \mathbb{1}(period_{tk}) \times treated_{ct} + \rho_{ctk} + \varepsilon_{ctk} \tag{2}$$

Here Y_{ctk} is an outcome of interest for grid cell c in the experiment centered on period t and period relative to treatment k. γ_{ct} is a vector of experiment by grid cell fixed effects, which are constant across periods k. We allow for different grid cell averages by experiment t. $\sum_{k=-4}^{0} \beta_{tk} \times \mathbb{1}(period_{tk})$ is a vector of period-relative-to-treatment fixed effects multiplied with period-varying coefficients β_{tk}. We allow these effects to vary within each short panel as well and we express all effects relative to the last pre-treatment period, $k = -1$. $\sum_{k=-4}^{0} \beta_{tk}^{treatment} \times \mathbb{1}(period_{tk}) \times treated_{ct}$ is the vector of period-relative-to-treatment fixed effects multiplied with an indicator $treated_{ct}$ which is equal to one if grid cell c is treated in period $k = 0$ in within short panel t. This indicator is time-invariant within a short panel and the $\beta_{tk}^{treatment}$ capture the time-varying effect of being treated in $k = 0$ through their multiplication with the period-relative-to-treatment fixed effects. Since we express all effects relative to period $k = -1$ we obtain two coefficients of interest: $\beta_0^{treatment}$, the treatment effect for treated grid cells in the treatment period and $\beta_{-n}^{treatment}$, the treatment effect for treated grid cells in periods $k = -4$ to $k = -2$. Whereas the latter coefficients measures pre-trends relative to period $k = -1$ (of which we only report a joint test of statistical significance for all coefficients), $\beta_0^{treatment}$ is the coefficient of interest in this model: the measured effect of a river shift on outcome Y_{ctk}, across experiments t. We report this coefficient in Table RA33 which mimics the structure of Table 6 in our paper. We find very similar effects.

In Table RA34 we use the estimator proposed by De Chaisemartin and d'Haultfoeuille (2020). This estimator accounts for heterogeneous effects between units of observation, which may threaten estimation in regular linear models. We find that results are very similar to our results with a linear model.

[3]For the first four periods out of 31 in our sample, we do not have four pre-periods.

Table RA27: REPORTING: ALL LAGS FOR TABLE 4

	PUBLIC GOOD PROVISION (YES/NO)		ADMINISTRATION	
Dependent variable:	Canal	Wall	Tribute (yes/no)	N. Admin. Build.
	(1)	(2)	(3)	(4)
river shift (yes/no) t-4	-0.03	-0.00	0.05	-0.00
	(0.04)	(0.03)	(0.04)	(0.11)
river shift (yes/no) t-3	-0.04	-0.00	0.05	-0.04
	(0.03)	(0.03)	(0.04)	(0.14)
river shift (yes/no) t-2	0.01	-0.01	0.08	0.21
	(0.04)	(0.01)	(0.07)	(0.53)
river shift (yes/no)	0.12***	0.11**	0.21***	0.44***
	(0.03)	(0.04)	(0.06)	(0.15)
Mean dep. var.	0.28	0.14	0.19	0.70
Observations	4320	4424	4424	4424
Clusters	932	932	932	932
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Canal (yes/no) is an indicator variable equal to one if there is a canal within five kilometers (distances measured from the cell centroid). Wall (yes/no) is an indicator variable equal to one if there is a defensive wall in the nearest city. Tribute (yes/no) is an indicator variable equal to one if a cuneiform tablet was excavated in the nearest city. Nr. of admin buildings is the sum of the number of palaces, the number of temples, and the number of ziggurats in the nearest city. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA28: INFERENCE: DOUBLE CLUSTERING CITY X PERIOD

	PUBLIC GOOD PROVISION (YES/NO)		ADMINISTRATION	
Dependent variable:	Canal	Wall	Tribute (yes/no)	N. Admin. Build.
	(1)	(2)	(3)	(4)
river shift (yes/no)	0.12***	0.11	0.21*	0.44
	(0.04)	(0.06)	(0.11)	(0.30)
P-value pre-trend	0.87	0.75	0.50	0.73
Mean dep. var.	0.28	0.14	0.19	0.70
Observations	4320	4424	4424	4424
Clusters 1 - Grid cells	932	932	932	932
Clusters 2 - City x period	69	63	63	63
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Canal (yes/no) is an indicator variable equal to one if there is a canal within five kilometers (distances measured from the cell centroid). Wall (yes/no) is an indicator variable equal to one if there is a defensive wall in the nearest city. Tribute (yes/no) is an indicator variable equal to one if a cuneiform tablet was excavated in the nearest city. Nr. of admin buildings is the sum of the number of palaces, the number of temples, and the number of ziggurats in the nearest city. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level as well as at the city x period level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA29: VALIDATION: TABLETS AS PROXY FOR TRIBUTE

Dependent variable:	Tablet (yes/no)	Admin Tablet (yes/no)	Tax Tablet (yes/no)	Tax/food Tablet (yes/no)
	(1)	(2)	(3)	(4)
river shift (yes/no)	0.21***	0.12*	0.09**	0.10*
	(0.06)	(0.06)	(0.04)	(0.05)
P-value pre-trend	0.21	0.21	0.12	0.22
Mean dep. var.	0.33	0.31	0.03	0.23
Observations	2466	2466	2430	2430
Clusters	827	827	827	827
Conley SE	0.10	0.08	0.05	0.10
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Tablet (yes/no) is an indicator variable equal to one if at least one cuneiform tablet was found in the in the nearest city. Admin Tablet (yes/no) is an indicator variable equal to one if at least one cuneiform tablets that has been categorized by the Cuneiform Digital Library Initiative as administrative was found in the nearest city. Tax Tablet (yes/no) is an indicator variable equal to one if at least one cuneiform tablet excavated in the nearest city contains at least one word that indicates tribute payment. Tax/food Tablet (yes/no) is an indicator variable equal to one if at least one cuneiform tablet excavated in the nearest city contains at least one word that indicates tribute payment. We expand the definition of what constitutes such a word from direct references to tribute payment to mentions of items that were commonly used to pay tribute with. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA30: REPORTING: ALL LAGS FOR TABLE 5

Dependent variable:	UNDER CITY STATE (YES/NO)				
	(1)	(2)	(3)	(4)	(5)
	PANEL I: SOCIAL RETURNS AND COSTS OF CANAL BUILDING				
		SOCIAL RETURNS *Population density*		SOCIAL COSTS *Settl. aligned for canals*	
Sample:	*Full sample*	*High*	*Low*	*Aligned*	*Misaligned*
river shift (yes/no) t-4	0.00	-0.00	-0.01*	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
river shift (yes/no) t-3	0.00	-0.00	-0.01*	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
river shift (yes/no) t-2	0.00	-0.00	-0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
river shift (yes/no)	0.14***	0.18***	0.03**	0.22***	-0.01
	(0.04)	(0.05)	(0.02)	(0.06)	(0.03)
Mean dep. var.	0.06	0.07	0.04	0.08	0.03
Observations	4631	2323	2308	2365	2266
Clusters	932	465	467	477	455
	PANEL II: GEOGRAPHIC RETURNS AND COSTS OF CANAL BUILDING				
		GEOGRAPHIC RETURNS *Δ potential productivity*		GEOGRAPHIC COSTS *Water flow nearest river*	
Sample:	*Full sample*	*High Δ*	*Low Δ*	*High flow*	*Low flow*
river shift (yes/no) t-4	0.00	0.00	0.01	0.01	0.01
	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-3	0.00	0.00	0.01	0.01	0.01
	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)
river shift (yes/no) t-2	0.00	0.00	0.00	0.01	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
river shift (yes/no)	0.14***	0.16***	-0.05***	0.10**	0.03
	(0.04)	(0.05)	(0.02)	(0.05)	(0.06)
Mean dep. var.	0.06	0.07	0.04	0.08	0.02
Observations	4631	2319	2311	2775	1856
Clusters	932	465	467	555	377
Covariates (all regressions):					
Period x archeological excavation	Y	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. All estimated coefficients are standardized. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Under city state (yes/no) is an indicator equal to one if the grid cell is part of a state. We split the sample by four indicator variables, measuring social returns, social costs, geographical returns, and geographic costs. Change in potential productivity returns to irrigation is an indicator equal to one if the difference between the suitability of the soil for irrigated and rainfed cultivation of barley is above its median. Slow water flow is an indicator equal to one if the nearest river is the slow-flowing Euphrates and zero if the nearest river is the fast-flowing Tigris and Diyala river courses. Slower flowing rivers are easier to irrigate from as they cut less deep into the landscape. High settlement density area is an indicator equal to one if the spatial lag of the number of settlements in period t-1 is above its median. Settlement misaligned for canals is an indicator equal to one if the number of settlements aligned suitably for canal construction is lower than the number of settlement that are misaligned in period t-1. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA31: TEXT ANALYSIS OF CUNEIFORM TABLETS

	TABLET RATIO			
Dependent variable:	Lineage head	Chief	Canal	Tribute
	(1)	(2)	(3)	(4)
river shift (yes/no)	0.08**	0.09***	0.09***	0.10***
	(0.03)	(0.03)	(0.03)	(0.03)
P-value pre-trend	0.70	0.33	0.03	0.62
Mean dep. var.	0.03	0.04	0.03	0.02
Observations	2430	2430	2430	2430
Clusters	827	827	827	827
Conley SE	0.05	0.04	0.05	0.04
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Lineage head is the fraction of cuneiform tablets in the nearest city that contain a reference to the 'lugal'. Chief is the fraction of cuneiform tablets in the nearest city that contain a reference to 'gal'. Canal is the fraction of cuneiform tablets in the nearest city that contain a reference to the canals. Tribute is the fraction of cuneiform tablet in the nearest city that contain a reference to tribute payment. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA32: TEXT ANALYSIS OF CUNEIFORM TABLETS INCLUDING TABLET INDICATOR

	TABLET RATIO			
Dependent variable:	Lineage head	Chief	Canal	Tribute
	(1)	(2)	(3)	(4)
tablet	0.10***	0.11***	0.10***	0.08***
	(0.01)	(0.01)	(0.01)	(0.01)
river shift (yes/no)	0.06*	0.07**	0.07**	0.08**
	(0.03)	(0.03)	(0.03)	(0.03)
P-value pre-trend	0.25	0.60	0.40	0.24
Mean dep. var.	0.03	0.04	0.03	0.02
Observations	2430	2430	2430	2430
Clusters	827	827	827	827
Conley SE	0.01	0.01	0.01	0.04
Period x archeological excavation	Y	Y	Y	Y
Period x rainfall	Y	Y	Y	Y
Period x temperature	Y	Y	Y	Y
Period x urban	Y	Y	Y	Y

Notes: All regressions are estimated using OLS. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Lineage head is the fraction of cuneiform tablets in the nearest city that contain a reference to the 'lugal'. Chief is the fraction of cuneiform tablets in the nearest city that contain a reference to 'gal'. Canal is the fraction of cuneiform tablets in the nearest city that contain a reference to the canals. Tribute is the fraction of cuneiform tablet in the nearest city that contain a reference to tribute payment. Tablet (yes/no) is an indicator variable equal to one if at least one cuneiform tablet was found in the in the nearest city. River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before treatment. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA33: ESTIMATOR: STACKED PANEL

Dependent variable:	CANAL (YES/NO)		
Period:	5000BCE-1950CE	5000BCE-2350BCE	2350BCE-1950CE
State:	All	First states	Subsequent states
	(1)	(2)	(3)
[1em] river shift (yes/no)	0.10***	0.13***	0.08***
	(0.02)	(0.03)	(0.03)
P-value pre-trend	0.67	0.62	0.30
Mean dep. var.	0.43	0.22	0.49
Observations	124653	28739	95914
Clusters	1094	1094	1094
Period x archeological excavation	Y	Y	Y
Period x rainfall	Y	Y	Y
Period x temperature	Y	Y	Y
Period x urban	Y	Y	Y

Notes: All regressions are estimated using the stacked panel estimator described in the introductory paragraph to this section. The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Canal (yes/no) is an indicator variable equal to one if there is a canal within five kilometers (distances measured from the cell centroid). River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before the first river shift. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

Table RA34: ESTIMATOR: DE CHAISEMARTIN AND D'HAULTFOEUILLE (2020) ESTIMATOR

Dependent variable:	CANAL (YES/NO)		
Period:	5000BCE-1950CE	5000BCE-2350BCE	2350BCE-1950CE
State:	All	First states	Subsequent states
	(1)	(2)	(3)
Placebo t-4	-0.00	-0.02	0.02
	(0.02)	(0.02)	(0.02)
Placebo t-3	-0.00	-0.02	-0.01
	(0.01)	(0.02)	(0.01)
Placebo t-2	0.02	0.01	0.02
	(0.02)	(0.03)	(0.02)
Placebo t-1	-0.02	-0.00	-0.03**
	(0.01)	(0.02)	(0.02)
Effect t-0	0.11***	0.11***	0.09***
	(0.02)	(0.03)	(0.03)
Mean dep. var.	0.39	0.20	0.51
Observations	22494	7013	14740
Clusters	1094	1094	1094
Period x archeological excavation	Y	Y	Y
Period x rainfall	Y	Y	Y
Period x temperature	Y	Y	Y
Period x urban	Y	Y	Y

Notes: All regressions are estimated using the estimator proposed by De Chaisemartin and d'Haultfoeuille (2020). The cross-sectional unit of observation is a 5x5 kilometer grid cell. The time-series period is an archeological period. We describe periodization in our Data Appendix section 1.3. Canal (yes/no) is an indicator variable equal to one if there is a canal within five kilometers (distances measured from the cell centroid). River shift (yes/no) is an indicator equal to one if the nearest river was within 5 kilometers in period t-1 and is further than 5 kilometers away in period t (distances measured from the cell centroid). All regressions include period and grid cell fixed effects. Period x archeological excavation is a vector of period fixed effects interacted with indicators for each of the three main archeological surveys of settlement we use. These surveys are described and mapped in the Data Appendix sections 1.2 and 4. Period x rainfall is a vector of period fixed effects interacted with average rainfall. Period x temperature is a vector of period fixed effects interacted with average temperature. Period x urban is a vector of period fixed effects interacted with an indicator equal to one if a grid cell contained a city in the last pre-period before the first river shift. Heteroskedasticity robust standard errors clustered at the grid cell level are in parentheses. * indicates significance at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level.

References

Algaze, G. (2008). *Ancient Mesopotamia at the Dawn of Civilization: the Evolution of an Urban Landscape*. Chicago: University of Chicago Press.

De Chaisemartin, C. and X. d'Haultfoeuille (2020). Two-way fixed effects estimators with heterogeneous treatment effects. *American Economic Review 110*(9), 2964–96.

Englund, R. (2011). Accounting in proto-cuneiform. In K. Radner and E. Robson (Eds.), *The Oxford Handbook of Cuneiform Culture*, pp. 32–50. Oxford: Oxford University Press.

Harris, C. D. (1954). The market as a factor in the localization of industry in the united states. *Annals of the association of American geographers 44*(4), 315–348.

Nissen, H. (1993). The context of the emergence of writing in Mesopotamia and Iran. In J. Curtis (Ed.), *Early Mesopotamia and Iran: contact and conflict 3500-1600 BC: proceedings of a seminar in memory of Vladimir G. Lukonin*, pp. 54–71. London: British Museum Press.

Nissen, H. J. (1986). The archaic texts from uruk. *World archaeology 17*(3), 317–334.

Pollock, S. (1999). *Ancient Mesopotamia: the Eden that never was*. Cambridge: Cambridge University Press.

Data Appendix for: The Economic Origins of Government

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October 2022

For online publication only

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Contents

1 Introduction

This appendix provides a description of the sources and methodology that we used to create the dataset of our paper "The Economic Origins of Government". It also discusses potential pitfalls in the use of archeological data in economics. Our dataset covers a period spanning from the formation of the first permanent agricultural settlements in southern Iraq around 5000BCE, to the 1950CE, with an average frequency of 235 years. We have created a complete dataset of changing river courses, settlement, state formation, and public good provision in southern Iraq which is, to the best of our knowledge, an unprecedented attempt to collect longitudinal data on economic activity anywhere in the world. The scope of the data collection is best exemplified by some statistics for the main variables: we have information on a total of 13,131 unique settlements and 1,117 canals, 222 administrative buildings, 35 city walls and roughly 170,000 cuneiform tablets.

For our main results, we focus on a 'main study period' of five archeological periods covering between 3900BCE and 2700BCE. Within these 1200 years, we observe the emergence of the first states and a major river shift towards the end of the period, around 2850BCE. We focus on this main study period as this allows to estimate the effect of the first recorded river shift in the study area. For some estimates in the paper, we employ data for the full extent of our dataset. We call this our 'extended study period', and this period covers almost the entire history of human activity in southern Iraq. The extended study period includes an additional 5 major river shifts. We provide information on the data collection for both our extended and main study periods in both text and tables throughout this Data Appendix. However, for some variables we provide more detail on the main study period only.

In this introduction, we first discuss the main methodological challenges related to the use of archeological information. Second, we introduce our sample area and discuss archeological periodization. We then discuss the reconstruction of the shifting rivers in section 2, while section 3 contains a description of other environmental and geographical data employed in this study. In section 4, we describe the coverage and the quality of our data on settlements and canals. Section 5 discusses our reconstruction of the urban network over time. Section 6 introduces our data on administrative buildings. Finally, we describe our data on states and cuneiform tablets in sections 7 and 8 respectively. The online Atlas (Atlas Appendix) displays our entire database in graphical format.

1.1 Using archeological data

Data collection on state formation, and often economic development as well, is typically carried out by states. This feature makes state records the main (if not the only) source for economists and economic historians in political economy. Since states collect data on states, studying early state formation suffers from an endemic lack of historical data. This is particularly problematic if, as in our case, the emergence of the first states unfolds together with the development of writing as a new technology for record-keeping. The issue, therefore, must be largely approached by leveraging on non-written evidence. Archeological records can bridge this gap in the historical sources.

While opening up new avenues of research, the use of archeological data also presents some challenges. Each section of this Data Appendix discusses specific issues that relate to a particular type of archeological data or source. In this introductory section, we review on a more general level the potential problems that arise when dealing with archeological records. As discussed in the paper, archeological data suffer from selection into treatment, into sample or what we define as selection "into hypothesis". We find that most potential issues stem from the incentives and constraints archeologists face when deciding where to excavate.

Selection into sample and into treatment might originate from differences in the intensity and scope of the archeological research, as reflected by the distribution of the excavation campaigns. Archeologists target some sites instead of others in anticipation of finding more important material remains, or because the physical landscape or other practical considerations prevent them from excavating certain areas. Depending on whether excavation intensity correlates with unobservables or with treatment, this problem will lead to selection into sample or into treatment, respectively.

In our study area, for instance, the first archeologists systematically sought to locate and uncover famous sites that were mentioned in the Bible (Brusius, 2012). Scholars might thus neglect potentially important sites that have disappeared from the historical records, where the returns to excavation seem lower, or where digging is more difficult. In this scenario, we could mechanically have more data available for those parts of the sample area that were more extensively targeted and excavated, or we might systematically miss smaller sites that do not appear important enough to be recorded. Alternatively, selection into sample might originate from the different likelihood for certain types of archeological remains to survive compared to others. In other words, archeologists might not systematically excavate certain areas or sites more (or more accurately) than others, but they might simply be less likely to find certain types of material evidence. For instance, early layers of occupation could survive less easily than more recent ones, both because they are more likely to decay and because new buildings might have been constructed on top (see Leick (2002)). Alternatively, certain types of buildings might be more resilient than others due to particular choices of location or construction techniques.

Another possibility is that the river shifts might have affected the survival probability of certain types of material evidence in affected areas or the capacity of archaeologists to search there. If past changes in the environment, such as shifting rivers, are correlated with present-day economic activity this may facilitate or impair archeological excavations. In these cases, differential survival would take the form of selection into treatment.

These concerns are significantly attenuated by our careful selection of specific sources and by the choice of a study area that presents a particularly suitable environmental and historical characteristics. First, our main data sources for settlements and canals adopt a "sweep survey approach" that aims at uniformly covering the surveyed area. Thus, we are able to capture the universe of settlement and canals for most of southern Iraq (see Section 4 of this Appendix for a more detailed discussion). Second, the orography (the undulations of the terrain) of the study area, which is characterized by a very flat terrain, reduces the possibility of missing acheological sites. Thanks to the progressive accumulation of different construction layers, in fact, ancient cities, settlements and canals formed distinct mounds and levees that, to this date, stand out across the plain (Hritz, 2010). Third, due to the historical significance of southern Iraq, the area has been heavily excavated since the nineteenth century and numerous written sources (such as cuneiform tablets) have been retrieved, translated, and published. Important urban centers and buildings are likely to be mentioned in the written documents retrieved in nearby archeological sites. We can use archeologial compendia to triangulate material remains with textual sources, thus allowing us to improve on the existing archeological records or signalling when they are incomplete. This procedure makes it unlikely for a settlement or a building to disappear completely from the records, even if the site was not excavated or was destroyed. For instance, we have several examples of important cities in our panel that, although mentioned in written sources, have not been excavated (e.g. Akkad, Akshak and Kesh). Even in these cases, however, we typically know from alternative sources retrieved elsewhere the location of the city and the dates of occupation. Moreover, we can interpolate the archeological record of important sites that have been only partially excavated (for instance in the case of the second millennium BCE layers of Babylon), by looking at secondary literature that draws information from alternative written sources (see Section 6 of this Appendix). Finally, archeologists in our sample area normally proceed by excavating a site vertically, thus going through the different layers of occupation until they reach virgin soil at the bottom. This feature of archeological research in the area - in combination with the described extensive geographical coverage of the archeological campaigns - also helps in minimizing the possibility of systematically missing particular types of archeological evidence.[1]

[1]More specifically and with respect to selection into treatment, we can perform some empirical tests to verify whether past river

Selection "into hypothesis" might instead originate from the different thematic focus and degree of accuracy of the archeological studies. Excavations were carried out by different experts at various points in time, with changing excavation techniques, time frames and means and could be motivated by very different research objectives. While some archeological campaigns apply a uniform "sweep survey approach" to excavations and surveys, many studies targeted particular types of remains (e.g. palaces, temples, graveyards, treasuries), concentrated on specific parts of a settlement (e.g. fortifications, city center, private houses), were dedicated to a certain period of occupation, or focused on a particular theme (e.g. religious history). As a consequence, even if the sample area was uniformly surveyed and major sites were targeted by a similar number of excavation campaigns, selection "into hypothesis" might still occur due to systematic differences in the research hypotheses that were being tested (some aspects might have been neglected on purpose) and the quality of the archeological investigation (some evidence might have been neglected by mistake).

We adopt two strategies to tackle this problem. First, while we always attempt to collect each variable from a single, comprehensive source covering the entire study area, we adopt different sources for different variables. In this way, we can triangulate across several, independently produced data sources. By testing our hypothesis using different variables that were collected from independent sources, we thus mitigate the risk that our results are driven by a situation of "selection into hypothesis" for a specific source. Second, we rely on authoritative compendia that comprehensively survey the specialist literature on individual sites or subjects and operate an informed synthesis for each city. These sources strive to achieve a consistent level of detail for all sites and flag limited excavations where necessary. We use them to cross-check and complement individual sources.

In summary, archeologists might systematically target certain parts of the sample area, they might be mechanically less likely to find certain types of remains, or they might be motivated by particular research hypotheses. Depending on which variable drove these systematic differences, these characteristics of archeological research might lead to selection into sample, treatment or "hypothesis". We select our sources in a way that helps in addressing these general challenges linked to the use of archeological data. First, we use sources that aim at reporting the universe of records in the sample area. Second, we chose to study southern Iraq, an area that has been intensively excavated over the last three centuries and that presents geographical characteristics that facilitate the work of archeologists. This fact increases our chances of observing the universe of the archeological remains. Third, we use a different source for each variable, which enables us to cross-validate our results with data from independent studies. Fourth, we cross-check and complement the data with compendia that aim at providing the universe of the relevant records and that operate an informed synthesis of local studies.

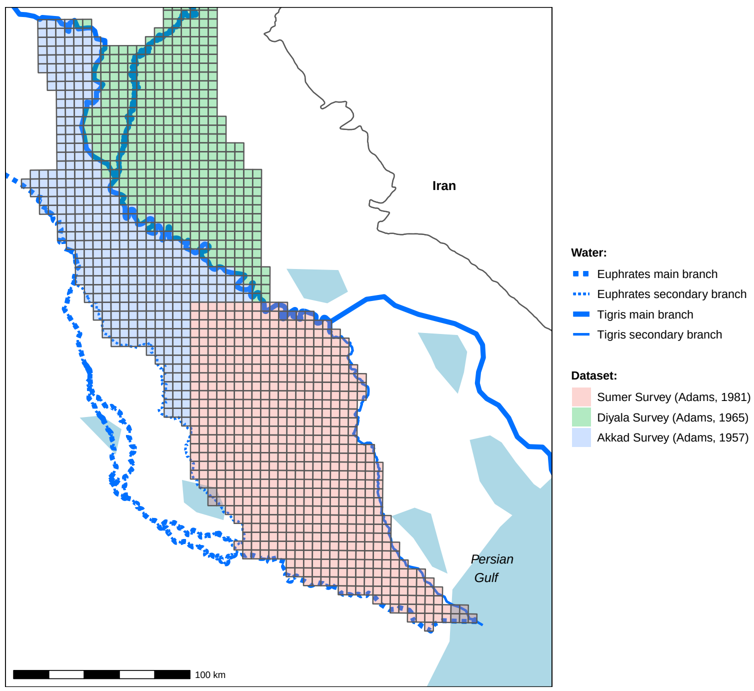
1.2 Sample area

We confine our dataset to cover those areas that were systematically surveyed by archeologists in a series of campaigns spanning between the 1950s and 1980s. We do so to minimize the chances of missing data and thus having false negatives owing to un-systematic surveying of a certain area. These campaigns were executed under the umbrella of the Chicago Oriental Institute and directed by Robert McCormick Adams. The core data source for our study is a series of books that document these archeological surveys. The findings of these different campaigns are aggregated into three distinct areas, each with a corresponding unique publication. The complete and final version of the survey commonly referred to as "Sumer survey", which covers the area between the Tigris and the Euphrates south of the ancient city of Nippur

shifts may have led to a differential discovery of archeological remains. In Table RA1 of our Results Appendix, we show that past river shifts are not correlated with the location of artificial canals before the start of the sweep surveys in 1952 (column 1), nor with terrain cover in 2010 (column 2). This suggests how contemporary land use is unlikely to have prevented archeological research systematically and differentially with respect to the river shifts that we study. This fact is confirmed by column 3, where we show that there is no significant difference between ever and never treated grid cells in the likelihood of having been located near a city that was not excavated in a given period of our panel.

and north of Uruk, is published in Adams (1981). The "Akkad survey" covers the narrower strip of land located between the two major rivers and north of Nippur and south of Sippar, and was first published as Adams (1957) and then as an appendix of Gibson (1972). Finally, the "Diyala survey" covers the Diyala plain, the stretch of land located to the south-east of the Diyala river near Baghdad, and was published in Adams (1965). The "Sumer" and "Akkad" surveys jointly cover roughly the catchment area of the Tigris and the Euphrates between the contemporary Hilla branch of the Euphrates, the main course of the Tigris and its Al Sharraff branch, north of the ancient city of Uruk and south of Sippar. The "Diyala" survey covers the catchment area of the Diyala river. Our sample area is the union of these three surveys. We map the extent of the three surveys in Figure DA1. We partition this area into 5x5 kilometer grid cells that form the units of observation of this study. We have a total of 1,374 cells.[2] In the following Section, we introduce the periodization that we use to build our panel of archeological data. In the remainder of this Data Appendix, we explain how we link each set of data to the grid cells. We also present the sources that we employed to construct the dataset, and we briefly discuss the reliability of each type of data.

Figure DA1: SURVEY AREAS AND COVERAGE



Notes: the gridded area corresponds to the sample employed in the paper, and shows the 5x5 kilometer grid cells.

[2]Two points on the sample area. First, while the surveys virtually covered the entire area reported in Figure DA1, only a portion of this area was surveyed intensively. The main results reported in the paper subset to those areas that were intensively surveyed as reported by the original publications. For the "Akkad" and "Diyala" we include the totality of the survey area in our baseline sample. For the "Sumer" survey, we restrict the baseline sample to those area that were fully or partially surveyed. This additional restriction brings the total number of grid cells down to 1,094. When also cells that ended up close to a new branch of the river are excluded for our main study period, the baseline sample drops to 933 cells. We test the robustness of our results to a variety of different sample restrictions that we report in our Results Appendix (Tables RA8 to RA11). This includes replicating the results with the full sample of 1,374 cells, the inclusion of cells that found themselves on a new branch, and the exclusion of those parts of the "Sumer" survey that were only partially surveyed. Second, known and excavated cities could fall outside the sample area. As we explain more in detail for specific outcomes below, if a grid cell in the sample area and in a given period was nearest a known city that falls outside the sample area, we use data from that city. If data are missing because the city was not excavated, we set the data for the grid-cell to missing. In other words, for some outcomes at the city-level, observations from the sample area maybe coded based on data from cities located outside the sample area surveyed by Adams. While this is conceptually important for the precision of our data collection, this is only the case for a handful of grid-cells and periods. See section 6 for more detail.

1.3 Periodization

The time dimension of our dataset comprises 31 periods that stretch between 5300BCE and 1950CE. Periods have an average length of 235 years. We use the archeological periodization used in Adams (1981), which is uniformly employed across all "sweep" surveys and other archeological sources to date sites, canals and other remains. Adams' chronology for southern Iraq is consistent with the standard periodization in the literature.[3]

This type of periodization is based on the dating of pottery sherds found in each location, and is referred to by specialists as the "relative chronology".[4] A new period is recorded by archeologists when a pottery style changes sufficiently to represent a clear stylistic shift. Naturally, the farther back we go in time, the more difficult it is to date these pottery types precisely. The association of pottery styles with absolute dates (in other words the transformation of the "relative" into an "absolute chronology") relies, for the early periods of our extended study period on radio-carbon dating. After 3000BCE, when writing was invented, archeologists are able to link pottery styles and historical events with more precision, both due to the wider range of available pottery finds and to the possibility of cross-checking with historical written sources. Table DA1 reports the starting and ending dates for all periods of our panel, as well as the event (if known), that ended each of them. The (few) discrepancies in periodization across surveys are described in the notes of Table DA1. Figure DA2 shows some examples of pottery styles that were employed by Adams in the dating of archeological sites. As is visible from Table DA1, start and end years become more precise for more recent periods. Naturally, stylistic shifts may coincide with political change. This is the case of the Cassite period, which almost perfectly coincides with the duration of the Cassite dynasty of Babylon. More often than not, however, the adoption of pottery styles preceded and outlasted the establishment of the main political regime from a certain period. In some cases, foreign invasions terminated both a political regime and a material culture. These events make it easier to pinpoint the start and end year of a period.

For a given site, the methodology for dating different archeological layers relies on reconstructing the chronological order of different types of pottery, rather the identification of the exact time-span of each pottery style, as information that would allow such precise dating may not be available at the site. Absolute dates are then derived in a second step, by comparison to other sites featuring pottery of similar styles and for which dates are available, for instance through radio carbon dating. For each site, archeologists can therefore either directly or indirectly date its occupation span, and an individual archeological site is considered "active" in a period if the corresponding pottery style is found there. The methodology is similar for building complexes, with the only difference that architectural features in themselves offer relevant information for dating, on top of the general dating of the layer based on pottery. The use of this chronology is standard in the archeological literature, and allows us to link information from various sources with Adams' data. Buildings, for instance, are dated based on their architectural style and are catalogued across different compendia according to Adams (1981)'s periodization.

Figure DA2: PERIODIZATION AND POTTERY STYLES

[This figure is unavailable due to copyright.]

Notes: examples of early pottery styles used for the dating of the settlements (Adams, 1965, Pottery Appendix, Figure 11)

[3] See Roaf (1990)

[4] See Rothman (2001) for a discussion. This approach originated from the necessity of developing a consistent chronology for prehistoric periods.

Table DA1: PERIODIZATION

	Period name	Dates	End of the period
1	Eridu	5300-4900BCE	Uncertain/Peaceful
2	Early Ubaid	4900-4300BCE	Uncertain/Peaceful
3	Late Ubaid	4300-3900BCE	Uncertain/Peaceful
	Main study period		
4	Early Uruk	3900-3600BCE	Uncertain/Peaceful
5	Middle Uruk	3600-3500BCE	Uncertain/Peaceful
6	Late Uruk	3500-3100BCE	Uncertain/Peaceful
7	Jemdet Nasr	3100-2900BCE	Uncertain/Peaceful
8	Early Dynastic I	2900-2700BCE	Uncertain/Peaceful
9	Early Dynastic II	2700-2600BCE	Internal warfare?
10	Early Dynastic III	2600-2350BCE	Internal warfare?
11	Akkadian	2350-2150BCE	Gutian invasion and drought
12	Ur III	2150-2000BCE	Elamite invasion
13	Isin	2000-1900BCE	Internal warfare
14	Larsa	1900-1800BCE	Internal warfare
15	Old Babylonian	1800-1600BCE	Hittite invasion
16	Cassite	1600-1200BCE	Elamite invasion
17	Middle Babylonian	1200-750BCE	Assyrian invasion
18	Neo Assyrian	750-626 BCE	Babylonian revolt
19	Neo Babylonian	626-539 BCE	Persian invasion
20	Achaemenid	539-330BCE	Greek invasion
21	Seleucid	330-150BCE	Parthian invasion
22	Parthian	150BCE-224 CE	Sassanian invasion
23	Sassanian	224-651 CE	Islamic invasion
24	Early Islamic	651-835? CE	Capital moves to Samarra
25	Samarran	835-1000? CE	Uncertain
26	Middle Islamic	1000-1200? CE	Uncertain
27	(Late) Abbasid	1200-1258 CE	Mongol invasion
28	Late Islamic A	1258-1330? CE	Uncertain
29	Late Islamic B	1330-1533 CE	Turkish occupation
30	Ottoman	1533-1918 CE	Turkish defeat in World War I
31	Recent	1918-1950? CE	Start of surveys

Notes: the periodization follows the relative chronology proposed by Adams and Nissen (1972) and updated by Adams (1981). Adams and Nissen (1972, pp.97-8) discuss some of the methodological problems related to the chronology. Roaf (1990) provides more precise dates from the second millennium BCE onwards, which we use to improve the precision on the starting and ending date of each period. The distinction between different Islamic sub-periods varies slightly across the different surveys by Adams. See Table DA4 for more details. Question marks indicate an uncertain ending date for a given period.

For the periods between Early Ubaid and Late Uruk, Adams (1981) partially changed the periodization from Adams and Nissen (1972). The updated periodization is more in line with the standard one normally employed in Mesopotamian history (see Rothman (2001)) but deviates from the one used by Adams and Nissen (1972) as follows: instead of being divided in two sub-periods only, as in Adams and Nissen (1972), the Uruk period is split into three sub-periods, namely the Early, Middle and Late Uruk periods. The Late Uruk period covers the time span 3500 - 3100BCE instead of the shorter 3300-3100BCE that was previously used. The Early Uruk period in Adams and Nissen (1972) is split into two additional sub-periods, namely Early and Middle Uruk that cover the periods 3900-3600BCE and 3600-3500BCE, respectively. New archeological findings allowed to antedate the appearance of the Early Ubaid pottery, so that the Early and Late Ubaid periods could be dated between 4900 and 3900BCE. Thanks to these new findings, the Hajji Mohammed period from Adams and Nissen (1972) was renamed Early Ubaid and this led to the antedating of all periods between Early Ubaid and Middle Uruk by one position, relative to the chronology proposed by Adams and Nissen (1972). Starting and ending dates for the Islamic periods should be considered as indicative (Adams, 1981, pp.234-2416).

2 The river network

This section starts by illustrating the general characteristics of the riverine system of southern Iraq and describes the methodology employed to reconstruct the transformations that occurred during our extended study period. It concludes by describing the characteristics of each river shift and how we use it in the context of our analysis. We are able to reconstruct 11 river cross-sections, which we use to trace 10 transformations that occurred between 5000BCE and present. We record both the location of the river branches and whether these were the primary or a secondary stream of the river.[5] Six of these transformations entailed a shift in the location of a river branch. Of these six river shifts, the first one of 2850BCE falls into our main study period, while the subsequent five occurred within our extended study period. The other four recorded transformations of the riverine system, instead, only led to a change in the relative importance of the river branches, that switched from primary to secondary or vice versa. We map all cross-sections in the Atlas. Table DA2 presents the sources of each river cross-section. Table DA3 describes the characteristics of each river shift.

2.1 Shifting rivers in southern Iraq

Three watercourses relevant for our analysis flow through our sample area in the southern Iraqi plain. The Tigris and the Euphrates are the two main ones, and run in somewhat parallel streams from north-west to south-east. The Diyala river, instead, flows from the Zagros mountains in western Iran and joins the Tigris near Baghdad.[6]

The Diyala river only changed position once over our sample period, owing to its relatively stable course across the valleys of the piedmont of the Zagros mountains. The courses of the Euphrates and Tigris, instead, were more erratic throughout history, due to their location in the much flatter southern Iraq's alluvium (the term alluvium is used to refer to the river valley between the Tigris and the Euphrates). As explained below, this particular characteristic of the area favored river shifts. These sudden events were typically triggered by unusual rainfall episodes in Turkey, Syria and northern Iraq, where the rivers originate.

This phenomenon, technically referred to as "avulsion" of the river's bed, can be explained by the following mechanism. Before entering the alluvium near the ancient city of Sippar, the Tigris and Euphrates rivers carry significant amounts of sediment collected in the upper part of the Iraqi plain and proceed at a sustained speed. The terrain flattens abruptly immediately after entering the alluvium and the stream's flow slows down. This change in the regimen of the flow leads to a substantial accumulation of sediment on the river's bed and on its banks.

Over time, sediment deposited on the river bed gets pushed to the side by the weight of the water and forms natural levees. As deposits grow, the rivers are lifted above the landscape. When the stream swelled beyond the pressure that the levees could withstand, typically due to exceptional precipitation in Turkey or northern Iraq, the levees would break at weak spots, water would start flowing out, and the river would find a new equilibrium position. These events could either lead to the splitting of the old branch into several smaller ones (thus creating an "anastomosing" river pattern), or to a full shift in the location of the river branch. Farther downstream, these changes could lead to the disappearance of smaller branches due to the reduced volume of the flow. As is visible from Figure AA1 in the Atlas Appendix, the Tigris and the Euphrates were running jointly in the middle of the alluvium at the beginning of our extended study period. Subsequent avulsions progressively pushed the two rivers to the south-west (Euphrates) and the east (Tigris), respectively. The progressive shifting of the river beds only

[5] The distinction between primary and secondary branches reflects differences in water volume.

[6] This summary of the general geographical characteristics of the southern Iraq's alluvium is based on the descriptions in Adams (1981), Pournelle (2003) and Wilkinson (2012).

Table DA2: RIVER CROSS-SECTIONS

	Cross-section name	Period	Shift's date	Sources	Rainfall variability window	Atlas figure
1	5000BCE	5000-3950BCE	na	Algaze (2008, p.45) Adams (1981, p.56) Adams (1965, Figure 2)	na	Figure AA1
2	4000BCE	3950-3600BCE	3950BCE	Algaze (2008, p.45) Adams (1981, p.56) Adams (1965, Figure 2)	3975-3935 BCE	Figure AA2
3	3500BCE	3600-2850BCE	3600BCE	Algaze (2008, p.45) Adams (1981, pp.14-19) Adams (1981, pp.61-63)	3625-3575 BCE	Figure AA3
4	3000BCE	2850-2450BCE	2850BCE	Adams (1974, p.70) Roaf (1990, p.80)	2875-2825 BCE	Figure AA4
5	2000BCE	2450-1750BCE	2450BCE	Gasche et al. (2002, Carte 1) Adams (1981, p.157,162)	2475-2425 BCE	Figure AA5
6	1500BCE	1750-1000BCE	1750BCE	Gasche et al. (2002, Carte 1) Gibson (1972, p.216) Cole and Gasche (1998, p.27) Adams (1981, p.18)	1775-1725 BCE	Figure AA6
7	1000BCE	1000-700BCE	1000BCE	Gibson (1972, p.216) Cole and Gasche (2007, pp.31-33) Cole and Gasche (1998, p.32)	1025-975 BCE	Figure AA7
8	0CE	700BCE-450CE	700BCE	Cole (1994) Adams (1965, Maps, Figure 4)	725-675 BCE	Figure AA8
9	500CE	450-900CE	450CE	Adams (1981, p.212) Adams (1965, Maps, Figures 5 and 6) Verkinderen (2015)	425-475 CE	Figure AA9
10	1000CE	900-1850CE	900CE	Verkinderen (2015)	875-925 CE	Figure AA10
11	2000CE	1850-2020CE	1850CE	Adams (1981, p.18) Verkinderen (2015, p.48)	1825-1875 CE	Figure AA11

Notes: this table provides a concise overview of the river cross-sections and the sources. Column "cross-section name" reports the label of each cross-section. Column "period" indicates the actual period covered by each cross-section. Column "shift's date" indicates the approximate timing of each shift. Column "sources" reports the references from the secondary literature that allowed to reconstruct each river cross-section and to date the shift. The source for the basemap is reported first. Column "rainfall variability window" indicates the 50-year window with abnormal rainfall variability that we use to cross-check the timing of each shift (see Figure RA1). Column "atlas figure" indicates the figure relevant for each cross-section as reported in the Atlas. A more precise description of the procedure employed to reconstruct each cross-section is reported in the Atlas Appendix.

stopped relatively recently due to the main branches eventually reaching the hills that delimit the alluvial plain.[7]

Given the nature of the process, these sudden shifts were difficult to predict and impossible to prevent with the technology available up until the twentieth century. Even when powerful, centralized empires had emerged and irrigation infrastructure was at its peak (for instance in the second and first millennium BCE), governments lacked the capacity to fix the position of the rivers. This is best exemplified by the attempts made by the powerful Neo-Babylonian kings, at the peak of the Babylonian civilization in the seventh century BCE, to build artificial levees to prevent further shifts. The records suggest that all attempts inevitably failed and that the rivers split further apart (Rost, 2017, p.15). The situation only changed in the nineteenth and twentieth centuries CE, when better civil-engineering technology and construction materials opened up the possibility for building large dams to regulate the flow.

2.2 The reconstruction and dating of the river shifts

While describing the phenomenon of the river shifts in general, Adams does not provide a complete reconstruction of the transformations occurred to the river network over the extended study period. To the best of our knowledge, in fact, no single study has attempted to comprehensively reconstruct historical river shifts in southern Mesopotamia. However, several scholars have specialized on specific sub-periods providing reconstructions at different points in time. To reconstruct the evolution of the river network over our extended study period, therefore, we have combined the limited information from Adams with other contributions that provide a river cross-section for the study area at specific points in time.

The procedure adopted by archeologists to reconstruct the riverine network at different points in time varies depending on the publication. While more details on the archeological evidence can be found in the methodological sections of each study (see Table DA2), a few common elements form the basis of these reconstructions (see Cole and Gasche (1998)). Similarly to man-made canals, ancient river branches leave traces on the landscape which, depending on various factors, can take the form of dry river beds below the alluvium's surface, or large river banks. Compared to artificial canals, these marks on the landscape

[7]See Cole and Gasche (1998, pp.4-7) for a concise description. Morozova (2005) offers a more detailed analysis of this process in southern Iraq. Sherratt (2004) provides an effective visualization of the process.

Table DA3: RIVER SHIFTS

	Shift's date	Treatment period number	Treatment period name	Shift	Shift's characteristics
1	3950BCE	4	Early Uruk	No	No river branches disappear, only new branches form
2	3600BCE	6	Late Uruk	No	No river branches disappear, only a change in the relative importance between branches takes place
3	2850BCE	8	Early Dynastic I	Yes	Several branches disappear. Part of the main study period
4	2450BCE	10	Early Dynastic III	Yes	Several branches disappear. Part of the extended study period
5	1750BCE	15	Old Babylonian	Yes	Several branches disappear. Part of the extended study period
6	1000BCE	17	Middle Babylonian	Yes	Several branches disappear. Part of the extended study period
7	700BCE	19	Neo Babylonian	Yes	Several branches disappear. Part of the extended study period
8	450CE	23	Sassanian	Yes	Several branches disappear. Part of the extended study period
9	900CE	25	Samarran	No	No river branches disappear, only a change in the relative importance between branches takes place
10	1850/1950CE?	30-31?	Ottoman-Recent	Yes	Two adjustments happen. First a change in relative importance between branches. Second, a small shift happens in the course of the Tigris North of Baghdad. This shift cannot be dated accurately. We therefore exclude it from our analysis. Our results are robust to including it.

Notes: this table provides a concise overview of the river shifts that affected our sample area over the extended study period. The column "shift's date" indicates the approximate timing of each shift. " Treatment period number" and "name" indicate the treatment period. Column "shift" indicates whether we study the river shift as an shift in the paper. Column "shift's characteristics" describes the nature of each shift. Each river shift and cross-section are described in more detail in the Atlas Appendix.

tend to be more irregular, characterized by meandering and wider beds. Scholars triangulate this type of geomorphological data with archeological evidence and information from written sources to date each branch and then draw precise maps for each period.

If precise information on the timing of a shift is available from the primary sources or from the secondary literature we use it to link each river cross-section to our archeological data. For some shifts, however, the secondary literature does not specify a precise date, but only a range of possible dates. To improve the precision of the dating of these events, we exploit the fact that river shifts resulted from extreme rainfall events in Syria and Turkey. In particular, we use high-frequency paleoclimatic rainfall data (see section 3 for a description of the data) to trace rainfall volatility upstream. From these data, we compute the standard deviation of annual rainfall in fifty year windows, which we plot in Figure RA1. We note that river shifts for which we have precise data fall in periods of high rainfall volatility near their source. We then proceed to date river shifts that are not dated precisely by the secondary literature, by matching the approximate time range from the literature to 50-year windows from our rainfall volatility data. This systematic cross-referencing of the archeological literature with recent paleoclimatic data allows us to link each shift to a fifty year window quite precisely.

In the remainder of the supplementary materials, we describe this procedure more in detail. First, Table DA2 lists the sources employed to reconstruct each cross-section. Second, the Atlas Appendix provides maps for each cross-section, discusses the source material, the dating of the shift in detail. Table DA3 summarizes these more detailed descriptions.

2.3 Individual river shifts

Of the ten known major transformations that occurred to the riverine network of southern Iraq between 5000BCE and the 1950s, six entailed river shifts within our sample area.[8] In this section, we describe the salient characteristics of each of these river shifts as well as the periods around each shift and we

[8]We do not presume to be able to trace every single adjustment that occurred to the courses of the Tigris and the Euphrates between 5000BCE and today. We do not include in our sample changes of the network that are mentioned by some sources, but that

provide some historical context for each of them. Table DA3 summarizes the characteristics of all shifts. We provide a more detailed description of the political context that characterized each period in the Atlas Appendix.

1. **Early Dynastic I** shift: This is the main river shift that we study in the paper as the first documented river shift in our sample area. It falls at the end of our main study period and occurred around 2850BCE. The shift occurred at the beginning of the Early Dynastic I period, which is the treatment period. The four pre-periods are the Early Uruk, Middle Uruk, Late Uruk and Jemdet Nasr periods. The Early Dynastic I river shift allows to study the transition from periods with a political landscape characterized by small, independent city states (that only controlled small parts of the countryside around them) to the first territorial city states (that controlled a larger countryside and, at times, multiple cities). As the name of the period suggests, the Early Dynastic I period witnessed the emergence of kingship as a political institution. This river shift defines our main study period as this is the first shift that we are able to record.

2. **Early dynastic III** shift: This river shift is part of our extended study period and occurred around 2450BCE. The shift occurred at the beginning of the Early Dynastic III period, which is the treatment period. The relevant pre-periods are the Late Uruk, Jemdet Nasr, and Early Dynastic I and II periods. As the name suggests, the period was characterized by a political context similar to the ones of the Early Dynastic I and II periods. All periods around the river shift were characterized by territorial city states.

3. **Old Babylonian** shift: This river shift is part of our extended study period and occurred around 1750BCE. The shift occurred at the beginning of the Old Babylonian period, which is the treatment period. The relevant pre-periods are the Akkadian, UrIII, Isin and Larsa periods. The transition between the Larsa period to the Old Babylonian one marked a persistent shift from political fragmentation (the plain was divided into several territorial city states in both the Isin and Larsa periods) to full political centralization in the treatment period. The Old Babylonian empire managed to control the entire sample area for roughly 200 years and permanently shifted the center of power from the south to Babylon. After the successful Old Babylonian centralization, the entire area was stably controlled by centralized states during the rest of our panel, with the only exception of the Middle Babylonian and Neo Assyrian periods, in the first half of the first millennium BCE.

4. **Middle Babylonian** shift: This river shift is part of our extended study period and occurred around 1000BCE. This coincides with the beginning of the Middle Babylonian period, which is the treatment period. The pre-periods are the Isin, Larsa, Old Babylonian and Cassite periods. The shift took place in an epoch that witnessed the collapse of the highly centralized Babylonian state, which had been created at the beginning of the Old Babylonian period by the Babylonian Amorite dynasty and preserved by Cassite rulers until the twelfth century BCE. The Middle Babylonian period was characterized by a weakening of the political power of Babylon, whose dynasty lost control over much of the plain owing to continuous foreign pressure and invasions. Babylon retained some formal authority over the sample area, but cities enjoyed a great deal of political independence in this era and Babylonian territorial control became fragmentary.

5. **Neo Babylonian** shift: This river shift is part of our extended study period and occurred around 700BCE. The shift occurred at the beginning of the Neo Babylonian period, which is the treatment period. The pre-periods are the Old Babylonian, Cassite, Middle Babylonian and Neo Assyrian

have not received sufficient attention from paleoclimatologists and archeologists. One example is the transformation of the Tigris that occurred in the 7th century CE and mentioned by both Morozova (2005, pp.409-411) and Le Strange (1905, pp.27-8). While it is clear how the flood that occurred around 630CE had significant consequences on the environment of southern Mesopotamia, it is unclear whether is led to the disappearance of river branches and the appearance of new ones. Thus, one should interpret our collection of river cross-sections as tracing the major changes that have occurred to the riverine system, but not the universe of these changes. The only exception is the small adjustment of the Tigris north of Baghdad that we observe in the sources but that we cannot date. See Table DA3 for details. Results are virtually identical if we include this shift in period 31 (not shown).

periods. The period represents another example of successful centralization after a period of substantial political fragmentation for southern Iraq, due to the continuous fighting that characterized the Middle Babylonian period and the foreign Assyrian occupation of the Neo Assyrian period.

6. **Sassanian** shift: This river shift is part of our extended study period and occurred around 450CE. The shift occurred during the first half of the Sassanian period, which is the treatment period. The pre-periods are the Neo Babylonian, Achaemenid, Seleucid and Parthian periods. The shift occurred in a period of interregnum between the Parthian and the Sassanian states. The Parthian empire had virtually renounced its control over southern Iraq due to the continuous political confrontation with the Romans towards the middle and the end of the Parthian period. Similarly, after taking control of the area, the Sassanian empire opted for an administrative strategy based on indirect rule for the first half of the Sassanian period and only increased state presence from the sixth century CE.

3 Other environmental data

- **Land suitability**: We use land suitability for rain-fed and irrigated barley from the FAO-GAEZ database.[9] Barley was the most widespread staple crop throughout Iraqi history (Adams, 1981, p.86). The data come in raster format with cells measuring roughly 10x10 kilometers. Suitability is expressed in kilograms per hectare of attainable produce. We select intermediate input suitability, as this is appropriate for the non-mechanized equipment (such as the manual plow) that was employed throughout our extended study period (Roaf, 1990, p.47). South of the ancient city of Kish, rain-fed agriculture is not viable due to very low amounts of rainfall. The southern part of the plain, however, is characterized by the highest levels of irrigated suitability across the sample area.

- **Historical rainfall**: We exploit historical rainfall data from paleoclimatic studies to trace climate change over the period of our study. In the paper, we use two different sources, one more suitable to trace long-term changes to rainfall patterns in southern Iraq (Roberts et al., 2008), and one better able to capture periods of exceptional rainfall variation in the proximity of the sources of the Tigris and Euphrates rivers (Fleitmann et al., 2009). Both sources employ the ratio of $\delta^{18}O$ Oxygen isotopes and $\delta^{16}O$ ones (expressed relative to a standard isotopic composition) trapped in sediment as a proxy for historical rainfall and are strongly correlated.[10]

  1. We employ data collected by Roberts et al. (2008) from lake Van, located in the south-east corner of Turkey, to describe long term changes in rainfall patterns. These records are widely used in the archeological literature on southern Iraq to describe past changes in the climate and, in particular, to trace long-run fluctuations in rainfall patterns (see for instance Wilkinson (2012) and Pournelle (2003)). Roberts et al. (2008) look at the ratio of Oxygen isotopes $\delta^{18}O$ and $\delta^{16}O$ ones contained in the different layers composing the sediments accumulated by the lake's water over several millennia. The records cover the time-span between the fourteenth millennium BCE and today with a 200-year resolution.[11]
  2. We also employ data from Fleitmann et al. (2009) to capture episodes of extreme short-term rainfall variability near the sources of the Euphrates and Tigris and, thus, to validate the dating of the river shifts we employ in the paper. This study uses the $\delta^{18}O$ to $\delta^{16}O$ ratio from stalagmites' layers in the Sofular cave, which is also located in Turkey.[12] The more granular

[9] Downloaded on 4/5/2019 at http://www.fao.org/nr/gaez/en/

[10] This methodology relies on the fact that "heavier" (^{18}O) and "lighter" (^{16}O) Oxygen isotopes evaporate at different rates and precipitate at different speeds. ^{16}O isotopes evaporate more quickly from the ocean surface and thus rainfall water tends to have a higher concentration of this type of isotopes. This feature gets accentuated at higher latitudes in the Northern Hemisphere by the fact that ^{18}O isotopes, already found in lower quantities in rainfall vapor, precipitate earlier during the cyclical movement that brings clouds from the equator to the poles. Thus, by the time the clouds reach the tropics, they contain rainfall water rich in ^{16}O isotopes and poor in ^{18}O ones. After precipitating, rainfall water gets trapped inside superimposed layers of sediment. A lower ^{18}O to ^{16}O ratio in a given sediment layer, therefore, indicates more precipitation in the corresponding period.

[11] Accessed on 20/5/2020 at https://www.ncdc.noaa.gov/paleo-search/study/24450

[12] Accessed on 20/5/2020 at https://www.ncdc.noaa.gov/paleo-search/study/8637

records linked to the particular layering process that occurs for stalagmites offer, in this case, a 2 to 20-year resolution (depending on the geological period). While the location of the Sofular cave is more remote from southern Iraq compared to lake Van (and thus Lake Van's records are preferable to study long-term climate change in the area), the higher granularity of the Sofular records allows to capture periods of extreme rainfall volatility upstream in the courses of the Tigris and the Euphrates. In the context of southern Iraq, changes in rainfall upstream could lead to changes in river levels - and even to shifts - downstream. The location of the cave in Turkey makes these paleoclimatic records well suited for our purpose, as this is close to the sources of the Tigris and the Euphrates rivers.

- **Contemporary rainfall**: Cross-sectional data on rainfall come from the WordClim database.[13] This source provides the monthly rainfall averages calculated over the 1970-2000 period. These are available in raster format at a 1x1 kilometer resolution. Rainfall is expressed in centimeters. We calculate the yearly average over twelve months and we compute the average value within the 5x5 kilometer level grid cells.

- **Temperature**: Data on average temperature come from the WorldClim database in raster format and reports monthly averages calculated between 1970 and 2000.[14] Raster cells measure roughly 1x1 kilometer. Temperature is expressed in degrees Celsius. We calculate the yearly average over twelve months and we then compute the average value within the 5x5 kilometer level grid cells.

- **Elevation**: High-resolution elevation data come from the Shuttle Radar Topography Mission (SRTM) of the NASA. This source provides raster data at a 90x90 m resolution and it is expressed in meters. We use the information from SRTM to double-check the location of dubious canals' levees and to interpolate settlement from the Akkad survey (see section 4). Figure DA3 shows how SRTM data allow to trace the course of ancient levees.

- **Coastline**: We digitize a set of six maps from Rzoska (1980), which show the evolution of the delta area between 3000BCE and 1850CE. We use information on the historical location of the coastline together with the rest of our geographical data for mapping purposes. Transformations in the delta area of the Tigris and Euphrates rivers were substantial over the period of our study but largely took place outside our sample area.

- **Canals in 1952**: We digitize a cross-section of existing canals in 1952 from the map *Tigris and Euphrates rivers irrigation and drainage system* in Knappen and McCarthy (1952). We use data on the location of 1952 canals in the Result Appendix to test for possible issues of selection into sample due to the distribution of economic activity across the sample area when the main archeological surveys were carried out.

- **Land cover around 2000**: We download Iraq's land cover around 2000 from DIVA-GIS. This source provides raster information from satellite imagery at, roughly, a 1x1 kilometer resolution. We attribute each grid cell to a land-cover type based on the code of the raster's cells its centroid falls into. We consider cultivated areas those coded as "16" in the raster data. We use land cover information in the Result Appendix to test for possible issues of selection into sample due to the distribution of economic activity across the sample area when the main archeological surveys were carried out.

4 Settlement and canals

This section introduces the main sources for our data on settlement and canals. We gather information on a total of 13,131 unique settlements from 4,372 archeological sites and 1,117 canals for our extended study period. For our main study period, we record a total of 1,796 unique settlements and 151 canals. We use

[13]Downloaded on 6/5/2017 at http://www.worldclim.org/
[14]Downloaded on 6/5/2017 at http://www.worldclim.org/

the exact location of recorded settlements to link them to grid cells. We use GIS to link each grid cell to its nearest canal in any given period by computing the linear distance between a grid cell's centroid and the nearest canal. All period cross-sections for settlement and canals are mapped in the Atlas Appendix.

4.1 The archeological data on settlement and canals

The data on the size and period of occupation of settlements and on the location of canals come from a series of archeological surveys carried out by Robert McCormick Adams, which we already introduced above. In short, he performed a first study between 1956 and 1957, the so called "Akkad Survey" in the area surrounding the ancient city of Kish (Adams, 1957), which is also reported as an appendix in Gibson (1972). Adams and Nissen (1972) surveyed the existing settlement in the area surrounding the city of Uruk ("Warka survey"), in the south-eastern part of the plain. This survey was then extended in Adams (1981), which also reports the results from the area between Uruk and Nippur. Together, the two surveys constitute the so called "Sumer survey". Finally, Adams (1965, 1981) presents the maps and catalogs collected during the surveys of the archeological sites of the Diyala plain ("Diyala survey"). We did not digitize settlement data ourselves. Carrie Hritz (2010) has digitized Adams' maps, checked each site with the catalogue and compiled a full dataset of Adams' work, which she generously shared with us. By contrast, we independently digitize canal data from the original map. We describe the exact digitization procedure below. Figure DA1 shows the extent of each survey.

The methodology followed by Adams relies on a combination of aerial photographs and in-the-field examination of the ground surface. Ancient settlements and canals stand out on the surface of the southern Mesopotamian alluvium due the peculiar characteristics of the area's landscape, which features a particularly flat terrain. Abandoned villages and towns formed mounds due to the accumulation of mudbricks and debris that piled up during the different phases of settlement and these are clearly visible today across the area. Ancient canals, already when in use, ran above the plain due to the progressive accumulation of sediments that made their levees taller. Today, high, dry levees can be easily identified from remote through satellite images and aerial photographs and are visible on the ground (see Figure DA3).

Table DA4: DATA COVERAGE BY SURVEY AND VARIABLE

	Period name	Dates	Settlement			Canals		
Survey:			Sumer	Akkad	Diyala	Sumer	Akkad	Diyala
1	Eridu	5300-4900BCE	Y	.	.	.[a]	.[a]	.
2	Early Ubaid	4900-4300BCE	Y	2	.	.[a]	.[a]	.
3	Late Ubaid	4300-3900BCE	Y	2	.	.[a]	.[a]	.
		Main study period						
4	Early Uruk	3900-3600BCE	Y	3	Y[b]	2	3	Y[b]
5	Middle Uruk	3600-3500BCE	Y	3	2	2	3	2
6	Late Uruk	3500-3100BCE	Y	3	2	Y	3	2
7	Jemdet Nasr	3100-2900BCE	Y	Y	N	Y	Y	N
8	Early Dynastic I	2900-2700BCE	Y	3	3	Y	3	3
9	Early Dynastic II	2700-2600BCE	Y	3	3	Y	3	3
10	Early Dynastic III	2600-2350BCE	Y	3	3	Y	3	3
11	Akkadian	2350-2150BCE	Y	Y	Y	Y	Y	Y
12	Ur III	2150-2000BCE	Y	3	3	Y	3	3
13	Isin	2000-1900BCE	Y	3	3	Y	3	3
14	Larsa	1900-1800BCE	Y	3	3	Y	3	3
15	Old Babylonian	1800-1600BCE	Y	Y	Y	Y	Y	Y
16	Cassite	1600-1200BCE	Y	Y	Y	Y	Y	Y
17	Middle Babylonian	1200-750BCE	Y	Y	Y	Y	Y	Y
18	Neo Assyrian	750-626 BCE	Y	N	N	Y	N	N
19	Neo Babylonian	626-539 BCE	Y	Y	Y	Y	Y	Y
20	Achaemenid	539-330BCE	Y	Y	Y	Y	Y	Y
21	Seleucid	330-150BCE	Y	2	Y	Y	2	Y
22	Parthian	150BCE-224 CE	Y	2	Y	Y	2	Y
23	Sassanian	224-651 CE	Y	Y	Y	Y	Y	Y
24	Early Islamic	651-835? CE	Y	Y	Y	Y	Y	Y
25	Samarran	835-1000? CE	Y	Y	Y	Y	Y	Y
26	Middle Islamic	1000-1200? CE	Y	Y	N	2	Y	N
27	(Late) Abbasid	1200-1258? CE	Y	N	Y	2	N	Y
28	Late Islamic A[c]	1258-1330? CE	Y	Y	N	3	Y	N
29	Late Islamic B[c]	1330-1533 CE	Y	N	Y	3	N	Y
30	Ottoman[e]	1533-1918 CE	Y	N	Y[d]	3	N	N
31	Recent[e]	1918-1950? CE	Y	N	N	N	N	N

Notes: see Table DA1 for notes on the chronology. See main text for the sources.
Y data available for a unique period from the sources.
Numbers indicate the number of sub-periods lumped together and plotted on the same map by Adams for each survey.
. No recorded human settlement or canals in the corresponding area and period.
N Indicates that data are missing for a given period and survey area.
[a] Adams (1981, p.56)
[b] For the Diyala area, the Ubaid pottery is coeval to the Early Uruk one in the Sumer survey area (Adams, 1965, Figure 2).
[c] The periodization for the late Islamic epoch (between Middle Islamic and Ottoman) is imprecise due to limited knowledge of pottery types and varies slightly across surveys. The Late Islamic A period in our panel corresponds to the Late Islamic period for the Sumer and Akkad surveys. The Late Islamic B period, corresponds to the Ilkhanid period for the Sumer and the Diyala surveys.
[d] The Ottoman period corresponds to the Post-Ilkhanid period for this survey area.
[e] While included in the dataset, the Ottoman and Recent periods are excluded from all regressions

Adams proceeded as follows. First, he would identify a set of potential ancient mounds through aerial photographs covering the survey area. These would show small differences in elevation across the surface. After locating possible ancient remains from these photographs, he would check potential locations of settlements through on-foot exploration of the area. Once the mounds were correctly identified, he would sample pottery sherds from the site to establish the periods of occupation based on the dating of the pottery. Adams' field work provided three pieces of information that were then incorporated into the survey's catalog. First, he would record the exact location of the mound on a base-map. Second, he would date each mound by looking at the style of pottery sherds (fragments of pottery artifacts) retrieved from the different layers of the site. Third, he would record the area of the mound.

Adams followed a similar procedure for the canal network. After identifying the levees of ancient artificial canals through aerial photographs and on-foot inspection, he would date each canal based on the occupation of settlements in the proximity of the canal's levees in given periods. If settlements that could be confidently dated align next to the levees of an ancient canal, the latter is considered active in the corresponding periods. See Adams (1981, pp.27-47) for a more detailed account of the methodology.

The resulting data are presented by Adams as maps with an accompanying site catalog. The maps cover individual periods or several periods on one map. The accompanying catalog details the period of occupation for sites that are on the map. Table DA4 describes the coverage of the survey data by period and area for both settlements and canals. Hritz (2010) combined the location data with the catalog data to create a complete dataset of settlement. She shared the data with us. We provide an example of a survey map from Adams (1981) in Figure DA4, as well as a page from the catalog of settlements (corresponding to some of the sites mapped in Figure DA4), in Figure DA5. We digitized all canals ourselves. Because the different surveys were carried out at different points in time, the periodization into which the archeological finds are classified is not fully stable over time. Importantly, for some of the smaller surveys, some periods are combined into one larger period. We indicate these in Table DA4. In these cases, settlement and canal data do not vary over multiple periods within a survey area. What is important for our analysis is that we have time-variation around the river shift that we study in our main study period.

The data from Adams provide exceptionally valuable information. On the one hand, his methodology for data collection, which has set the standard for later researchers (Marchetti et al., 2019, p.217), provides high quality micro-data that are comparable across different surveys. On the other hand, the "sweep survey approach" offers the possibility to reconstruct the universe of settlement and canals across the sample area over the extended study period. In practice, with respect to settlement data, this means all ancient settlements with a total area equal or larger than one hectare. For canals, this implies all canals ever built and used for irrigation across the sample area. The fact that data collection was completed by the end of the 1970s allowed Adams to operate across a virtually uninhabited terrain that had not yet been significantly altered by the more recent agricultural development works that, later on, leveled large parts of the sample area thus destroying some of the smaller remains (Rost, 2017).

4.2 Harmonization of the data on settlement and canals

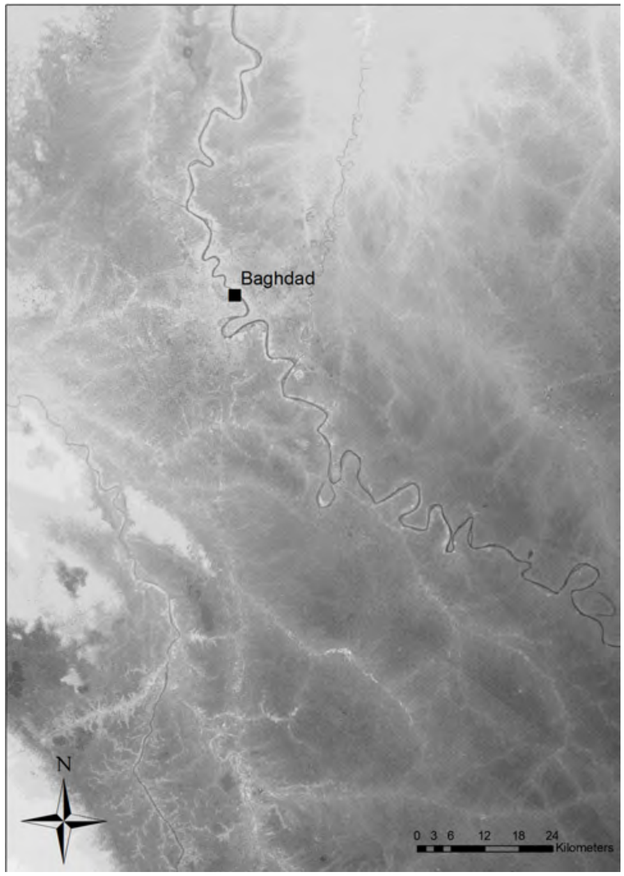
As a general rule for both settlement and canals data, if information on a certain period and survey area is not provided by Adams, we code the data as missing. This is only the case for a few instances, which are all reported in table DA4. Although the data on settlement and canals from different surveys are provided in a highly consistent format both over our extended study period and across our sample area, we augmented the data published by Adams in a lumped format, as described in the remainder of this section so to have the most complete coverage possible for both settlement and canal data.

4.2.1 Settlement

Data on settlement were consistently collected for all surveys across the entire area, except for the "Akkad survey", reported in Gibson (1972). For this part of the plain, Adams identified 1,384 ancient mounds, but only dated 319 of them. This leaves us with 1,065 mounds with information on the location and size of the archeological site, but not on the periods of occupation.

We impute the missing dates using a simple procedure. We use raster data on elevation from the SRTM database (with a resolution of roughly 90x90 meters), in combination with survey data from the "Sumer

Figure DA3: ANCIENT CANALS' LEVEES AND SRTM ELEVATION DATA



Notes: the area corresponds to the northern part of sample area and covers to the "Akkad" and "Diyala" survey areas. See Section 3 for the sources of the SRTM elevation data.

survey".[15] Using these data, we compute the average height above the plain of settlements across the Sumer survey for each period. We then compute the height of undated sites in the Akkad survey and we infer the period of last occupation based on heights from the Sumer survey. For example, if the altitude of mounds that were active in a given period across the "Sumer survey" ranges between 29.8 and 29.3 meters above the sea level, we record mounds in the "Akkad survey" within that range as active in the corresponding period and all previous ones. This methodology relies on the fact that sites that were occupied for longer, or in more recent periods, are on average taller. This is the result of continued occupation over multiple periods of a certain site leading to the superimposition of several construction layers that increase the height of the mound.

Figure DA4: EXAMPLE OF AN ARCHEOLOGICAL SURVEY MAP

[This figure is unavailable due to copyright.]

Notes: example of an archeological survey map from (Adams, 1981, p.166). Major settlements are numbered (or labelled), whereas smaller ones could be associated to the catalogue via a base map.

One obvious problem that arises with this procedure is that we are likely to overestimate settlement

[15]https://www2.jpl.nasa.gov/srtm/, current as of September 2019.

density in the early periods. The existence of a settlement in a certain period, in fact, does not necessarily imply that the site was also active in previous ones. To address this issue, as a third step, we adjust our predicted periods of occupation by exploiting survival probabilities computed from the "Sumer survey". In other words, we randomly eliminate settlements in previous periods based on the observed probability for a mound from a period to have been inhabited in previous ones. For instance, if in the "Sumer survey" the probability that a Neo-Babylonian settlement was in existence in the previous Neo-Assyrian period is, say, 50%, we randomly draw 50% of the Neo-Babylonian mounds and code them as inactive for the previous period.[16]

This procedure admits a simple validation. We can impute periods for the 319 mounds for which we do have data in the Akkad survey based on our procedure and compare them to the periods of activity recorded by Adams. We obtain an accuracy of over 80% between the interpolated periods of occupation from height ranges and observed ones, which supports the validity of the procedure.

Figure DA5: EXAMPLE OF A PAGE OF AN ARCHEOLOGICAL SURVEY CATALOG

[This figure is unavailable due to copyright.]

Notes: example of an archeological survey catalog's page from (Adams, 1981, p.254). Numbered catalog entries correspond to individual settlements.

4.2.2 Canals

To reconstruct the network of canals for the different periods of our panel, we digitized the maps of the canal network from Adams (1965); Gibson (1972, pp.182-208) and Adams (1981). The reconstructed canal networks in all these maps are largely complete. We only improve a few aspects of the original data by proceeding as follows.

First, small parts of the canal networks reported on the maps (typically where the levees were not clearly visible on the surface or where the dating of the nearby mounds is dubious) were drawn by Adams as dashed lines, so to indicate a certain degree of uncertainty in their location and period(s) of existence. If the "dashed" canals clearly connect two "certain" canal branches we interpolate the missing part. If the direction of the interpolated canal is unclear, we leave it blank.

Second, for presentation purposes, Adams sometimes lumped canal networks from different periods together in the same map. In these cases, we use the available data on settlement, in combination with the existing maps, to obtain a unique canal cross-section for each settlement period. We do so by deleting those parts of the canal network that, while being plotted on a lumped map, had no active settlements aligned within a ten kilometers radius in one of the periods lumped in the map. As described before, this procedure is fully consistent with Adams' methodology to date canals' levees.

Third, as described in Section 2 below, we combine the settlement and canal data from Adams with information on the location of natural rivers over our extended study period. If a canal drawn on one of Adams' maps fully overlaps with a river branch in any given period, we remove the canal from the corresponding cross-section(s). This correction aims at improving Adams' reconstruction of the canal network, as he could not rely on more recent reconstructions of the riverine network over different periods and might have at times mistaken levees of ancient river branches for artificial canals.

[16]For the first period (Ubaid) and the latest one (Islamic) we adjust the interpolation by looking at the proportion settlements that existed in those periods, relative to total settlement within the right height cut-off, based on data from the "Sumer survey".

4.3 Potential concerns about settlement and canals data

As mentioned above, the archeological surveys created by Adams were "sweep surveys", intended to collect the universe of sites and canals that were, at any point in time between 5000BCE and 1950CE, inhabited and used by humans across the survey area. In this sense, the data do not suffer from the standard selection into sample problems that normally might affect the quality archeological information.[17] As Adams himself discusses[18], however, some particular factors hampered his capacity to collect data with maximum accuracy. Parts of the survey area, for instance, were under permanent cultivation during the time of Adams' study. The author stresses how this feature limited his capacity to look for mounds across these parts of the plain, as opposed to stretches of empty land where inspection was easier. Marchetti et al. (2019), who checked the accuracy of Adams' survey in a small part of the alluvium, between the ancient cities of Adab and Puzrish Dagan, find that Adams (1981) missed roughly 28% of the sites. The missing sites are largely located in today's cultivated area. If Adams was systematically less likely to find ancient remains in areas under permanent farming, we could face a problem of selection into treatment if farming patterns were influenced by historical river shifts. This problem is mitigated by three factors. First and most importantly, Adams indicated the areas that he could not fully survey on this maps, and we exclude them from all regressions (see Figure DA4).[19] Second, the number of missing sites relative to surveyed ones is surprisingly small especially considering the extent of the area surveyed by Adams and the available technology at the time. The missing sites, at least for the Adab-Puzrish Dagan area investigated by Marchetti et al. (2019), do not cluster near current or historical river courses, but only alter settlement levels (Marchetti et al., 2019, p.237). Third, in our paper, we show that no statistically significant association exists between historical river shifts, proximity to irrigation canals in the twentieth century and intensive farming in 2000.

5 Cities

We create a panel of cities covering our extended study period by geo-coding all settlements that are catalogued as cities in Adams (1981). These are all those sites that are labelled with names (as opposed to just catalogue numbers) in any of the maps contained in the book. This list of labelled settlements contains all prominent urban centers that reached an approximate size of 40 ha.[20]

We obtain the exact coordinates of each site through online resources.[21] We code the period of occupation of each city based on Bryce (2009). Archeological sites in Mesopotamia are recorded alternatively with their ancient name or with their Arabic name. We always use the ancient name as reported by the secondary literature, unless this is not known. For instance, the pre-historic sites of Tell Jemdet Nasr and Tell Uqair are referred to with the Arabic name of the site, as their ancient name is not known. We have a panel of 62 cities, which we plot in Figure DA6. In our main study period, we record 11 cities in the Early Uruk period, the first of the main study period. This figure grows to 27 by the Early Dynastic I period. As discussed in Section 1.1, we are confident that we capture the universe of urban centers across the sample area and over our extended study period.[22] We use GIS to compute the linear distance between each grid

[17] See Sections 1 and 6

[18] See methodological sections in Adams (1965) and Adams (1981)

[19] This solution does not fully resolve the problem as Adams only provides information on the quality of the survey for the Sumer survey in Adams (1981).

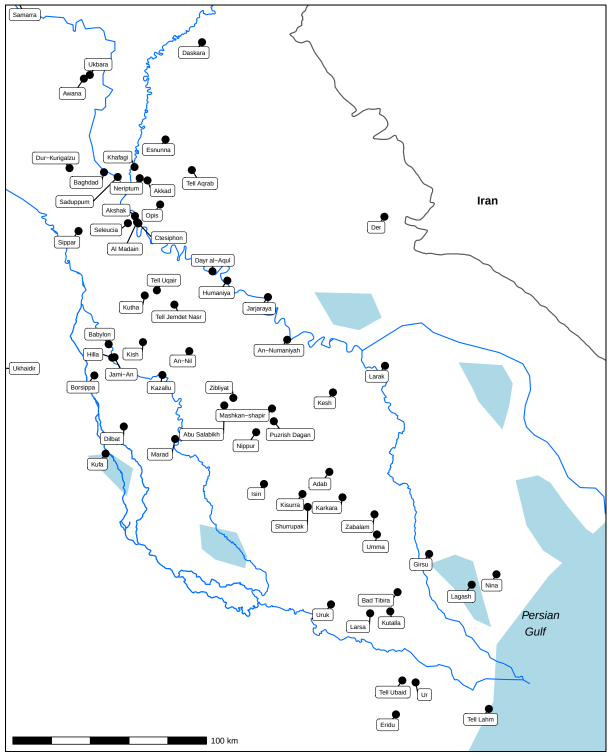
[20] In the earliest periods of our panel (and in particular before 3000BCE) not all cities reported in Adams had an actual size equal or above 40 ha. For these early periods the distinction between a city and a normal settlement is often based on the presence of important public buildings (see Section 6) on the more general historical prominence that allowed their ancient name to survive through written sources. We cross-check the completeness of the data from Adams (1981) with Beek (1962, p.47), Roaf (1990) and Heinrich (1982, 1984).

[21] Several websites provide coordinates of ancient locations, we mainly relied on https://latitude.to/articles-by-country/iq/iraq and on the Pleiades database https://pleiades.stoa.org/. For some cities, the exact coordinates of the site are not known. The main examples are Akshak, Kazallu and Akkad. In these cases we rely on educated guesses from our sources (see Roaf (1990)). Locations in figures DA6 and in the Atlas, however, should be taken as approximations in these cases.

[22] For completeness, as explained in section 1.2, we also include cities that are just outside the sample area (the part of the plain

cell's centroid and the nearest city in our panel of cities. The maps in the Atlas Appendix show existing cities for each period.

Figure DA6: CITIES IN THE STUDY AREA BETWEEN 5000BCE AND 1850CE



Notes: the figure shows all cities contained in the city-panel (see main text for a description of the procedure and the sources) with contemporary watercourses and coastline (2000CE)

6 Buildings

In the paper, we use the geographical distribution and the number of administrative buildings to trace changes in state presence and administrative capacity across the sample area and over our extended study period. This section starts by presenting the rationale for the use of administrative buildings as a proxy for state capacity. Second, it discusses the distinction between secular and religious buildings in the study area. Third, it describes the sources. Fourth, we describe our data on defensive walls an additional indicator public good provision at the city level. For each city we know how many administrative buildings existed in a given period, their type and their total size. When a city in our panel was not excavated, we set buildings to missing.[23] We record a total of 64 buildings for our main study period, which grow from just 4 in the Early Uruk period to 21 in the Early Dynastic I one. Over our extended study period we record

surveyed by Adams) as these could still be the closest city of a grid-cell that fell into the sample area proper.

[23]For our main study period this data limitation affects the cities of Akshak, Bad Tibira, Kesh and Larak.

222 buildings.[24] We also observe city walls across 35 cities over our extended study period. Of these, 10 belong to our main study period. Some of these buildings straddle multiple periods of our dataset. The Atlas Appendix provides a city-by-city description of the main architectural features in section 5.

6.1 Buildings as a measure of state capacity

In our paper, we exploit the fact that states and governments need administrative buildings to exert power, raise taxes and administer their territories. We collect data on the number, type and size of buildings in each city of our dataset to measure changes in state capacity at the local level over our extended study period. In doing so, we follow a small but growing literature in political economy that employs physical infrastructure to proxy for state capacity (Acemoglu et al., 2015). Due to the peculiar building technology characteristic of the area and to the political use that rulers made of monumental constructions, southern Iraq constitutes a particularly suitable context to employ buildings as a proxy for state presence and capacity.

First, owing to the lack of alternative materials (such as stone or marble), mud-bricks (sun-dried or baked) were the main construction material throughout the history of southern Iraq. This feature made the structures short-lived in the absence of frequent maintenance. Thus, when a shift of political power occurred and buildings were not in use even for relatively short periods of time, these tended to fall apart. Second, the peculiar building style employed during the different periods of Mesopotamian history, in combination with pottery sherds, inscriptions and tablets, allowed archeologists to precisely date the construction and demise of each building. Third, monumental buildings represented the tangible sign of royal and political power over the period of this study. Conquerors moved fast to destroy structures linked to the previous regimes and, at the same time, employed means proportional to their available fiscal resources to build new symbols of their own power. In other words, changes in the political history of southern Iraq were mirrored with a surprising precision by its architectural history.[25]

6.2 Secular and religious buildings

While tracing the distribution of monumental buildings trough archeological and historical sources is relatively straightforward due to the large body of archeological literature that is available, distinguishing between monumental buildings that carried out administrative functions and those that only had religious ones is more complex. In fact, there is convincing archeological and textual evidence that temples, and especially large ones, carried out administrative tasks. This was particularly the case during the early phases of Mesopotamian history that constitute our main study period (Postgate, 2017, p.137). In the baseline specification we take a conservative approach and we consider all public buildings (both temples and secular palaces) as centers of administration. For robustness, we exploit the distinction between regular temples and ziggurats, which allows to trace a qualitative distinction in the importance of different religious institutions to differentiate more precisely between large temples with administrative capacity and purely ceremonial ones. The remainder of this section provides an overview of the history and role of the administrative buildings employed in the paper.

The first sizeable development of monumental buildings took off at the peak of the Uruk civilization, during the late fourth millennium BCE. In this period, religious and administrative tasks were often combined and centralized in large temple complexes (see van de Mieroop (2015, pp.27-30) and Algaze (2008, p.87)). Important temples started to be built above ground-level on top of large platforms which, over time, created the ziggurat architectural type (Postgate, 2017, pp.110-112).[26] A ziggurat is in fact a large

[24] The data on buildings should only be considered complete until the Neo-Babylonian period. After that date the sources report presence of administrative buildings selectively. We only use administrative buildings in our estimates for the main study period.

[25] See Leick (2002) and Postgate (2017) for a discussion.

[26] While most of these large structures are interpreted by the archeologists as religious, there is debate as to whether they served ceremonial functions or were simply meeting places for communal gatherings.

mud brick platform featuring a temple on top. The ziggurat proper was typically part of a larger religious complex made of several other buildings, such as auxiliary temples and other administrative buildings. Important temple complexes often carried out administrative tasks and were arguably the political center of the first city-states (Postgate, 2017, pp.110-114). For the early period of this study (fourth-third millennium BCE), the most prominent examples are the Eanna and Anu complexes in Uruk (Algaze, 2008) and the Ekur temple in Nippur (Leick, 2002, p.159), which all featured a temple on platform of the ziggurat type. Smaller temples could also wield some level of political power in a city state. Even after the creation of large empires ruled by secular monarchs, temple complexes continued to play an administrative role in the local administration (Leick, 2002, p.159).

It was only from the Early Dynastic I period that kingship emerged as the predominant political institution and progressively supplanted temples in carrying out administrative duties. During the third millennium BCE, in fact, a more formal separation between religious and secular power was established (Roaf, 1990, pp.82-3). This process is embodied in the appearance of the royal palace, which progressively achieved a prominent status as the center of absolute power. The first attested royal residence is Palaces A and B in Kish, whose construction dates back to the first half of the third millennium BCE (Bryce, 2009). While the palaces in Kish are the first attested examples of royal architecture, older examples of secular buildings, that were likely involved in the administration of the state, also exist. Examples are the secular buildings in Eridu, Larsa, Tell Jemdet Nasr, Umma and Uruk dating from between the Late Uruk and the Early Dynastic I periods. Even after the appearance of secular buildings and royal palaces, temples continued to play an important administrative role in the third and second millennium BCE, in particular in cities with large and powerful religious institutions, such as Nippur, that remained independent from secular power until much later in history.[27]

6.3 The data on buildings

We rely on the seminal work by Ernst Heinrich to reconstruct the location, life-span and size of the administrative buildings in each city contained in our panel. He collected data on palaces (Heinrich, 1984) and temples (including ziggurats) (Heinrich, 1982) between the Ubaid and the Neo-Babylonian periods in two separate contributions. For later periods we employ alternative sources as discussed below and in our Atlas Appendix, section 5, but the data remain incomplete after the Neo Babylonian period.

Heinrich's work relies on information from archeological excavations and does not include buildings that are only known from textual sources. Moreover, as he published his work before 1985, results from later excavation campaigns have not been included in his catalog. To address these two shortcomings, we improve Heinrich's data by incorporating, on a city-by-city basis, all additional information that is available from alternative sources. We update Heinrich's catalog by cross-checking information through two authoritative archeological compendia, namely Meyers (1997) and Bryce (2009). When the information reported in these sources derives from textual sources, data on the size of each building are typically not available. We consistently code size of administrative buildings as missing in these cases.

If a city was excavated and no record of buildings is provided across the different sources employed, we code that city as having zero buildings. If a city was not excavated and no suitable textual sources exist to complement the archeological record, we code buildings data as missing for the entire lifespan of the city. In the baseline, if information on the size of buildings is missing in the sources we code it as missing. For our main study period this is the case for the cities of Akshak, Bad Tibira, Kesh and Larak. Section 5 in the Atlas Appendix provides a description of the archeological history of each city included in the database and specifies the sources that we used in each case to complement Heinrich's work.

[27] See Leick (2002, p.159) and Postgate (2017, pp.109-137)

6.4 Defensive walls

In our paper we use city walls as an additional indicator of public good provision at the city-level. As opposed to our main data on buildings, which, as explained in detail in section 7 provide key information to define states in our main study period, city walls do not by themselves indicate the existence of a functioning government as there is evidence that their construction could be organized communally (Hamblin, 2006; Burke, 2008). In our context, however, the presence of communal defence structure, such as large city walls, does indicate in the context of Early Dynastic Southern Mesopotamia a form of public good provision centrally organized (Leick, 2002; Postgate, 2017). The most famous example of such communal endeavour managed by centralized royal institutions is the building of the Early Dynastic I city wall of Uruk, which is attributed to Gilgamesh in the famous epic tale. A large city wall with a circumference of about 9km was indeed built around Uruk at the time and that is in our data.

We collect city-level data on the existence of defensive walls from Bryce (2009) and Meyers (1997), who provide a detailed overview of the architectural history for most of the cities across the sample area in a fairly standardized manner and with a comparable level of precision across locations. We collect data for both the main and the extended study period from these sources. However, we are only fully confident about the precision of our data on city walls for the main study period and, consequently, we only run regression analysis on city walls for this sample. The main reason for variation in reliability over time is the literature being very precise when dating the first construction of a wall in a given city, and then becoming less precise when tracing its later history, such its destruction(s), improvements and re-builds.

For our main study period, no city walls have been identified before the Late Uruk period. In the Late Uruk period, we record the first city-wall in our sample area in the city of Abu Salabikh. This wall remained functional throughout the 3rd millennium BCE in the Early Dynastic periods. Most city walls in our main study period appear in the Early Dynastic I period. At this stage, we observe city walls being built in Adab, Esnunna, Khafaji, Nippur, Tell Aqrab, Umma, Ur and Uruk. As for all other city-level outcomes, we match grid-cells to cities based on nearest-city association. All these walls are recorded in either Meyers (1997) or Bryce (2009). We cross-check the information from these sources with a variety of city-specific references cited in Meyers (1997) and Bryce (2009) and, where possible, we improve precision on dating.[28] As for all city-level outcomes we set data to missing if a city has not been located or excavated. For our main study period this is the case for the cities of Akshak, Bad Tibira, Kesh and Larak.

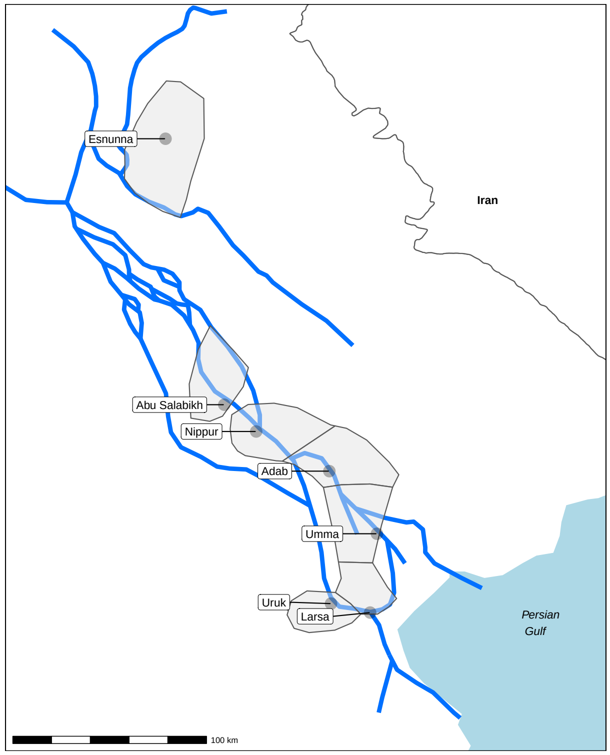
7 States

To capture state formation, we reconstruct the location and territorial control of states across our sample area and over the extended study period. Thus, we create a panel of states. As discussed in the historical background section of the paper, political hierarchy and complexity changed dramatically over the course of our extended study period, from city states with very limited control over the countryside (as in the Early Uruk period), to small territorial city states (Early Dynastic I period) and centralized states that could control our entire sample area (such as the Akkadian empire). Our data on the location and territorial reach of these states come from the secondary literature. The precision of the reconstruction of states location and boundaries varies over time, as more information from historical sources become available. In the remainder of this section we provide detail on the methodology for reconstructing in our main and extended study periods. Table DA5 provides a summary of the sources employed.

Main study period

[28] These include Postgate (1984, p.107) and Pollock et al. (1996, p.689) for Abu Salabikh. Stone (2014, Supplementary Materials) for Adab. Delougaz et al. (1967, pp.194-199) for Esnunna. Stone (2014, Supplementary Materials) and Delougaz et al. (1967, p.24) for Khafaji. Gibson et al. (1998) for Nippur. Stone (2014, Supplementary Materials) and Delougaz et al. (1967, p.267) for Tell Aqrab. Oraibi Almamori (2014, p.157) for Umma. Postgate (2017, pp.74-77) and Leick (2002, p.118) for Ur. Leick (2002, p.38) and Boehmer (1991, p.468) for Uruk.

Figure DA7: STATES AND RIVERS IN THE EARLY DYNASTIC I PERIOD



Notes: the figure shows the states from the Early Dynastic I period contained in our dataset, together with major watercourses and coastline after 2850BCE. See text for the sources and methodology.

Our method to create a panel of states for the main study period relies on data on the presence of administrative public buildings across cities and on the documented territorial reach of city states from the secondary literature. This combined approach is necessary due to a lack of time-varying mapping of city states from the secondary literature for this historical phase. As discussed in section 6, we rely on the notion that governments need administrative buildings to exert their power. Thus, we use the location of administrative buildings to map the location of states over our main study period.[29] We proceed with a multi-step process as follows:

1. Through our panel of cities (see section 5) we know which cities existed in each period.

2. We use our buildings data to code all existing city with at least one public building with administrative functions (either a ziggurat, a palace or a temple) as a capital city of a city-state.

3. We assign each grid-cell c to the relevant state based on nearest matching association or, if boundaries are available (Early Dynastic I period), based on the state' s boundary the grid-cell's centroid falls into. Thus, if the city nearest a given cell's centroid has an administrative building in a given period, or a city within city state boundaries has one, that grid cell is coded as being part of a state.

[29] The described methodology for the main study period is also relevant for the Early Dynastic II and Early Dynastic III periods, for which period-specific boundaries are not available.

4. In our main study period and in particular between the Early Uruk and the Jemdet Nasr period, capital cities (which we code as those cities with at least one administrative building) controlled limited areas around them. Assigning all grid cells that are near a capital city to a state would dramatically overstate the reach of these polities. We correct for this feature as follows. First, we rely on information from Lafont et al. (2017), who reconstruct time-invariant boundaries of city states based on textual and archeological evidence for the third millennium BCE, to define the territorial reach of the Early Dynastic I city states. Grid-cells, therefore, are coded as part of a state only if they fall within state boundaries and a city within those boundaries has at least one administrative building.[30] Second, as Roaf (1990, p.59) and Adams (1981, p.87) suggest that the area that cities controlled before the Early Dynastic I period was about six kilometers around the capital city, we use a fixed six kilometers distance cut-off to approximate their territorial reach in the pre-treatment periods. While this cut-off is based on the estimates of leading scholars of these periods, the radius is likely an approximation. In Tables RA18 to RA20 of the Results Appendix, we check the robustness of the results to alternative cut-offs that expand the territorial reach of these early city states.

Extended study period

After the emergence of the Akkadian empire in 2350BCE, the secondary literature provides detailed information on the level of political centralization and the existing polities in each period. Thus, we can fully rely on the secondary literature and on boundaries reconstructions to map states over our entire extended study period. However, we do not use post Early Dynastic I states reconstructions in the estimates of our main paper. Table DA5 summarizes our data and provides detail on the sources employed to reconstruct the political situation across our sample area in each period. The Atlas Appendix gives a more detailed description of the political situation in each period.[31]

8 Cuneiform tablets

In the paper, we rely on data from cuneiform tablets for two main purposes. First, based on the notion that cuneiform tablets in the early periods of Mesopotamian history were chiefly used by states for bookkeeping related to tribute payment, we use the information on the geographical and temporal distribution of tablets finds to map the existence of tribute collection across our sample area and over time. Second, we implement a text analysis exercise on the tablets' texts to gauge information about what states were recording and how the frequency of specific words changed over time. We can thus observe how the frequency of specific words changed in relation to rivers shifting away. In this section, we first describe the sources and the challenges related to working with cuneiform tablets. Second, we describe the mechanics of our text analysis.

8.1 The data on tablets

We download data on tablets from the online repository of the Digital Cuneiform Tablets Initiative (CDLI), a joint project between the University of Oxford, the Max Plank Institute and the Centre National de Recherche Scientifique (CNRS), together with a number of partner institutions across the globe.[32] The project aims at collecting information on the entirety of cuneiform tablets, that are presently scattered in museums and private collections across the globe, into one, standardized and easily accessible online

[30] Generally, Early Dynastic city states only featured one city with administrative buildings in their territory, the capital city. In only one instance, city states could contain multiple cities with administrative buildings of which one was the capital. This is the case, for the treatment period, only for Tell Aqrab and Khafaji, both featuring a public building and being part of the Esnunna city state.

[31] A note on timing. If a period was characterized by territorial stability, we employ the boundaries that reflect the political situation that was in place for most of the period. By contrast, if the period was characterized by political instability, we adopt the boundaries that were in place at the end of the period.

[32] Accessed on 22/2/2022 at https://cdli.ucla.edu/

Table DA5: STATES

	Period	Dates	Political status	Boundaries	Radius	Sources
1	Eridu	5300-4900BCE	No states	NO	n.a.	Nissen (1988, pp.55-59)
2	Early Ubaid	4900-4300BCE	No states	NO	n.a.	Nissen (1988, pp.55-59)
3	Late Ubaid	4300-3900BCE	No states	NO	n.a.	Nissen (1988, pp.55-59)
			Main study period			
4	Early Uruk	3900-3600BCE	City states	NO	6 km	Adams (1981, p.87) Roaf (1990, p.59)
5	Middle Uruk	3600-3500BCE	City states	NO	6 km	Adams (1981, p.87) Roaf (1990, p.59)
6	Late Uruk	3500-3100BCE	City states	NO	6 km	Adams (1981, p.87) Roaf (1990, p.59)
7	Jemdet Nasr	3100-2900BCE	City states	NO	6 km	Adams (1981, p.87) Roaf (1990, p.59)
8	Early Dynastic I	2900-2700BCE	City states	YES	n.a.	Lafont et al. (2017, p.107)
9	Early Dynastic II	2700-2600BCE	City states	YES	n.a.	Lafont et al. (2017, p.107)
10	Early Dynastic III	2600-2350BCE	City states	YES	n.a.	Lafont et al. (2017, p.107)
11	Akkadian	2350-2150BCE	Centralized state	YES	n.a.	Lafont et al. (2017, p.167)
12	Ur III	2150-2000BCE	Centralized state	YES	n.a.	Lafont et al. (2017, p.211)
13	Isin	2000-1900BCE	City states	YES	n.a.	Roaf (1990, p.109) (1910BCE)
14	Larsa	1900-1800BCE	City states	YES	n.a.	Roaf (1990, p.109) (1802 BCE)
15	Old Babylonian	1800-1600BCE	Centralized state	YES	n.a.	Roaf (1990, p.120)
16	Cassite	1600-1200BCE	Centralized state	YES	n.a.	Roaf (1990, p.142)
17	Middle Babylonian	1200-750BCE	Centralized state	YES	n.a.	Lafont et al. (2017, p.613)
18	Neo Assyrian	750-626 BCE	Centralized state	YES	n.a.	Roaf (1990, p.191)
19	Neo Babylonian	626-539 BCE	Centralized state	YES	n.a.	Roaf (1990, p.203)
20	Achaemenid	539-330BCE	Centralized state	YES	n.a.	Roaf (1990, p.203)
21	Seleucid	330-150BCE	Centralized state	YES	n.a.	Davidson (2011, pp.54-55)
22	Parthian	150BCE-224 CE	Centralized state	YES	n.a.	Davidson (2011, pp.58-59)
23	Sassanian	224-651 CE	Centralized state	YES	n.a.	Davidson (2011, pp.60-61)
24	Early Islamic	651-835? CE	Centralized state	YES	n.a.	Davidson (2011, pp.92-93)
25	Samarran	835-1000? CE	Centralized state	YES	n.a.	Davidson (2011, pp.92-93)
26	Middle Islamic	1000-1200? CE	Centralized state	YES	n.a.	Davidson (2011, pp.92-93)
27	(Late) Abbasid	1200-1258? CE	Centralized state	YES	n.a.	Davidson (2011, pp.92-93)
28	Late Islamic A	1258-1330? CE	Centralized state	YES	n.a.	Davidson (2011, pp.92-93)
29	Late Islamic B	1330-1533 CE	Centralized state	YES	n.a.	Davidson (2011, pp.102-103)
30	Ottoman	1533-1918 CE	Centralized state	YES	n.a.	Davidson (2011, pp.122-123)
31	Recent	1918-1950? CE	n.a.	n.a.	n.a.	n.a.

Notes: this table provides a concise overview of the level of political centralization, together with the sources employed to map the political situation, in each period of our panel and across our sample area. The column "political status" indicates the level of political centralization during a given period. Note that over our extended study period, what we define as for enhanced clarity "city states" could vary considerably in terms of territorial reach. These Column "boundaries" indicates whether a reconstruction of historical boundaries is available for a given period. Column "radius" indicates the radius used in periods of political decentralization to define the territory of a city. The six kilometers radius employed between the Early Uruk and Jemdet Nasr periods is based on estimates of intensively cultivated areas around a city. Column "sources" reports the main source(s) employed to reconstruct the political situation in a given period. A detailed description of the political situation in each period is included in the Atlas Appendix.

platform.

Where this is available, the CDLI project records information from scientific publications on several characteristics of each tablet. For our purposes, we focus on the location of the tablet (this is where the tablet was produced and, normally, excavated)[33], the archeological period when the tablet was written, the text (a string containing the transliterated text from the tablet), the genre of the text (whether it is an administrative, legal, literary text or a royal inscription) and a unique numeric identifier.

The body of tablets contained in the CDLI catalogue continues to grow as more collections are made accessible, although it is virtually complete for parts of the Near East that were excavated earlier on, as in the case of Southern Mesopotamia. At present, the project has collected information on roughly 350,000 tablets from across the Near East covering a period that goes from the late 4th millennium BCE to the first half of the 1st millennium CE, when clay tablets became obsolete as a writing technology. Roughly 170,000 tablets of these 350,000 belong to cities in our sample area. These 170,000 tablets consistently cover our sample area and extended study period.[34]

[33] In principle, tablets could be produced in location i and be found in location j. In practice, however, the two locations coincide in the vast majority of the cases.

[34] Up until the 1st millennium CE. There are a few periodization discrepancies between our main archeological data and CDLI

During the five periods that constitute our main study period (Early Uruk to Early Dynastic I period), tablets were only found in the last three, namely Late Uruk, Jamdet Nasr and Early Dynastic I. This feature of the data reflects the fact that writing was invented as a record-keeping technology only around 3,300BCE with the first attested examples likely being from the city of Uruk (Roaf, 1990, p.70). In total, CDLI records 6,573 tablets for our main study period. The exact number of tablets available by period and genre is reported in Table DA6.

The first attested tablets were chiefly used for record-keeping and feature very simple texts. Usually these contained lists of objects and commodities that were recorded as part of a transaction. While the exact context of these transactions is not always clear owing to the simplicity of the text, the lack of literary context and our limited understanding of proto-cuneiform writing, the consensus in the field is that virtually all examples of cuneiform tablets from our main study period relate to transactions involving the state and, as such, forms of tribute payment or centralized redistribution of commodities. This fact is clearly reflected by the CDLI categorization (where CDLI experts look at tablets and categorize them based on their function) which places roughly 90% of all tablets from the main study period into the "administrative" category (this figure raises to the virtual totality of CDLI tablets for the Late Uruk and Early Dynastic I periods, see column 3 from Table DA6). This category defines a tablet type pertaining to public record-keeping linked to state administrative transactions. The situation clearly changes later on in history, when societies became more complex and writing more common, which made the share of literary and legal texts larger.

The fact that the early tablets are generally recognized as texts pertaining to public administration and tribute payment is also reflected in the qualitative analysis carried out by the world-leading experts on early cuneiform tablets, who generally interpret these texts as transactions between institutions and citizens or management of public resources (Englund, 2011; Nissen, 1993, 1986)[35], originating from tribute payment and extraction of labor surplus (Pollock, 1999; Bramanti, 2020; Lafont et al., 2017).[36] This notion is evident from three main characteristics of the *corpus* of tablets of our main study period. First, in many instances public officials are mentioned in the text. Second, the recorded quantities were very large for the economy of the time and it is difficult to interpret such large movements of goods as private transactions. Third, writing was a very rare skill at the time and only important and wealthy public institutions had the means to maintain a professional bureaucracy able to consistently record transactions in proto-cuneiform writing (Nissen, 1993). This effort to collect and manage resources by state institutions was focused on three main domains, namely agricultural land, labor and animal husbandry (Nissen et al., 1993). It was this tribute payment system that formed the bedrock of the hierarchical lineage-based societies that char-

periodization. These discrepancies explain the periods for which data are missing (represented by dots in Table DA6). The most important discrepancy for the purpose of our empirical investigation is the lumping of the Early Dynastic periods I and II into one period, in line with the more recent archeological periodization. In practice, however, the Early Dynastic II period is not well documented in the archeological record and the vast majority of tablets that fall into this period belong to the 2900-2700 time-range. See section 1.3 for a discussion of periodization.

[35]Nissen (1993, p.66) clearly makes this point: "At this point, I should like to stress again the fact that except for the category of lists, all texts belong to the economic sphere, without a single example that could be called religious or literary. The obvious conclusion is that writing came into being as a recording system for economic data."

[36]This point emerges very clearly in the concept of "tributary economy" in Pollock (1999, pp.112-3): "Overall, the available evidence suggests that there was more administrative concern with the distribution of goods than with their production. Texts record goods issued and received; [...] The administrative concern with the exchange in contrast with the apparent lack of interest in production suggests that elites may have been content to allow producers to raise animals, grow crops, and manufacture products in whatever way they chose as long as tribute demands were met." Bramanti (2020, p.25) reinforces this point: "It has long been known that cuneiform emerged in Mesopotamia as a strategy to administer the increasing resources available in Southern Mesopotamia at the end of the fourth millennium. The management and accounting of resources led to a greater level of complexity in administrative mechanisms —or, at any rate, the presence of written evidence renders the modern reader aware of such complexity. The presence of an agricultural surplus combined with increasing social stratification, the implementation of new models of power, and the appearance within the sources of major initiatives of collective interest such as canal maintenance and redistribution of goods made unavoidable the emergence of some sort of levy or imposition attached to at least part of the resources. For the sake of simplicity, this attached added value will here be improperly called "taxation".".

acterized archaic city-states (Pollock, 1999; Ur, 2014; Benati, 2015).[37]

Based on the notion that most tablets from our main study period were related to public administration and recorded payments or redistribution of tribute, in the paper we use tablets to approximate the existence - in a given period and part of the sample area - of a functioning administration that collected some form of tribute. As the content of early cuneiform tablets could vary (Bramanti, 2020) and the study of early taxation in ancient Mesopotamia is limited (Postgate, 2017, p.xxiii), in our Results Appendix, we validate this notion by replicating the analysis of tablets as proxies for tribute payment using only administrative tablets (based on the CDLI categorization by genre), tablets that explicitly mention taxes (see section 8.2 for details on the text analysis), and tablets that mention some of the most common commodities and objects related to tax payment, such as cereals and fields (see Table RA29).

Some of the more complex texts also list individuals, sometimes using their proper name, while at times using their official titles if they were performing specific administrative tasks for the state.[38] Individuals were mentioned for instance in the context of fields ownership, in some proto-cadastral context, or if they were tasked with specific responsibilities, such as organizing corvee labor. Some tablets can be fairly long and list, together with a transaction and the people involved in it, also the tasks performed by the people involved in the transaction. In section 8.2, we provide some examples of these tablets while discussing the specific words employed in our text-analysis of Sumerian tablets.

[37]Pollock (1999) argues that the political economy of ancient Mesopotamian city-states changed later on in the 3rd millennium, when powerful households (such as important temples) became more directly involved in production. This transition, however, only materialized in the Early Dynastic II period: "These patterns indicate relatively little change in economic organization in the Khafaja neighborhood from the Late Uruk through Early Dynastic I period. Only at the beginning of Early Dynastic II, with the founding of the Temple Oval, is there clear indication of an oikos organization." (Pollock, 1999, p.130)

[38]In this context, the notion of "state" and "institutions" should be interpreted very broadly to incorporate both secular and religious institutions.

Table DA6: CUNEIFORM TABLETS BY PERIOD

	Period name	Dates	Tot tablets	Transliterated	Administrative
	(1)	(2)	(3)	(4)	(5)
1	Eridu	5300-4900BCE	0	0	0
2	Early Ubaid	4900-4300BCE	0	0	0
3	Late Ubaid	4300-3900BCE	0	0	0
	Main study period				
4	Early Uruk	3900-3600BCE	0	0	0
5	Middle Uruk	3600-3500BCE	0	0	0
6	Late Uruk	3500-3100BCE	1,884	1,846	1,871
7	Jemdet Nasr	3100-2900BCE	3,870	3,567	3,165
8	Early Dynastic I	2900-2700BCE	819	472	789
9	Early Dynastic II	2700-2600BCE	.	.	.
10	Early Dynastic III	2600-2350BCE	6,102	5,218	4,255
11	Akkadian	2350-2150BCE	10,086	8,436	6,638
12	Ur III	2150-2000BCE	93,348	71,002	90,689
13	Isin	2000-1900BCE	.	.	.
14	Larsa	1900-1800BCE	.	.	.
15	Old Babylonian	1800-1600BCE	31,353	10,793	7,471
16	Cassite	1600-1200BCE	.	.	.
17	Middle Babylonian	1200-750BCE	5,433	112	3,494
18	Neo Assyrian	750-626 BCE	3,133	439	121
19	Neo Babylonian	626-539 BCE	9,398	347	6,089
20	Achaemenid	539-330BCE	2,302	9	783
21	Seleucid	330-150BCE	2,979	43	20
22	Parthian	150BCE-224 CE	11	0	2
23	Sassanian	224-651 CE	15	0	1
24	Early Islamic	651-835? CE	0	0	0
25	Samarran	835-1000? CE	0	0	0
26	Middle Islamic	1000-1200? CE	0	0	0
27	(Late) Abbasid	1200-1258? CE	0	0	0
28	Late Islamic A[c]	1258-1330? CE	0	0	0
29	Late Islamic B[c]	1330-1533 CE	0	0	0
30	Ottoman[e]	1533-1918 CE	0	0	0
31	Recent[e]	1918-1950? CE	0	0	0

Notes: Number of tablets across cities in the sample area. See section 5 for a description of the selection procedure for cities and Figure DA6 for a map of cities included in the sample area. Number refer to tablets contained in the CDLI database. If the period of production of a tablet is uncertain we attribute it to the later period. Numbers refer to tablets for which information on both city of production and archeological period are available. A tablet is coded as transliterated if the "content" variable provided by CDLI is populated. A tablet is coded as administrative if the CDLI catalogue categorizes it as such in the "genre" variable. Dots indicate missing data for a specific period.

8.2 Text analysis of cuneiform tablets

Other than using tablets as archeological artefacts that approximate the existence of a functioning bureaucracy that recorded tribute payments across our sample area, we can also exploit the content of the tablets to gauge information on what institutions were recording and how this changed across space and over time. For our text analysis, we exploit the large number of tablets that were dated, geo-located and transliterated by Assyriologists to implement a text analysis that allows us to trace the frequency in the occurrence of specific words across our sample of cities and over time. As one can see from Table DA6, only for a fraction of the CDLI tablets for our main study period transliterations are available, with the lowest share being the one for the Early Dynastic I period. We discuss this additional layer of selection below.

We restrict this part of the analysis to the main study period in order to facilitate textual analysis and increase precision. Tablets across our sample area were written in two main languages, Sumerian and Akkadian. Akkadian only became a language employed by the public administration with the emergence of the Akkadian empire in 2350BCE. Sumerian was the sole administrative language before that date. Sumerian as a well-defined and coded language, however, only emerged during the Early Dynastic period. Before 2900BCE, an earlier writing code was used, which is normally referred to in the literature as proto-cuneiform (or proto-Sumerian). While part of the same language and writing system, proto-cuneiform was characterized by a lower precision in the drawing of the symbols and a lower level of standardization, compared to 3rd millennium Sumerian.[39]

When transliterating cuneiform language, Assyriologists associate a particular combination of Roman letters and numerals to a cuneiform symbol. While the association between symbols and transliteration is standardized and well-established for the late Early Dynastic period (Early Dynastic III), for the periods in our main study period this is not always the case. In instances where the exact meaning of a given cuneiform symbol is not clear, scholars employ the same transliteration in capital letters. For the purpose of our textual analysis, we adjust our text-search to account for this factor by simply searching for both the standard transliteration (as reported in Table DA6) and its capitalized version.

We select four categories that speak to our research hypothesis to implement the text analysis on cuneiform tablets. We report all transliterated Sumerian words that we use for the text analysis by category in Table DA7, together with the different attestations of the same word. Sumerian transliterated words are selected based on the information provided by the most authoritative Sumerian lexicons. Our primary source for Sumerian words is the Electronic Pennsylvania Sumerian Dictionary (EPSD2)[40], which we cross-check with standard online Sumerian lexicons (Foxvog, 2016; Sallaberger, 2006). As a general principle we try to incorporate in our text analysis as many relevant words by category as possible so to minimize the chances of having an inflated frequency of false negatives. We provide the rationale for the different clusters of words, as well as the specific judgement calls for each category below.[41]

- *Big man*: "Big man" is the literal translation of the term "lugal", composed of "lu" (man) and "gal" (big, great, senior). The term originally defined the head of a family lineage and in the Early Dy-

[39] While table DA6 may suggest that writing was invented *ex-abrupto* around 3300BCE, the emergence of writing as an accounting device was arguably the final technological innovation in a slow development process of increasingly precise accounting techniques. The first accounting devices probably originated in the first half of the 4th millennium BCE (Englund, 2011).

[40] Accessed on 15/5/2022 at http://oracc.museum.upenn.edu/epsd2/sux

[41] In the Results Appendix (Table RA29) we also validate the notion of cuneiform tablets being largely records of tribute payment transactions by creating an indicator for whether at least a tablet in the nearest city contained common words that would often occur in a textual context related to tribute payment transactions in the form of lists of goods transacted. For this purpose we select a few common Sumerian words related to grains (barley and wheat), reed, livestock (sheep, cattle, goat), beer, types of field and containers of different materials. The full list of strings employed in the text analysis of this particular category is as follows: " sze " " SZE " " sze-am " " SZE-AM " "|sze " "|SZE " " sze " " SZE " " gig " " GIG " " gib " " GIB " " gib-ba " " GIB-BA " "ziz2" "ZIZ2" "ze2-za-an" "ZE2-ZA-AN" " ziz " " ZIZ " " kasz " " KASZ " "kasz2" "KASZ2" " ka-asz " " KA-ASZ " " gi " " GI " " u8" " U8" "masz " "MASZ " "masz2" "MASZ2" "udu-bi" "UDU-BI" "sze-bi" "SZE-BI" "gukkal" "GUKKAL" " udu " " UDU " "gud" "GUD" " gu4 " " GU4 " " gu4-ud " " GU4-UD " " ab2 " " AB2 " "gana2" "GANA2" "gan2-ne2" "GAN2-NE2" "a-szag4" "A-SZAG4" " a-sza3 " " A-SZA3 " "aszag" "ASZAG" " gur " " GUR " "gur9" "GUR9" "gur23" "GUR23" "lid2-ga" "LID2-GA" "lid2" "LID2" "li2-id-ga" "LI2-ID-GA" "geszlidda2" "GESZLIDDA2" "sida3" "SIDA3" "nig2-sila3" "NIG2-SILA3" "tun3-la2" "TUN3-LA2" " dug " " DUG " "dug" "DUG" "dugnig2" "DUGNIG2" "gesznig2" "GESZNIG2" "urudnig2" "URUDNIG2" " ba-an " " BA-AN " "ban2" "BAN2" " ba-an-ne2 " " BA-AN-NE2 " "geszba-an" "GESZBA-AN" "giba-an" "GIBA-AN" "i3" "I3" "i3-i3" "I3-I3" "i3-a" "I3-A" "kur-ku-du3" "KUR-KU-DU3" "dugkur-kam" "DUGKUR-KAM" " za-hum " " ZA-HUM " " za-hu-um " " ZA-HU-UM " "za-a-hum" "ZA-A-HUM".

nastic period became associated with the concept of "ruler", "king" (Marchesi and Marchetti, 2011, p.108). The title always retained a secular connotation, as opposed to alternative royal terminology that originated from the religious sphere and with the temple economy, such as "en" and "ensi" (Marchesi and Marchetti, 2011, pp.103-114). We focus on the term "lugal" as this is the best term to trace the transition from a lineage-based society where heads of households were in charge of conflict resolution, to governments that scaled up the lineage structure at the city-level. See Ur (2014) and Emberling (2015) for a discussion. In line with the relevant literature, the text analysis reveals how the term "lugal" started being recorded systematically by state administrations in the Early Dynastic I period. Before this period, no instance of the term is recorded in CDLI data. A good example of a tablet that mentions a "lugal" from the early Dynastic I period is CDLI P005800.

- *Chief*: "chief" is one interpretation of the Sumerian word "gal", which is a verb/adjective for "to be great", "to be senior", "to be important". Because of the meaning "to be great/senior" the term was used extensively to define specific figures involved in public administration, in the sense of "chief of a certain task" (Borger, 2004). Possibly, this connotation of the term derives from the meaning "chief" in pre-state lineage societies. A good example of this use is the term "kin-gal", "commander" (often used in a military sense), which literally translates "work-chief". On its own, "gal" can take the meaning of "great" (i.e. "great fish"), but is more frequently used with the meaning of "chief". For our main study period periods, we find that roughly 75% of the occurrences bear the latter meaning. We search for the generic word "gal" to capture the development of state administration, where individuals responsible for a specific task (i.e. organization of corvee labor, agricultural improvements, management of tribute payments) would be designated with this word in combination with words specific to the task. We search for the generic term "gal", as opposed to more complex combinations (i.e. "kingal") to account for the fact that these administrative figures were being codified throughout the periods of our main study period and only much later in history these became a regular word that defined a professional administrator tasked with a specific duty. As opposed to "lugal" that only appears on state's records in the Early Dynastic I period, the generic term "gal" was well attested before 2900BCE. Its frequency however increased by about 40% between the Jemdet Nasr and the Early Dynastic I period. There are several examples of the generic use of "gal" as "chief" in CDLI tablets. A good example is CDLI P005378, from the Jemdet Nasr period, where "gal" is mentioned in combination with other administrative figures linked to the temple economy such as the "sanga".

- *Irrigation system*: We also search for a cluster of words that designate different parts of the artificial irrigation system, as reported in Table DA7. The majority of the terms specifically refer to canals of different size, but several parts of the system are included in the text analysis, such as reservoirs and dikes. The idea is here to trace changes in the state's records in the frequency of mentions of parts of the irrigation system. To be conservative we exclude generic vocabulary for "water" and "river", which might have an ambiguous meaning, although they are frequently used in the context of artificial irrigation. The employed words are well attested and documented so their interpretation does not pose ambiguities of any sort. While we do observe in the data a jump in the frequency of these type of words (linked to the appearance of words for canal, such as "i" and "pa4") between the Jemdet Nasr and the Early Dynastic I period, the number of instances is very low (5 tablets in total in the Early Dynastic I period). This feature of the data likely reflects the low level of direct involvement of the state in the building and maintenance of canals during the periods of the main study period, as opposed to later periods when the government was more directly involved (Schrakamp, 2018). Second, the vocabulary for artificial irrigation was not well established around the turn of the 3rd millennium BCE, which implies that we are exposed, for this specific category, to several cases of false negatives due to the exclusion of generic words for "water" and "river". CDLI P499152 is a good example of an Early Dynastic I tablet mentioning a canal in the context of tribute payment and state management. Here the word for canal "pa5" occurs in the context of a tribute list.

- *Tribute*: As discussed above, the general interpretation for the majority of administrative tablets from periods in our main study period relates to transactions involving the state and, thus, likely some form of tribute payment (Nissen, 1993). We can improve the precision of our mapping of tribute payment across the sample area by searching for specific words that indicate forms of taxation. The concept of "taxation" was not well established during proto-cuneiform writing periods, as the distinction between transactions for rent, tribute or generic payments was probably not yet consolidated around 3000BCE. Forms of taxation in the modern sense of the term however were emerging and specific words for taxes start to appear at this stage. See Bramanti (2020) for a discussion.

Proto-cuneiform tablets are very parsimonious in providing information on the context of the transaction. Thus, the word "tribute" was, in most cases, likely not written on a receipt that both parties involved understood as a tribute payment. Possibly owing to this fact, the number of tablets reporting a word for "tribute" in our main study period is small relative to the total number of tablets. Interestingly, however, specific symbols for tribute only appear in the Early Dynastic I period, when we identify 20 tablets containing a word for "tribute". The vast majority of the occurrences is represented by "gu2", a symbol indicating a tax on barley production. It is also worth noting the appearance of the terms "bala" and "masz-da", both terms indicating a regular tax payment to the state that are well attested in later periods. A good examples of the barley tax "gu2" being mentioned in an Early Dynastic I text is CDLI tablet P005943, which describes a transaction where a certain output from a field is given to a state official.

Table DA7: WORDS FOR TEXT ANALYSIS

Word	Sumerian word	Alternative attestations
(1)	(2)	(3)
Big Man		
Big man, king	lugal	lu2-gal
Lineage head/chief		
Great, superior, chief	gal	gal∼, gal-
Canal, or part of the irrigation network		
Main canal	i7	i
Main canal	id	id2, id3, id5, idx, id-da
Small canal	pa4	pa5, pa6, pa-bi-zu, pa-re
Small canal	szita3	szi-de2-na, sze-ten-ba, szi-ten-ba, sze-de2-na
Canal intake	ka id2	
Canal reservoir	kun-zi	
Reservoir	kun	ku-un, kun4
Reservoir	nag2-ku5	kab2-ku5, kab2-tar
Reservoir	durunx	
Part of irrigation system	u3-ter	
Irrigation ditch	a-da-ga	
Dam	gesz-kesz2	gesz-kesze2
Tribute		
Tribute	nig2-ku5	nig2-kud, nig2-KU
Tribute	gu2 ma-da	gu2-un ma-da, gun ma-da
Tribute	gu2	gun, gu2-un, gu2-na, un
Tax official	enkux	en-ku3, en-ku4, ZAG.HA
Taxable land	gan2-il2	
Grain tax	sze-bala	sze-bal
Quota for corvee labor	ku3 a2 gul	
Corvee labor	esz2-gar3	esz5-gar3, is-gar3, esz-gar3
Annual contribution	bala	mu bal, bal, bal-, bala gub
Rent	addir	addirx
Payment delivery	szu-a gi4	
Payment delivery	masz2-da	masz-da, masz-dar
Barley tax	sze gub	
Irrigation tax	masz a-sza3	masz asza5, masz2 a-sza3, masz2 asza5
Irrigation tax	masz ki-duru5	
Irrigation tax	ku3 masz	ku masz

Notes: List of words employed for the text search for key categories. These are words for "big man", "chief", "canal" and "Tribute". All words are searched in both their lower and upper-case version. In the main search we also include spaces on both sides of the transliterated word to increase precision when the word is likely to yield too many false positives. This is the case for all words less than four characters long.

8.3 Data on seals

The CDLI catalogue also provides data on seals. These carved items (typically in stone) were invented before cuneiform writing developed in full and were traditionally used to record transactions by stamping clay tablets, jars and other storage items (Englund, 2011). Their main purpose was to record and validate transactions, in the context of urban administrative systems across southern Mesopotamia (Nissen, 1977). Evidence, however, exists on the role that seals played in facilitating medium and long-distance trade across cities and polities (see Pittman (2018) and Algaze (2008, pp.133-136) for a discussion). While it is virtually impossible to unequivocally distinguish between seals uniquely used for storage and administration within a city and those employed for medium and long-distance trade, the presence of seals in a given city indicates a level of economic complexity and social structure that was normally also associated with stable trade linkages within Southern Iraq and across the Near East. In Table RA26 in the Results Appendix, we exploit this notion by using seals recorded in the CDLI catalogue for our main study period to approximate differences in trade linkages across cities in our sample area.

8.4 Potential concerns about tablets data

CDLI provides the most complete catalogue of excavated cuneiform tablets. However several layers of selection exist with this type of artefact, which may raise concerns about selection into sample. We do not presume to observe the universe of cuneiform tablets, but only a sample. In this section, we discuss these concerns.

The first potential layer of selection is a general survivor bias problem relevant to all archeological evidence. This issue maybe particular severe for smaller artefacts, like tablets, that leave no traces if aptly destroyed or stolen during illegal excavations. This is different from other archeological evidence that we use, such as buildings and city-walls, as the latter tend to leave traces that are hard to miss for archeologists that systematically dig a certain location. Once again, selection into sample of this type would only create a problem if selection was systematic. In other words, if only a particular type of tablets (say temple or governmental records) were preserved owing to higher intensity excavations in particular areas of an archeological site or better preservation of state archives where tablets were stored. Interestingly, however, the information we have on the major tablets finds across different sites is encouraging for our analysis in terms of random sampling. Most tablets in fact were not found *in situ* (i.e. where they were produced or stored). Rather, the largest tablets finds that constitute the core of the cuneiform tablets corpus for Southern Iraq were found in debris layers that were made of litter to level-up different layers of construction. The most famous example the case of Uruk, but the pattern is similar across cities (Nissen, 1993, p.60). Hence, although it is clear that we will never be able to observe the universe of cuneiform tablets, systematic selection into sample is unlikely (at least for our main study period), as all tablets were simply disposed when the transaction they recorded was not relevant anymore, so likely when a certain amount of time had elapsed. The survival of part of the corpus as opposed to others was likely due to idiosyncratic events.[42]

The second potential layer of selection relates to selective digging. Tablets might have not survived selectively but they might have been excavated differentially. In practice, similarly to other sources of archeological data, we only care about this potential problem if intensity of excavation and thus tablet finds correlate with treatment. We show in the Results Appendix that excavated cities are not differentially concentrated in treated areas. To alleviate this concern further (as for all other city-level outcomes), we set to missing those cells whose nearest city was not excavated systematically and thus is more likely to yield false negatives.

Third, tablets collections with particular characteristics might select into the CDLI catalogue. In practice, this is hardly a concern as the criteria with which some collections enter CDLI earlier or in a more complete form than others are largely random. The decision to join the CDLI online repository is voluntary and down to collections' curators. Factors that influence the decision to join CDLI and go online

[42] CDLI experts estimate that tablets that are currently in collections around the globe might be roughly 1/10 of those that were ever produced. CDLI collects an estimated 1/3 of tablets that were ever excavated and are presently in public or private collections. CDLI presently catalogues around 350,000 tablets.

include scholarly links between CDLI personnel and museum curators, size of the collection and availability of personnel to make the transition from paper to online, familiarity of curators with digital tools, and publication strategies where a curator might decide to publish the entirety or part of a collection before making it publicly available.

A final layer of selection regarding cuneiform tablets relates to their transliteration. As not all tablets are transliterated, which is to say not every tablet has been studied by an Assyriologist that transliterated the text from cuneiform symbols into Roman letters and then published the tablet, one might worry that the way tablets are selected for transliteration might not be random which may in turn affect our text analysis. Selection into transliteration is a clear feature of the data, as Assyriologists chose which tablets to work on and to publish. However, for the purpose of our analysis, we believe this is hardly a problem. First focusing on our main study period, as one can see from Table DA6, virtually all tablets from the Late Uruk and Jemdet Nasr periods are transliterated, which is reassuring. With respect to the Early Dynastic I period, for which only roughly 60% of tablets are transliterated, this seems to be a feature of the size of the tablet. As there was no systematic attempt to transliterate all tablets from this period, Assyriologists seem to have started from more extensive texts and selected based on the academic interest of the tablet, within the corpus of available tablets in each city. With the exception of Khafaji where only one tablet from the Early Dynastic period was found (and this is presently not transliterated), all cities where tablets were found show at least one tablet with transliteration. These are normally the ones with the richest and more complex texts. As there is no selective transliteration across cities but only within cities, this feature of the data is unlikely severely affect the accuracy of the mapping of specific terms across the sample area.

References

Acemoglu, D., C. García-Jimeno, and J. A. Robinson (2015). State capacity and economic development: A network approach. *The American Economic Review 105*(8), 2364–2409.

Adams, R. M. (1957). Settlements in ancient Akkad. *Archaeology 10*(4), 270–273.

Adams, R. M. (1965). *Land Behind Baghdad*. Chicago: University of Chicago Press.

Adams, R. M. (1974). *The Evolution of Urban Society: early Mesopotamia and prehispanic Mexico*. London: Weidenfeld and Nicholson.

Adams, R. M. (1981). *Heartland of cities*. Chicago: University of Chicago Press.

Adams, R. M. and H. J. Nissen (1972). *The Uruk Countryside: the Natural Setting of Urban Societies*. Chicago: University of Chicago Press.

Algaze, G. (2008). *Ancient Mesopotamia at the Dawn of Civilization: the Evolution of an Urban Landscape*. Chicago: University of Chicago Press.

Beek, M. A. (1962). *Atlas of Mesopotamia*. New York: Thomas Nelson.

Benati, G. (2015). Re-modeling political economy in early 3rd millennium bc mesopotamia: patterns of socio-economic organization in archaic ur (tell al-muqayyar, iraq). *Cuneiform Digital Library Journal 2*, 1–37.

Boehmer, R. (1991). Uruk 1980-1990 : a progress report. *Antiquity* (65), 465–478.

Borger, R. (2004). *Mesopotamisches Zeichenlexikon*. Ugarit-Verlag.

Bramanti, A. (2020). Management of resources and taxation in the early dynastic and sargonic periods. In J. Mynářová and S. Alivernini (Eds.), *Economic complexity in the ancient Near East : management of resources and taxation (third-second millenium BC)*, pp. 25–36. Prague: Charles University.

Brusius, M. (2012). Misfit Objects: Layard's Excavations in Ancient Mesopotamia and the Biblical Imagination in mid-nineteenth Century Britain. *The Journal of Literature and Science 5*(1), 38–52.

Bryce, T. (2009). *The Routledge Handbook of the Peoples and Places of Ancient Western Asia: The Near East from the Early Bronze Age to the Fall of the Persian Empire*. Abingdon: Routledge.

Burke, A. (2008). *"Walled up to heaven" : the evolution of Middle Bronze Age fortification strategies in the Levant*. Winona Lake, Indiana: Eisenbrauns.

Cole, S. W. (1994). Marsh formation in the Borsippa region and the course of the lower Euphrates. *Journal of Near Eastern Studies 53*(2), 81–109.

Cole, S. W. and H. Gasche (1998). Second- and first-millennium BC rivers in northern Babylonia. In H. Gasche and M. Tanret (Eds.), *Changing Watercourses in Babylonia*, pp. 1–64. Ghent: University of Ghent.

Cole, S. W. and H. Gasche (2007). Documentary and other archaeological and environmental evidence bearing on the identification and location of the rivers of lower Khuzestan and the position of the head of the Persian Gulf ca. 1200 BC-200 AD. *Akkadica 128*, 1–72.

Davidson, P. (2011). *Atlas of Empires: The World's Great Powers from Ancient Times to Today*. London: New Holland Publishers.

Delougaz, P., S. Lloyd, and H. D. Hill (1967). *Private houses and graves in the Diyala region [electronic resource]*. Chicago: University of Chicago Press.

Emberling, G. (2015). Mesopotamian cities and urban process, 3500–1600 bce. In N. Yoffee (Ed.), *The Cambridge World History, Volume 3: Early Cities in Comparative Perspective, 4000 BCE-1200 CE*, pp. 253–278. Cambridge: Cambridge University Press.

Englund, R. (2011). Accounting in proto-cuneiform. In K. Radner and E. Robson (Eds.), *The Oxford Handbook of Cuneiform Culture*, pp. 32–50. Oxford: Oxford University Press.

Fleitmann, D., H. Cheng, S. Badertscher, R. Edwards, M. Mudelsee, O. M. Göktürk, A. Fankhauser, R. Pickering, C. Raible, A. Matter, et al. (2009). Timing and climatic impact of Greenland interstadials recorded in stalagmites from northern Turkey. *Geophysical Research Letters 36*(19).

Foxvog, D. A. (2016). Elementary sumerian glossary. Technical report.

Gasche, H., M. Tanret, S. W. Cole, and K. Verhoeven (2002). Fleuves du temps et de la vie Permanence et instabilité du réseau fluviatile babylonien entre 2500 et 1500 avant notre čre. *Annales. Histoire, Sciences Sociales 57*(3), 531–544.

Gibson, M. (1972). *The city and area of Kish*. Miami: Field Research Projects.

Gibson, M., J. A. Armstrong, and A. McMahon (1998). The city walls of nippur and an islamic site beyond: Oriental institute excavations, 17th season, 1987. *Iraq 60*, 11–44.

Hamblin, W. J. (2006). *Warfare in the ancient Near East to 1600 BC: Holy warriors at the dawn of history*. Routledge: London.

Heinrich, E. (1982). *Die Tempel und Heiligtümer im alten Mesopotamien: Typologie, Morphologie und Geschichte*. Berlin: de Gruyter.

Heinrich, E. (1984). *Die Paläste im alten Mesopotamien*. Berlin: de Gruyter.

Hritz, C. (2010). Tracing settlement patterns and channel systems in southern Mesopotamia using remote sensing. *Journal of Field Archaeology 35*(2), 184–203.

Knappen, T. and A. McCarthy (1952). Report on the development of the Tigris and Euphrates River systems. Technical report.

Lafont, B., A. Tenu, F. Joannes, and P. Clancier (2017). *La Mésopotamie. De Gilgamesh à Artaban 3300-120 av. J.-C.* Paris: Belin.

Le Strange, G. (1905). *The lands of the eastern Caliphate: Mesopotamia, Persia, and central Asia, from the Moslem conquest to the time of Timur*. Cambridge: Cambridge University Press.

Leick, G. (2002). *Mesopotamia : the invention of the city*. London: Penguin.

Marchesi, G. and N. Marchetti (2011). *Royal statuary of early dynastic Mesopotamia*. Winona Lake, Ind.: Eisenbrauns.

Marchetti, N., A. Al-Hussainy, G. Benati, G. Luglio, G. Scazzosi, M. Valeri, and F. Zaina (2019). The Rise of Urbanized Landscapes in Mesopotamia: The QADIS Integrated Survey Results and the Interpretation of Multi-Layered Historical Landscapes. *Zeitschrift für Assyriologie und vorderasiatische Archäologie 109*(2), 214–237.

Meyers, E. (Ed.) (1997). *The Oxford Encyclopedia of Archaeology in the Near East. 5 Volumes*. Oxford: Oxford University Press.

Morozova, G. (2005). A review of Holocene avulsions of the Tigris and Euphrates rivers and possible effects on the evolution of civilizations in lower Mesopotamia. *Geoarchaeology 20*(4), 401–423.

Nissen, H. (1977). Aspects of the development of early cylinder seals. In M. Gibson and R. D. Biggs (Eds.), *Seals and sealing in the ancient Near East*, pp. 15–25. Malibu: Undena Publications.

Nissen, H. (1993). The context of the emergence of writing in Mesopotamia and Iran. In J. Curtis (Ed.), *Early Mesopotamia and Iran: contact and conflict 3500-1600 BC: proceedings of a seminar in memory of Vladimir G. Lukonin*, pp. 54–71. London: British Museum Press.

Nissen, H. J. (1986). The archaic texts from uruk. *World archaeology 17*(3), 317–334.

Nissen, H. J. (1988). *The early history of the ancient Near East, 9000-2000 B.C.* Chicago: Chicago: Chicago University Press.

Nissen, H. J., P. Damerow, and R. K. Englund (1993). *Archaic bookkeeping : early writing and techniques of the economic administration in the ancient Near East*. Chicago ; London: University of Chicago Press.

Oraibi Almamori, H. (2014). The early dynastic monumental buildings at umm al-aqarib. *Iraq 76*, 149–187.

Pittman, H. (2018). Administrative role of seal imagery in the early bronze age: Mesopotamian and iranian traders on the plateau. In S. Scott, S. K. Costello, M. Ameri, and G. Jamison (Eds.), *Seals and sealing in the ancient world : case studies from the Near East, Egypt, the Aegean, and South Asia*, pp. 13–35. Cambridge: Cambridge University Press.

Pollock, S. (1999). *Ancient Mesopotamia: the Eden that never was*. Cambridge: Cambridge University Press.

Pollock, S., M. Pope, and C. Coursey (1996). Household production at the uruk mound, abu salabikh, iraq. *American journal of archaeology 100*(4), 683–698.

Postgate, J. N. (1984). Excavations at abu salabikh, 1983. *Iraq 46*, 95–113.

Postgate, N. (2017). *Early Mesopotamia: society and economy at the dawn of history*. Abingdon: Taylor & Francis.

Pournelle, J. (2003). *Marshland of Cities: Deltaic Landscapes and the Evolutions of Early Mesopotamian Civilization*. Ph. D. thesis.

Roaf, M. (1990). *Cultural atlas of Mesopotamia and the ancient Near East*. New York: Facts on File Inc.

Roberts, N., M. Jones, A. Benkaddour, W. Eastwood, M. Filippi, M. Frogley, H. Lamb, M. Leng, J. Reed, M. Stein, L. Stevens, B. Valero-Garcés, and G. Zanchetta (2008). Stable isotope records of Late Quaternary climate and hydrology from Mediterranean lakes: the ISOMED synthesis. *Quaternary Science Reviews 27*(25-26), 2426–2441.

Rost, S. (2017). Water management in Mesopotamia from the sixth till the first millennium BC. *Wiley Interdisciplinary Reviews: Water 4*(5), e1230.

Rothman, M. (2001). *Uruk Mesopotamia & its neighbors: cross-cultural interactions in the era of state formation*. Oxford: James Currey.

Rzoska, J. (1980). *Euphrates and Tigris, mesopotamian ecology and destiny*. The Hague: Junk Publishers.

Sallaberger, W. (2006). Leipzig-münscher sumerische zettelkasten. Technical report.

Schrakamp, I. (2018). Irrigation in 3rd millennium Southern Mesopotamia: cuneiform evidence from the Early Dynastic IIIb city-state of Lagash (2475–2315 BC). In J. Berking (Ed.), *Water Management in Ancient Civilizations*. Berlin: Edition Topoi.

Sherratt, A. (2004). Environmental change: The evolution of mesopotamia. Technical report.

Stone, E. C. (2014). High-resolution imagery and the recovery of surface architectural patterns. *Advances In Archaeological Practice 2*(3), pp180–194.

Ur, J. (2014). Households and the emergence of cities in ancient Mesopotamia. *Cambridge Archaeological Journal 24*(2), 249–268.

van de Mieroop, M. (2015). *A History of the Ancient near East, Ca. 3000-323 BC*. New York: John Wiley and Sons.

Verkinderen, P. (2015). *The Waterways of Iraq and Iran in the Early Islamic Period: The Changing Rivers and Landscapes of the Middle East*. London: IB Tauris.

Wilkinson, T. J. (2012). Introduction to Geography, Climate, Topography, and Hydrology. In D. T. Potts (Ed.), *A companion to the archeology of the ancient Near East*, pp. 3–26. Malden, Mass.: Wiley-Blackwell.

An Atlas of Long-Run Development in southern Iraq

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October 2022

Appendix for: The Economic Origins of Government

For online publication only

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‡Kellogg School of Management, Northwestern University, 2211 Campus Drive, Evanston, IL 60208, USA. E-mail: leander.heldring@kellogg.northwestern.edu. Website: www.leanderheldring.com The image on the front page of this atlas is the 'Mask of Sargon'. The mask was thought to be of Sargon of Akkad, the founder of the world's first empire, but more likely depicts his grandson Naram-Sin.

Contents

1 Introduction

This Atlas provides an overview of development in southern Iraq from 5000 BCE to today. The graphs, figures, and lists we present complement our paper "The Economic Origins of Government". The paper provides evidence in favor of a theory of the origins of government that emphasizes government as an organization that solves coordination problems.

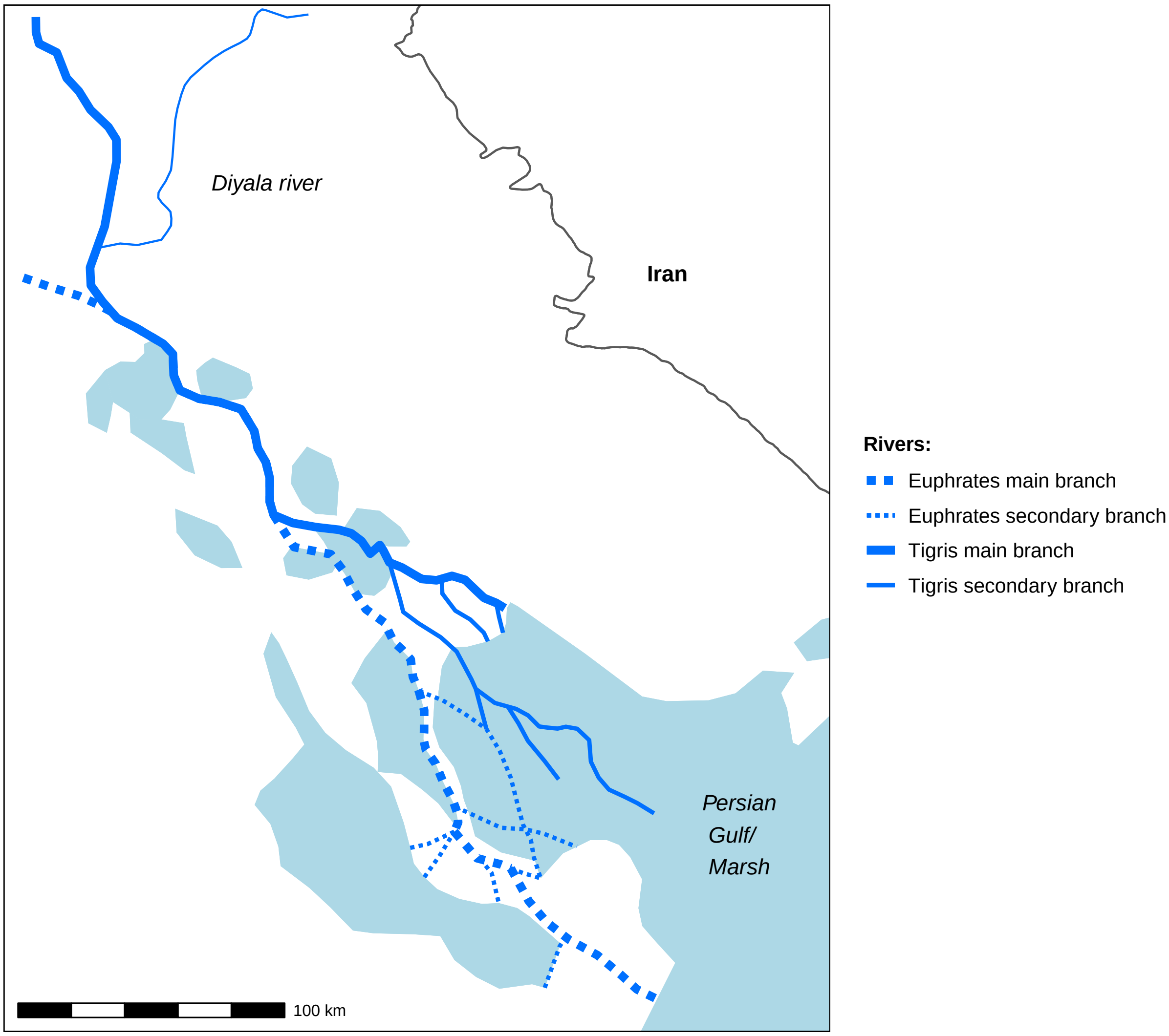
The main sources for the data used to test this theory are archeological surveys. These surveys document the results of several archeological campaigns excavating, cataloguing and mapping human activity in what historically was known as Mesopotamia, the 'land between rivers'. The Data Appendix to our paper provides descriptions of our data sources.

In this Atlas, we provide graphical representations of our data in the form of maps for each of the historical periods considered our paper, from about 5000 BCE until today. The overall pattern that emerges in these data is one of rise and decline of economic fortune. For example, some of the world's first cities, Ur and Uruk, are at their height around 3500 BCE. Hammurabi's famed law code is written in the Old-Babylonian period, which coincides with a marked rise in economic fortune around 1800 BCE. After the Muslim conquest around 630 CE, the Golden Age of Islam lasts for several centuries. Afterwards settlement retreats to the rivers and falls drastically. This collapse is in part driven by the disappearance of a centralized state and the public goods it provided. It was not until the twentieth century, and the global interest in oil, that settlement started recovering to the levels it had been at 5000 years earlier. In addition, we provide an overview of political development of states, as well as a list of all cities contained in our dataset.

2 The changing environment

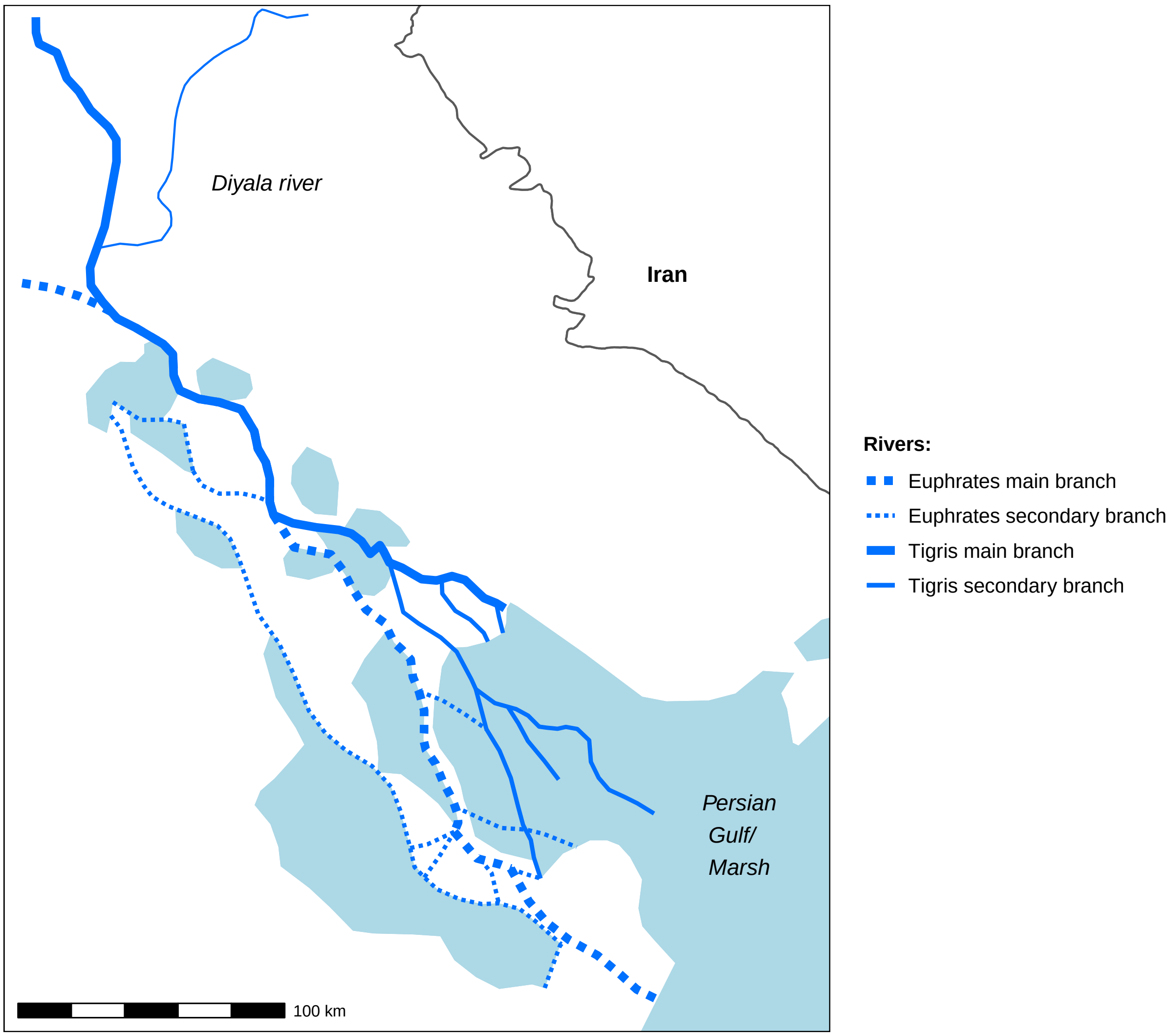
In this section, we map the river courses throughout our extended study period, between 5000 BCE and today. Every successive map paints the picture after a river move from the initial layout around 5000 BCE. Note the fluctuating coastline, which changes as a result of changes in the level of the water in the Persian Gulf. A description of the sources and the methodology employed to reconstruct the riverine system in each period and to date the shifts between different periods is provided below each figure.

Figure AA1: Watercourses in 5000 BCE



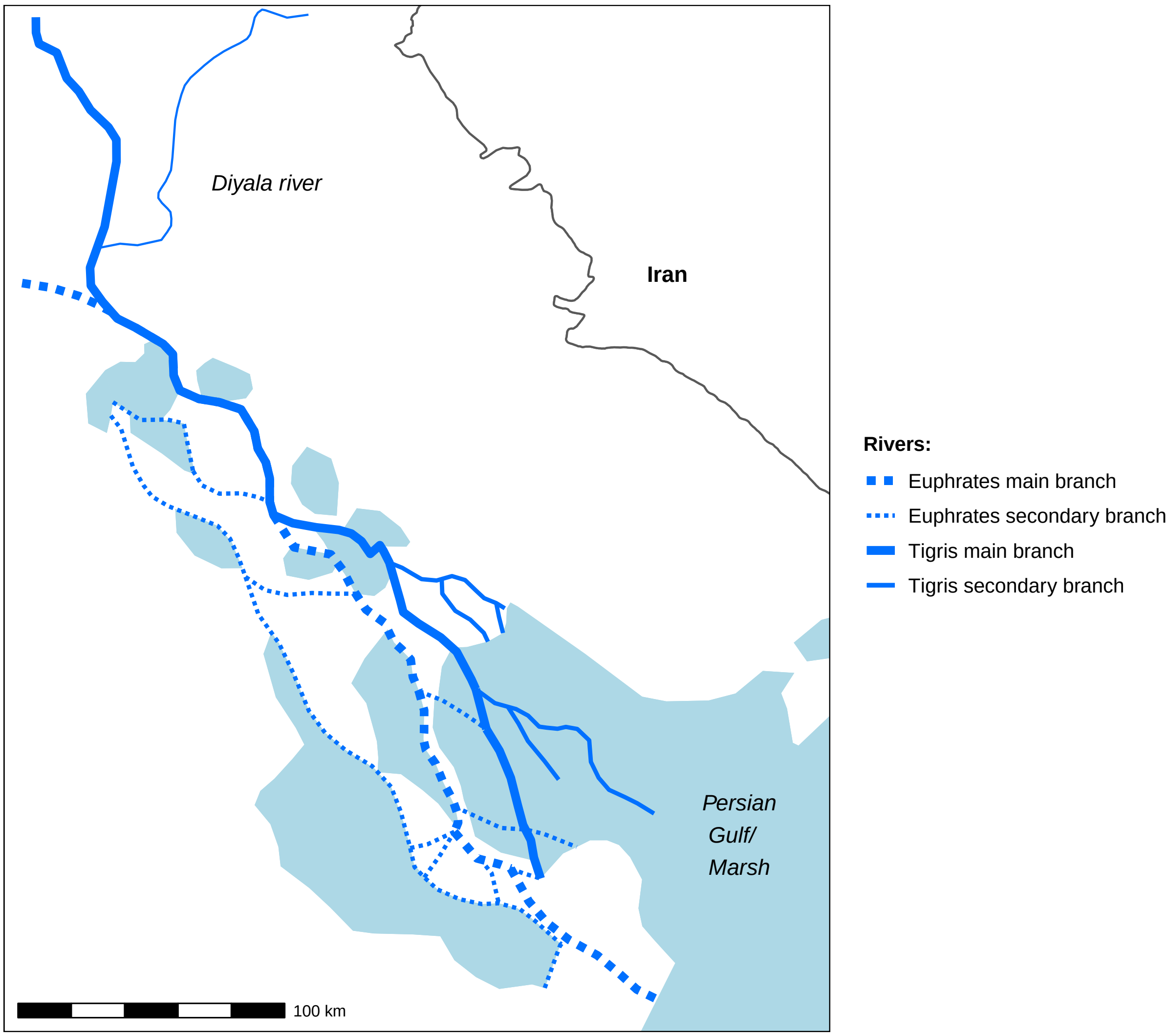
Although the riverine system in the 5th millennium BCE had already undergone significant transformations relative to previous millennia, we take 5000 BCE as the first cross-section of the study as this coincides with the first archeological period reported in Adams' surveys. We rely on Algaze (2008, p.45), who provides a map covering the 5th and the 4th millennium BCE. The author reports the westernmost branch of the Euphrates as uncertain. We do not code the latter branch as in existence in the 5000 BCE cross-section, as Adams (1981, p.56) reports settlements along this branch only from the Early Uruk period onwards. As we do not see any settlement in the pre-Uruk periods along this "uncertain" branch, we remove it from the 5000 BCE cross-section. We also remove the easternmost river located in Iran, which falls outside our study area. For the 5000 BCE, 4000 BCE and 3500 BCE river cross-sections, we derive the ancient location of the Diyala river (not reported in Algaze) from Adams (1965, Figure 2). We extend the length of the Diyala river from the inflow point shown by Adams to the nearest point of the Tigris' course reported by Algaze (2008, p.45).

Figure AA2: Watercourses in 4000 BCE



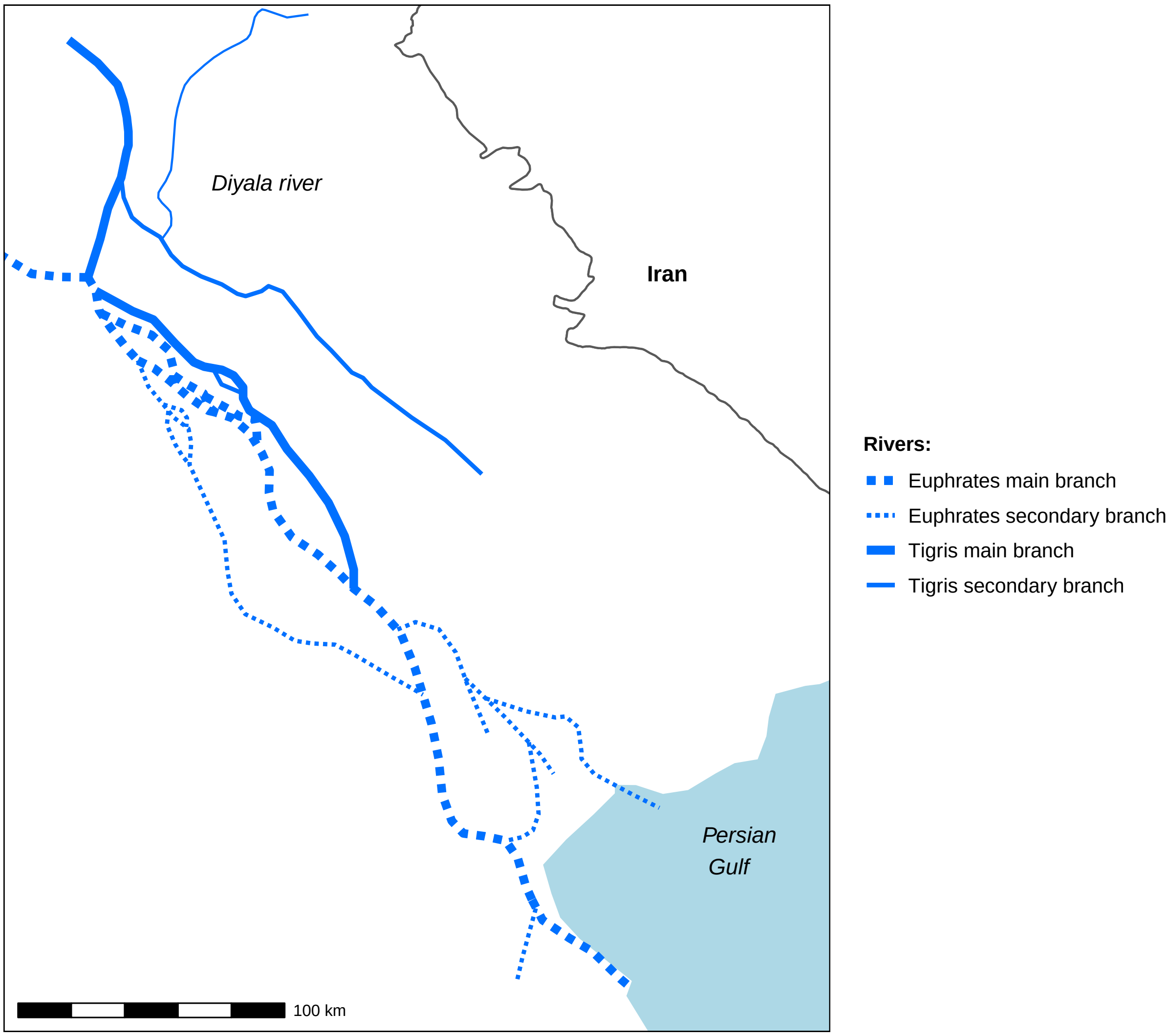
For the 4000 BCE cross-section, we rely on Algaze (2008, p.45), who depicts the river network between the 5th and the 4th millennium BCE. The 5000 and 4000 BCE cross-sections are therefore similar, with only a few differences. We include the two westernmost branches of the Euphrates that are reported by Algaze as uncertain, based on the fact that active settlements are observed from the Early Uruk period (Adams, 1981, p.56). This is also consistent with (Adams, 1981, pp.16-17) who, following Paepe (1971), argues that, for this period, the available evidence points to a joint watercourse in the upper part of the alluvium (near Sippar), which branched out in multiple natural canals only south of Kutha. The 4000 BCE river cross-section, therefore, is fully consistent with Algaze (2008, p.45). The location of settlements from Adams (1981, p.56) allows us to date the shift from the 5000 BCE to the 4000 BCE cross-sections between the end of the Late Ubaid and the beginning of the Early Uruk period. We date the shift at 3950 BCE based on a clear spike in rainfall variability in the 50-year window around that date (See Figure RA1).

Figure AA3: Watercourses in 3500 BCE



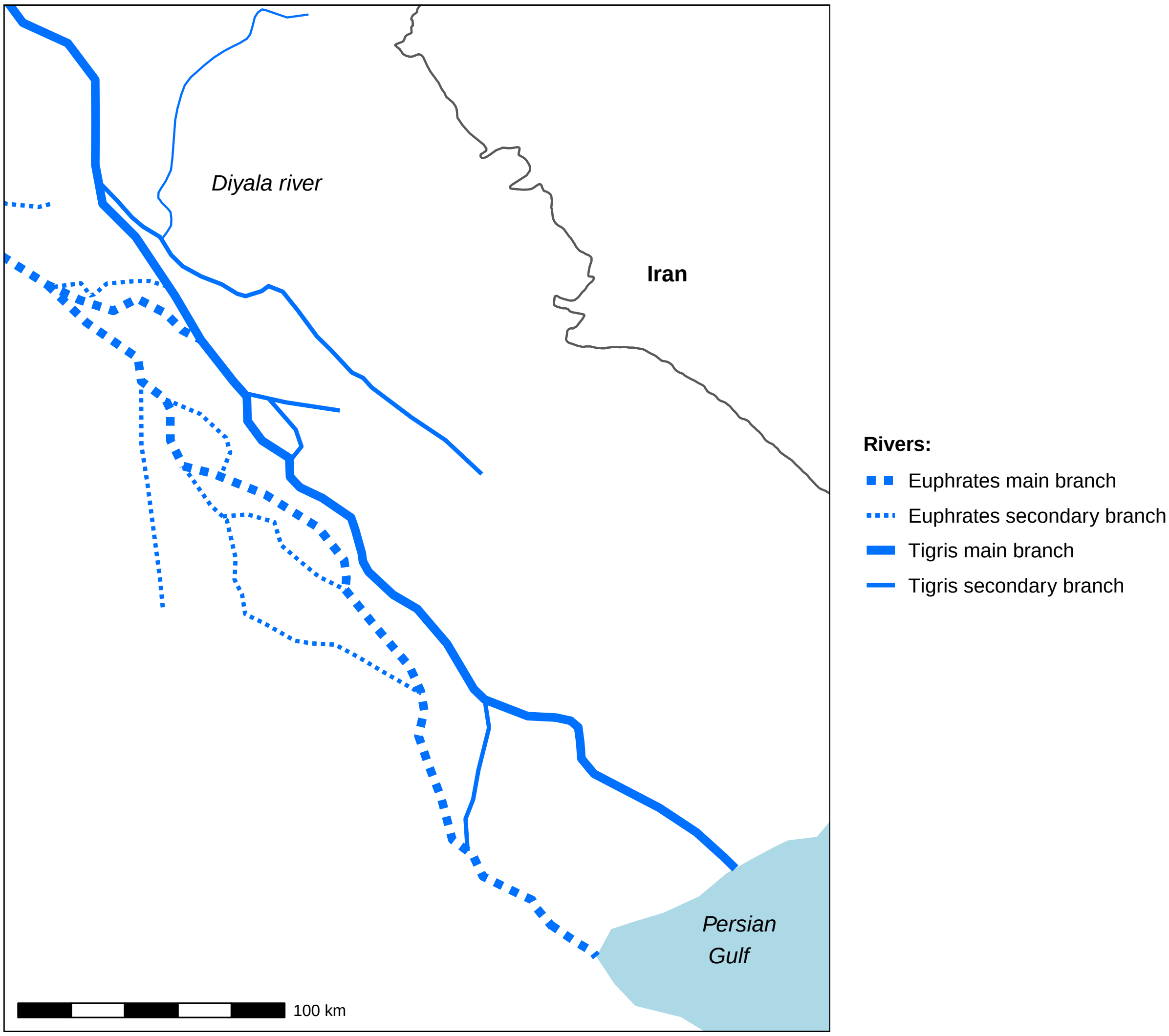
For the 3500 BCE cross-section, we rely again on Algaze (2008, p.45), who reconstructs the river network in the 5th and the 4th millennia BCE. Between 4000 and 3500 BCE, the main branch of the Tigris, which in 4000 BCE ran north of Adab, lost volume in favor of the Adab branch and became a secondary branch. This is described by Adams (1981, pp.14-9 and 61-3) when he discusses the collapse in settlement in the area between the Middle and Late Uruk periods. We therefore create an additional 3500 BCE cross-section from Algaze (2008, p.45), which only differs from the 4000 BCE one for the relative importance of the Tigris branches. Adams (1981) dates the shift to the Late Uruk period based on changes in the distribution of settlement. We observe a spike in rainfall variability in the 50-year window around 3600 BCE (See Figure RA1). Therefore, we date the shift as taking place during the short Middle Uruk period. The 3500 BCE river cross-section, therefore, was certainly in place by the beginning of the Late Uruk period and possibly already by the end of the Middle Uruk one.

Figure AA4: Watercourses in 3000 BCE



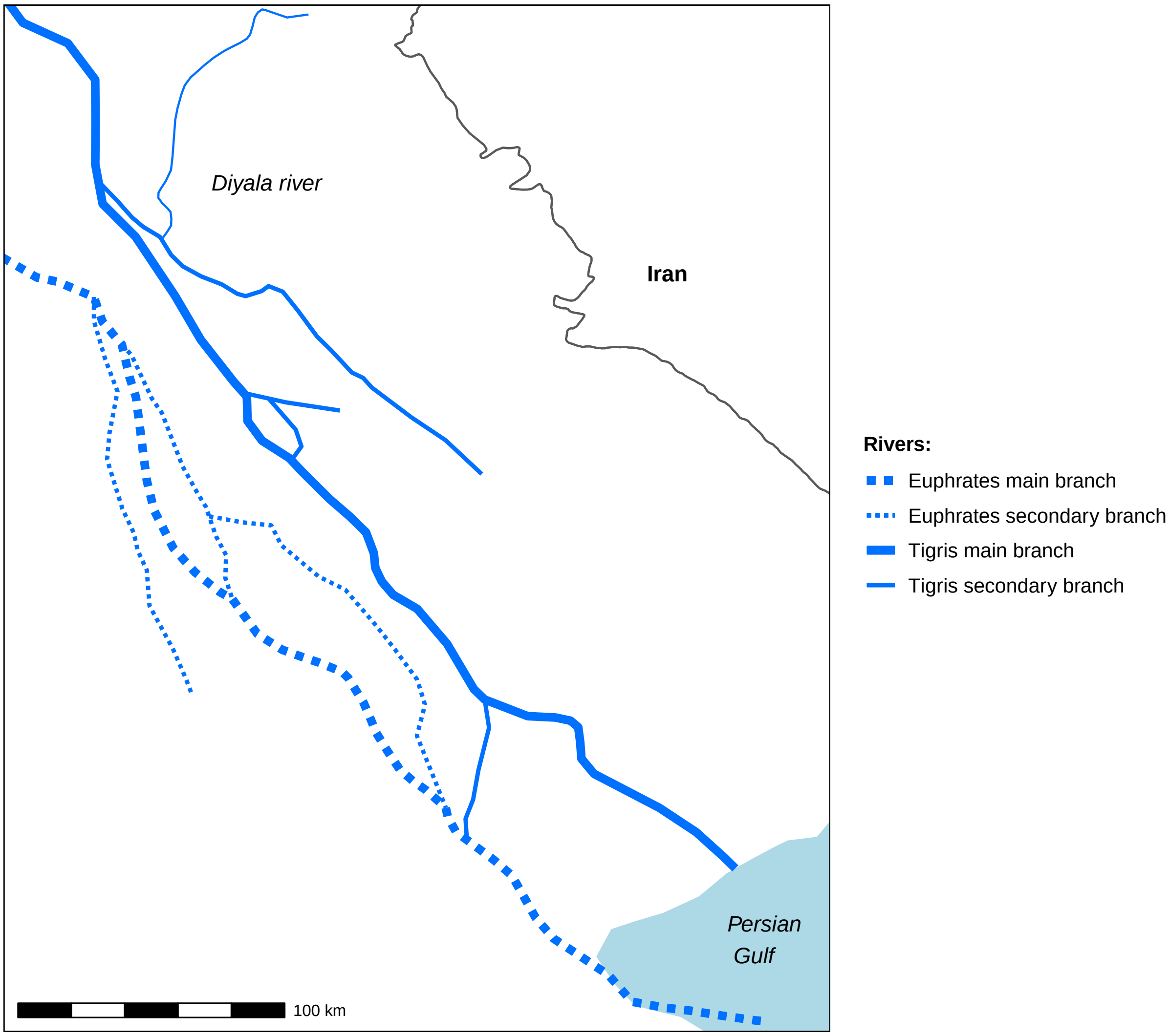
For the 3000 BCE cross-section, we rely on Adams (1974, p.70), who provides a map of the river network at the turn of the third millennium BCE. By the beginning of the third millennium, the Tigris had developed a new secondary branch located north of the current branch and running through the Diyala plain, near the bed of the later Nahrawan canal. This new stream branched off to the north-west of Baghdad and intersected with the Diyala river. The southern part of this branch has not yet been located, but probably reached and watered the ancient cities of Kesh and Larak. The main branch of the Euphrates had moved near the city of Kutha (which lends its name to the river branch), and proceeded south-east from there, reaching the southern cities of Uruk and Ur, after touching Nippur and Shurrupak. The branch directly north of the Kutha branch (but south of the new Tigris/Nahrawan branch) was, at the time, the main branch of the Tigris. The south-western branches of the Euphrates and, in particular, the one watering the ancient city of Kish were, in this epoch, secondary branches. The 3000 BCE cross-section that we employ only deviates from Adams (1974, p.70) for a few elements. First, while Adams codes parts of the Kish branch as primary, we code this section of the river network as secondary. This was possibly a mapping imprecision by Adams that codes the same branch as secondary further downstream. Second, we identify the main Tigris branch (Not marked by Adams) based on Gasche et al. (2002)'s subsequent cross-section for 2000 BCE (see below). Finally, we extend the upper streams of the Tigris and the Euphrates (not drawn in Adams (1974, p.70)) so that they connect around Sippar, thus making the map consistent with the subsequent 2000 BCE cross-section. Adams (1974, p.70) suggests that the river network had reached the described equilibrium by the beginning of the Early Dynastic period. However, he does not date the shift from the 3500 BCE to the 3000 BCE cross-sections precisely. We therefore rely on Roaf (1990, p.80), who suggests that the rivers had shifted at the very beginning of the Early Dynastic I period. This coincides with a spike in rainfall variability in the 50-year window around 2850 BCE (See Figure RA1). Thus, we date the shift at 2850 BCE.

Figure AA5: Watercourses in 2000 BCE



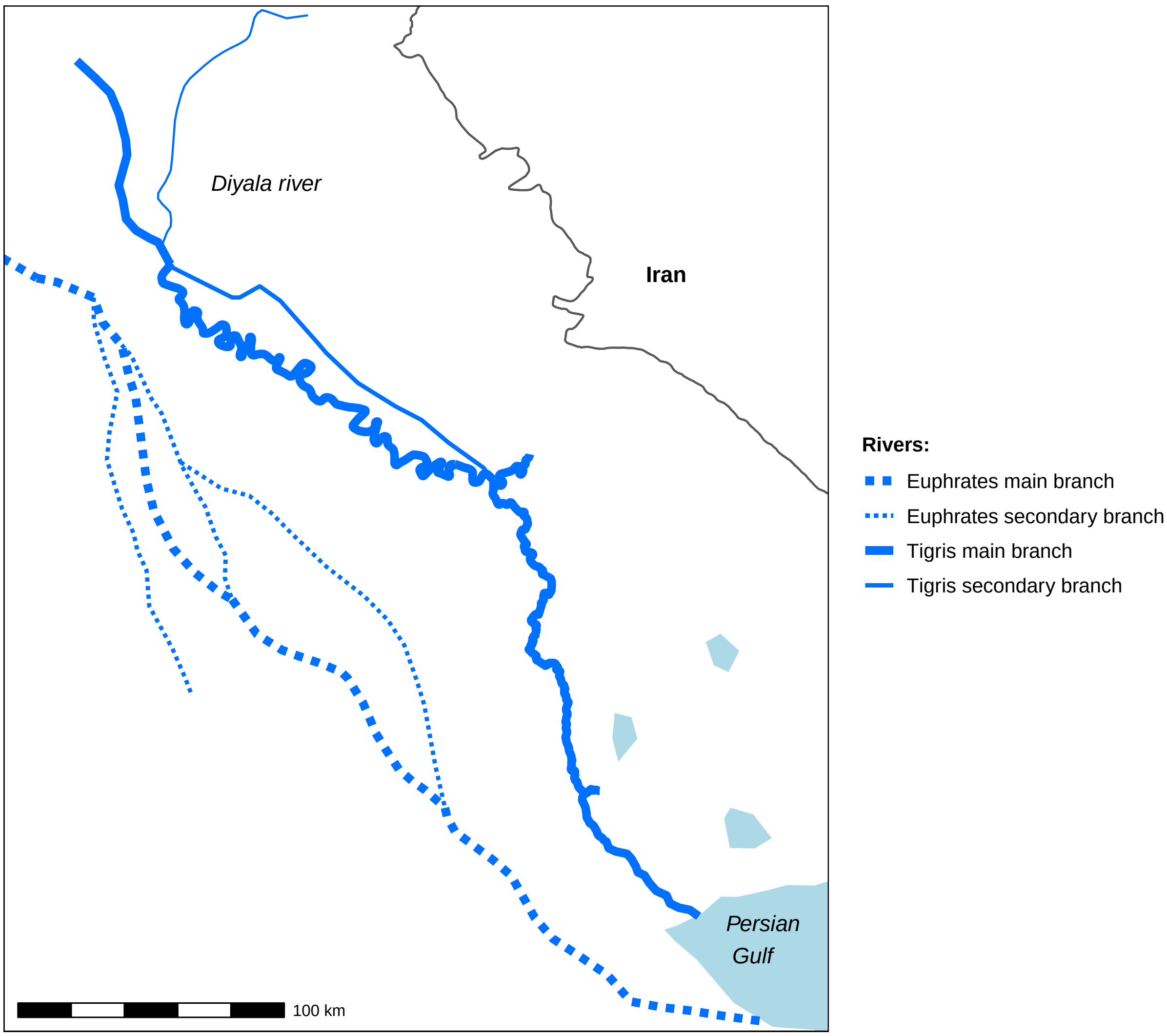
For the 2000 BCE cross-section, we rely on a study by Gasche et al. (2002, Carte 1) that provides a reconstruction of the riverine system between 2500 and 1500 BCE. By 2500 BCE, the Tigris and the Euphrates had started to separate more clearly south of Sippar. The Tigris' main branch had moved to the east, away from the Euphrates, although the two watercourses still merged in the northern part of the sample area, as one of the Euphrates' primary branches flowed into the Tigris north of Kutha. By this period, the Kish branch had become the main branch of the Euphrates, while the previous primary course, the Kutha branch, was reduced to a secondary flow. The Babylon branch, the westernmost stream of the Euphrates, appears for the first time in the 2000 BCE cross-section. The Babylon branch became the primary branch of the Euphrates by 1000 BCE and corresponds to the contemporary Hillah branch. We only make minor adjustments to Gasche et al. (2002)'s reconstruction. For completeness, we extend the Marad branch, located to the west of Nippur, by following the ancient meanders reported by Adams (1981, p.157) in the area. The interpolated branch touches the ancient city of Isin and re-joins the main branch of the Euphrates further south, next to the ancient city of Shurrupak. Where possible, we also harmonize the course of the Tigris south of Nippur (which is reported with a certain degree of approximation in Gasche et al. (2002)) with Adams' ancient rivers meanders near Adab (Adams, 1981, p.162). We know from Gasche et al. (2002) that all changes relative to the 3000 BCE cross-section had occurred by 2500 BCE, which allows us to date the shift precisely as occurring at the very beginning of the Early Dynastic III period. This coincides with a spike in rainfall variability in the 50-year window around 2450 BCE, which we use as the approximate date of the shift (See Figure RA1).

Figure AA6: Watercourses in 1500 BCE



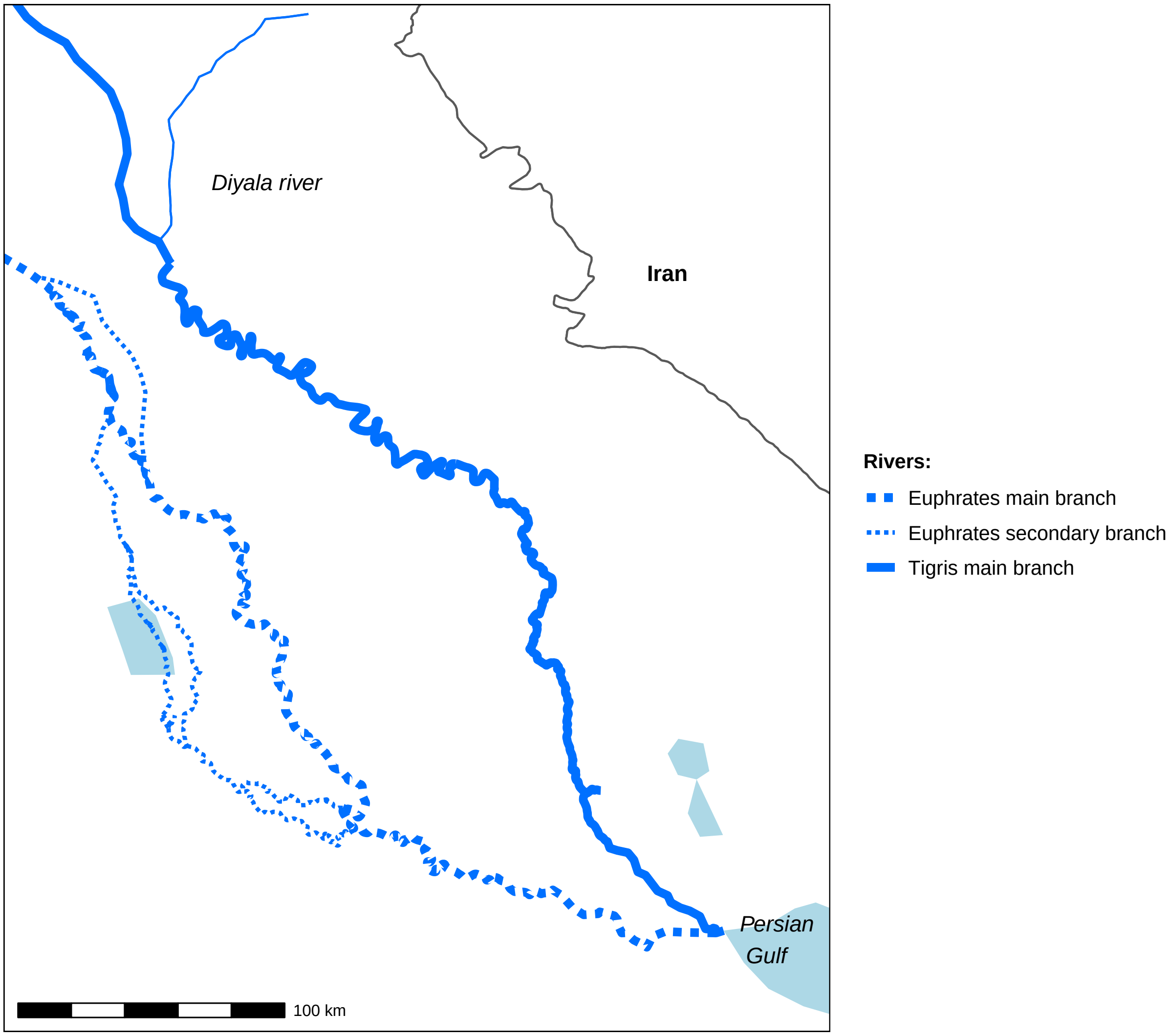
Cole and Gasche (1998) indicate that an additional shift occurred around 1800 BCE (see also Adams (1981) and Morozova (2005, p.410)). However, to the best of our knowledge, no map reconstructing the riverine system across southern Iraq around that date exists. By 1500 BCE, the Euphrates had witnessed a shift in the location of his primary stream that moved from the Kish to the Hillah branch, where Babylon was located (Cole and Gasche, 1998, p.27). The proto-Hillah branch was not precisely in its current position and it was referred to as Arathu branch. All the river branches of the Euphrates to the east of the Kish branch (e.g. the Me-enlil-la branch) become, at this stage, man-maintained canals (Adams, 1981, p.18). This general picture is also confirmed by other sources that refer to the Kutha branch, once the primary branch of the Euphrates, as canal rather than branch (Cole and Gasche, 1998). By 1500 BCE, the southern part of the Hillah branch had shifted about 40 kilometers to the south, relative to the 2000 BCE cross-section, and now joined the secondary central branch of the Tigris (the Irnina) roughly 10 kilometers south of the city of Uruk. The Tigris remained in its 2000 BCE position. We follow the literature and create the 1500 BCE cross-section by combining the Euphrates branches from the 1000 BCE cross-section (see below) and the Tigris ones from the 2000 BCE cross-section. The reconstructed cross-section is consistent with the reconstruction provided by Roaf for the Old Babylonian and Cassite periods (Roaf, 1990, p.120 and p.142). With respect to the dating of the shift from the 2000 BCE to 1500 BCE cross-section, we know from Cole and Gasche (1998, p.27) that the shift happened at the beginning of the Old Babylonian period, in the eighteenth century BCE. This approximate date coincides with a high rainfall variability 50-year window centered around 1750 BCE, which we use to date the shift more precisely at 1750 BCE (See Figure RA1).

Figure AA7: Watercourses in 1000 BCE



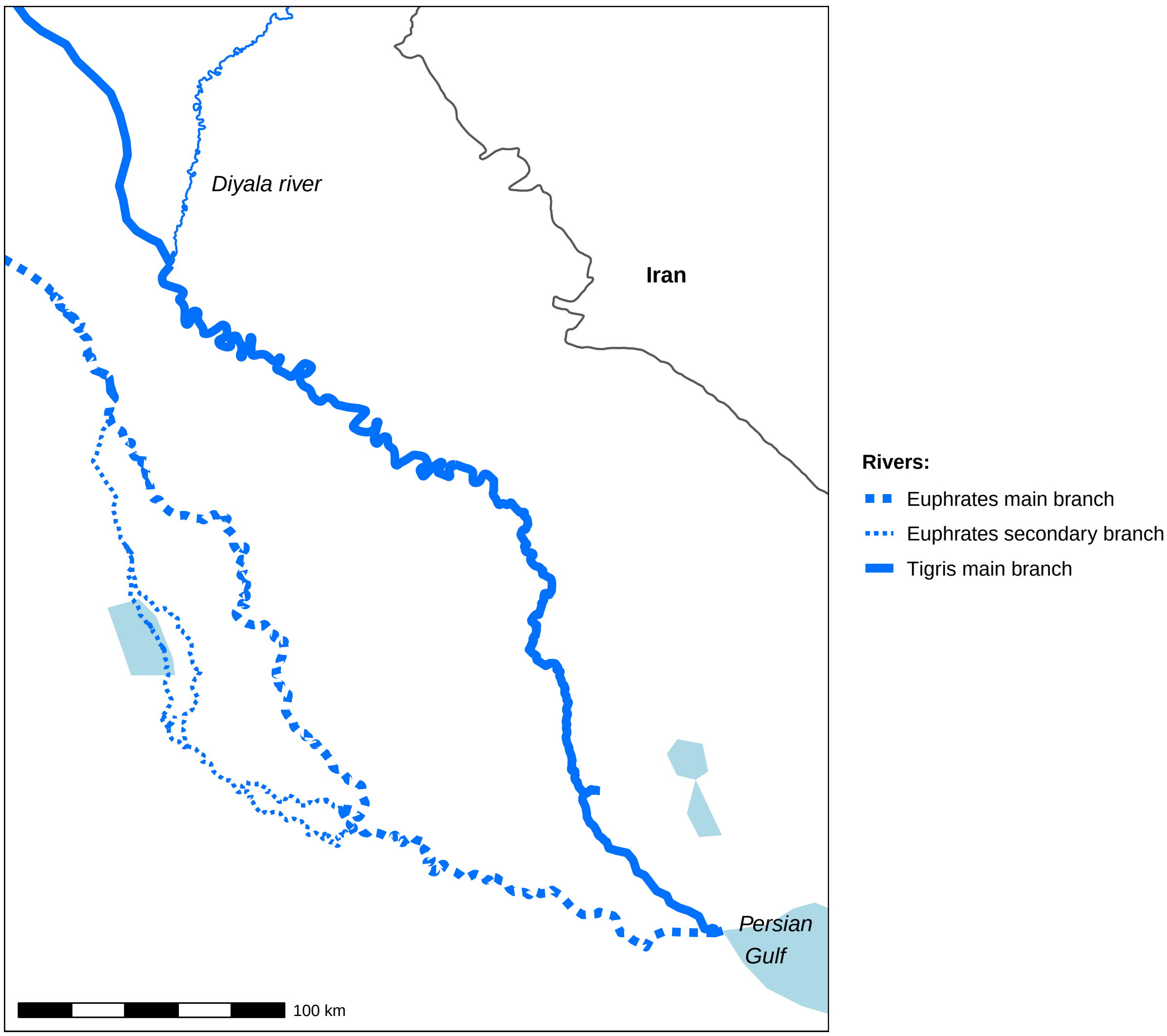
Gibson (1972, p.316) provides a reconstruction of the riverine system around 1000 BCE, which we use to identify the course of the Euphrates at the beginning of the first millennium BCE. The position of the main course of Tigris in 1000 BCE, instead, is more difficult to determine for this period, as Gibson (1972, p.316) only provides an approximate description of its location. The Tigris had certainly shifted into its current bed by the middle of the first millennium BCE (Cole and Gasche, 2007, pp.31-33), when large cities like Seleucia and Ctesiphon were founded along its banks. By 1000 BCE, the Euphrates riverine system was very similar to the 1500 BCE cross-section, with the main stream still being the Hillah branch, where Babylon was located (Gibson, 1972, p.316). The main course of the Tigris, instead, had reached its current position by 1000 BCE, with a transition that probably occurred late in the second millennium BCE. We know from the reconstruction of Cole and Gasche (1998) and Roaf (1990) that the riverine system had not changed significantly between the Old Babylonian and the Cassite period. The shift between the 2000 BCE and the 1000 BCE cross-sections, therefore, must have taken place in the Middle Babylonian period, certainly by the beginning of the ninenth century BCE (Cole and Gasche, 1998, p.32). We date the shift to the 50-year window around 1000 BCE, when we observe an abnormal spike in rainfall variability (See Figure RA1).

Figure AA8: Watercourses in 0 CE



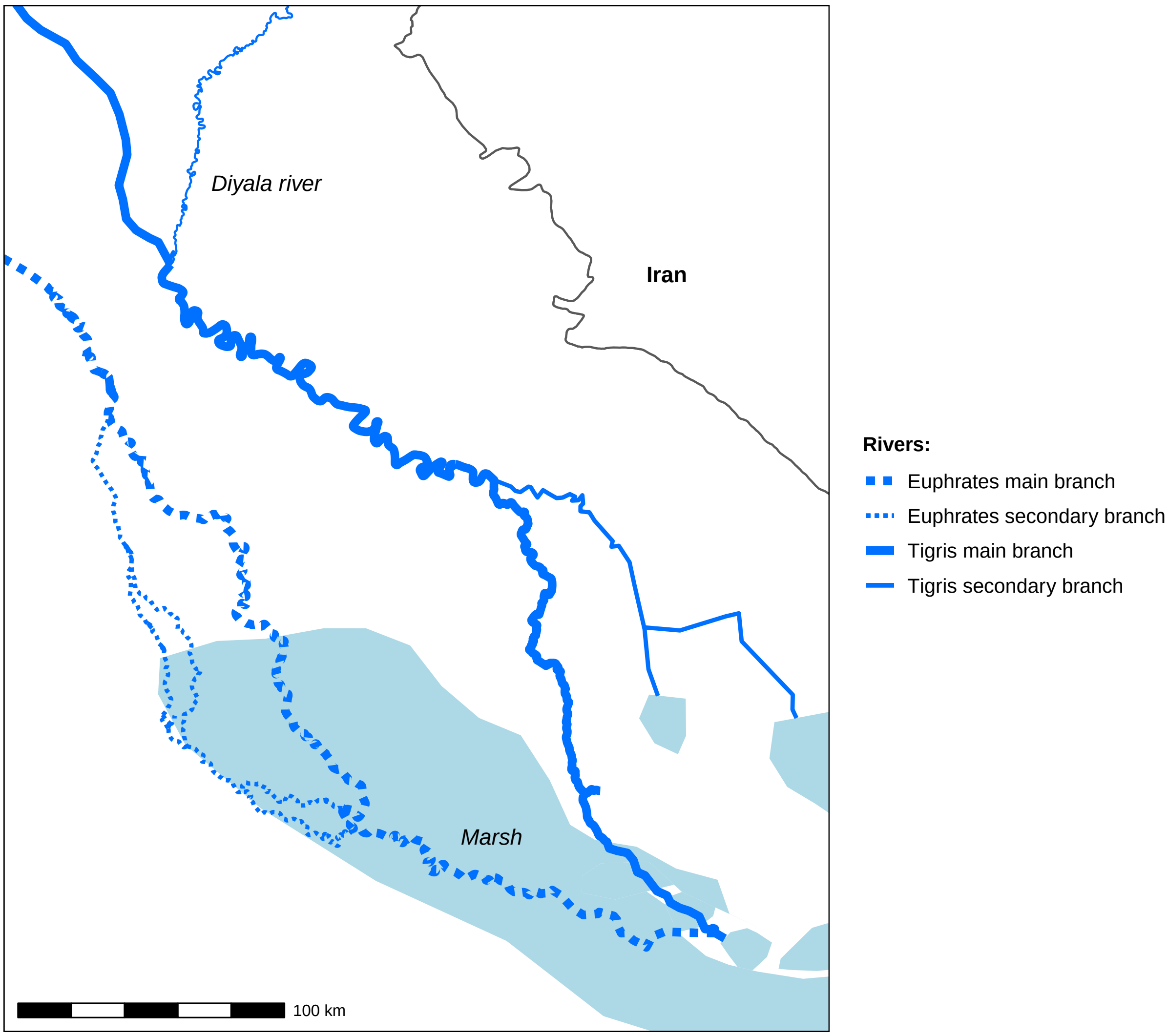
We do not have a unique map that reconstructs the riverine network around 0 CE. However, we know from the secondary literature that, around 700 BCE, the Euphrates also shifted into its current position. By 0 CE, in fact, both the Hillah and Indiyya branches were clearly distinct and followed a course that was very similar to the current one (Cole, 1994). By this period, the Kish branch had disappeared completely. Differently from the current situation, however, the Hillah branch was still the primary stream of the Euphrates. Only in a later period, in fact, this stream lost volume in favor of the Indiyya branch and became an artificially maintained secondary branch (see below). Uruk no longer was on the river, and water had to be supplied by a dense canal network, as reported by Adams (1981, p.198). Starting from the Neo Babylonian period, around the seventh century BCE, the northern branch of the Tigris, the so called Diglat (Gibson, 1972, p.316), stopped flowing naturally and had to be maintained artificially. Parts of this old river branch were incorporated in the Nahrawan canal. This change is visible from Figures 3 and 4 in Adams (1965). By 0 CE, the upper part of the Diyala river also shifted into its current position (Figure 4, Section Maps of the Appendix in Adams (1965)) The current south-east branch of the Tigris (between Kut and the Persian Gulf), which is the main branch today, did not exist at the time as it only formed in the nineteenth century. The Shatt-al-Garruff branch, in fact, was until recently the main branch of the Tigris south of Kut (Verkinderen, 2015, p.48). Cole (1994) dates the shift between the 1000 BCE and the 0 CE cross-sections precisely at the beginning of the seventh century BCE. We follow Cole (1994) and date the shift at 700 BCE, which coincides with a spike in rainfall variability (See Figure RA1).

Figure AA9: Watercourses in 500 CE



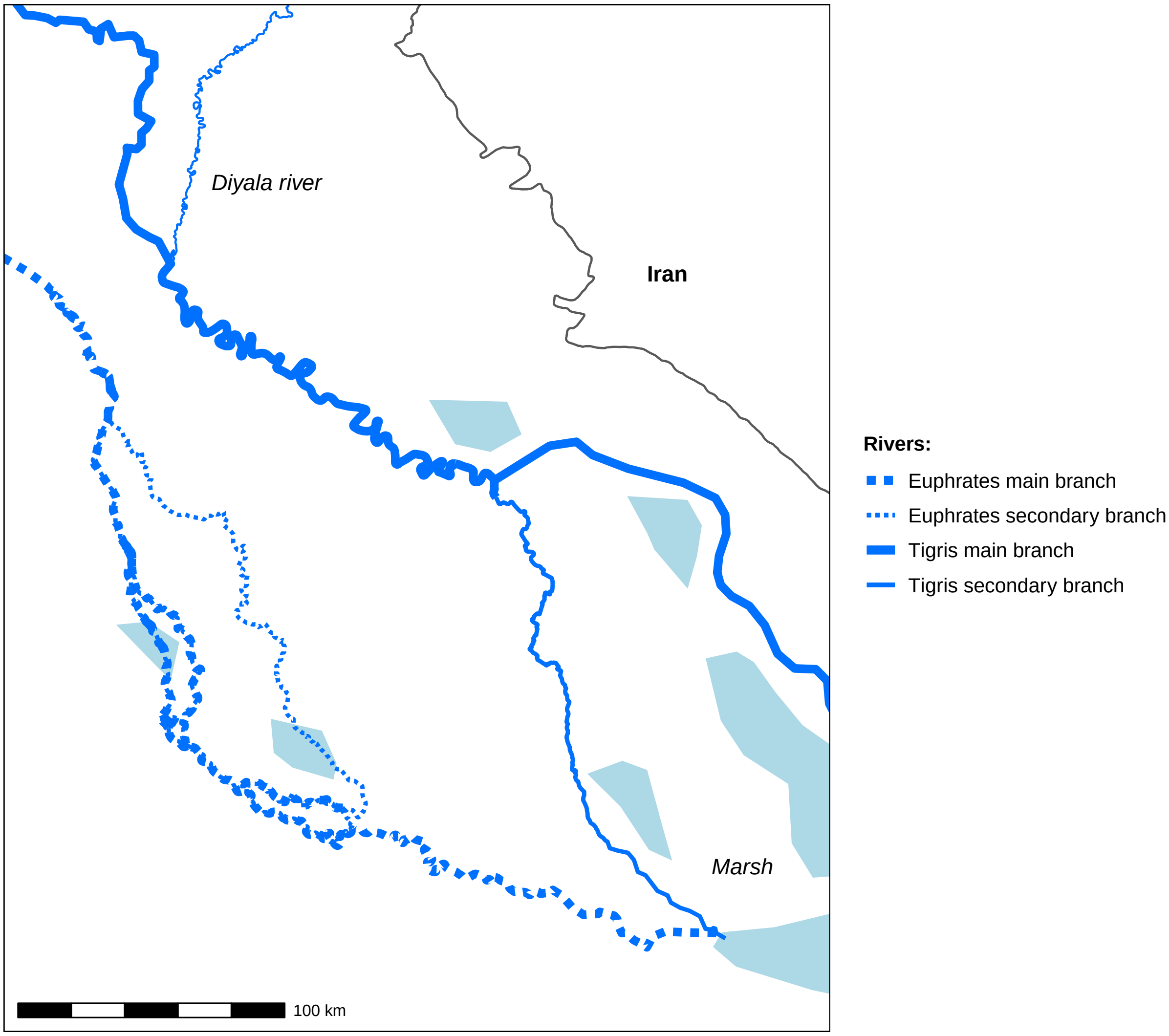
Only minor changes to the riverine network occurred after 0 CE. By 500 CE, the southern part of Diyala river also shifted into its current bed. In the Sassanian period, in fact, we observe the first settlements next to its modern course (Adams, 1981, p.212). In this period, we see large canals being built off of the Tigris course south of Baghdad. In particular, the al-Katul al-Kisrawi, the Yahudi, the al-Ma'muni and the Abu'l-Jund. These watercourses branched off of the main Nahrawan canal, and then fed the outskirts of Baghdad. These are reported in Figure 5 and 6 of the Maps appendix in Adams (1965). The small, secondary branch of the Euphrates that flowed to the east of its current bed around 0 CE, at the same latitude as the ancient city of Sippar, disappeared in this period and was substituted by a canal (Verkinderen, 2015). While we know from Verkinderen (2015) that these small shifts happened around 500 CE, we date these precisely at 450 CE, in coincidence with a 50-year window of abnormal rainfall variability (See Figure RA1).

Figure AA10: Watercourses in 1000 CE



The 1000 CE cross-section is very similar to the contemporary riverine network. By 1000 CE, the coastline had moved farther south-east, compared to the 500 CE cross-section, and the two rivers had formed a joint delta. Verkinderen (2015) dates the formation of the Al-Kut branch (located outside the sample area, but included in Figure AA10, later in history the primary branch of the Tigris) to around this period. The Hillah branch was still the main branch of the Euphrates around 1000 CE. Verkinderen (2015) dates the formation of the Al-Kut branch to between the ninenth and the tenth century CE. We date it at 900 CE, in coincidence with a spike in rainfall variability in the 50-year window around that date (See Figure RA1).

Figure AA11: Watercourses in 2000 CE



Between 1000 CE and 2000 CE, the coastline moved to its current position. There was also a small adjustment in the course of the Tigris north of Baghdad (Verkinderen, 2015). We cannot date this adjustment, so we artificially code it as taking place after WWI and we exclude it from the analysis. Today, the Indiyya branch of the Euphrates has become its main stream, with this change occurring around 1850 CE (Adams, 1981, p.18). The main branch of the Tigris shifted into its easternmost segment (the Al-Kut branch) during the nineteenth century (Verkinderen, 2015, p.48). We date these shifts at 1850 CE, which coincides with a spike in rainfall variability in the 50-year window around that date (See Figure RA1). The latter shift, however falls outside the survey area.

3 States, settlement and canals

In this section, we provide a full picture of our reconstruction of human activity in southern Iraq from 5000 BCE to today. The following series of maps shows, for each period of our dataset, states (in outlines, shaded in grey), settlement (villages and cities), rivers, canals and capital cities. For early periods, states were confined to an individual city. We indicate such cities as 'states' in the map legends to distinguish them from capital cities in later periods. From the Seleucid period onwards, and in the Neo Assyrian period, the entire plain was part of a large empire, and we no longer plot state boundary outlines, as these now fall outside the extent of our maps. All data are described in more detail in the Data Appendix of our paper.[1]

[1]Note that while we report major cities across the area for all periods, the ones to the very south of the sample area are located outside the area covered by the surveys of settlement and canals.

Figure AA12: Eridu Period and 5000 BCE rivers

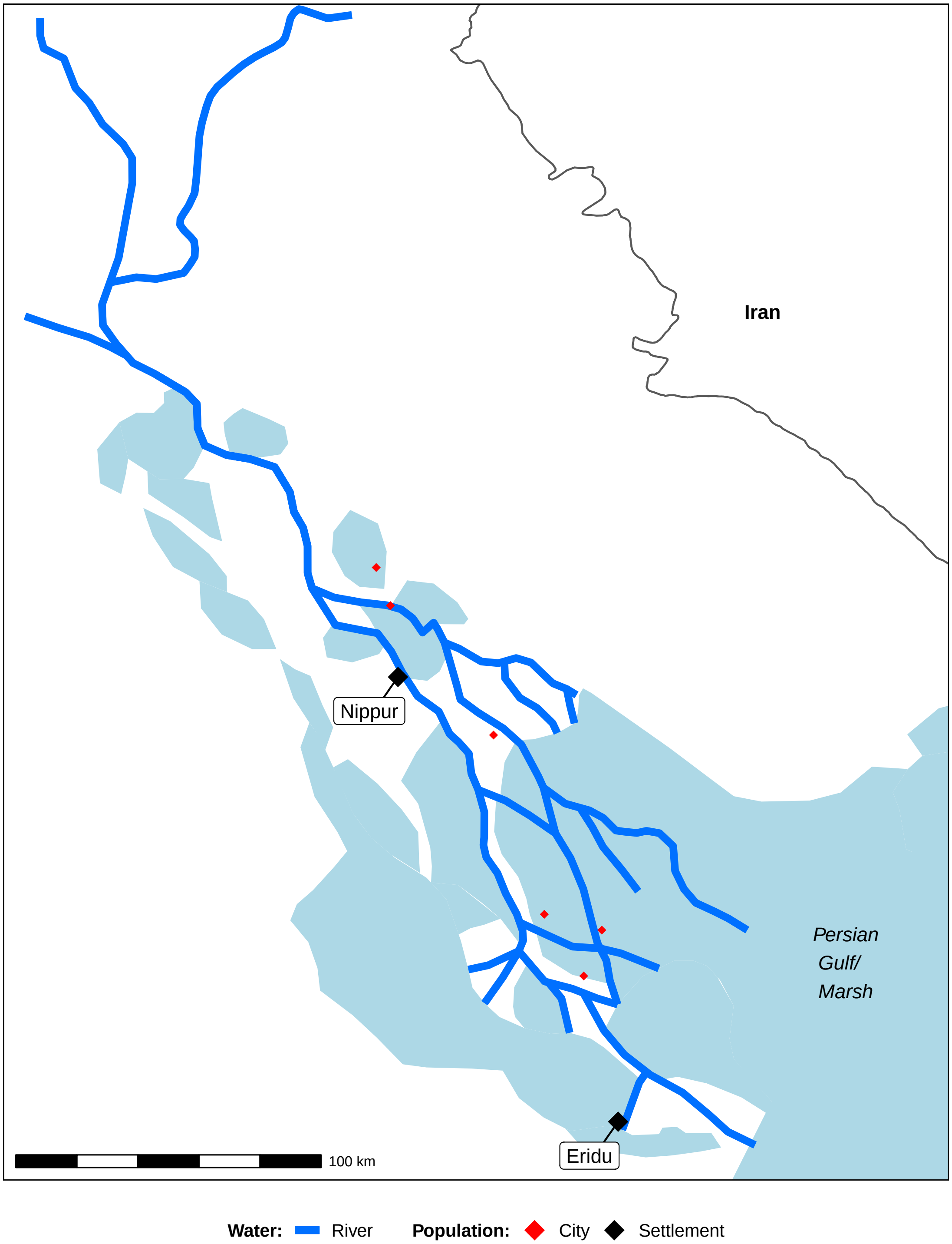


Figure AA13: Early Ubaid Period and 5000 BCE rivers

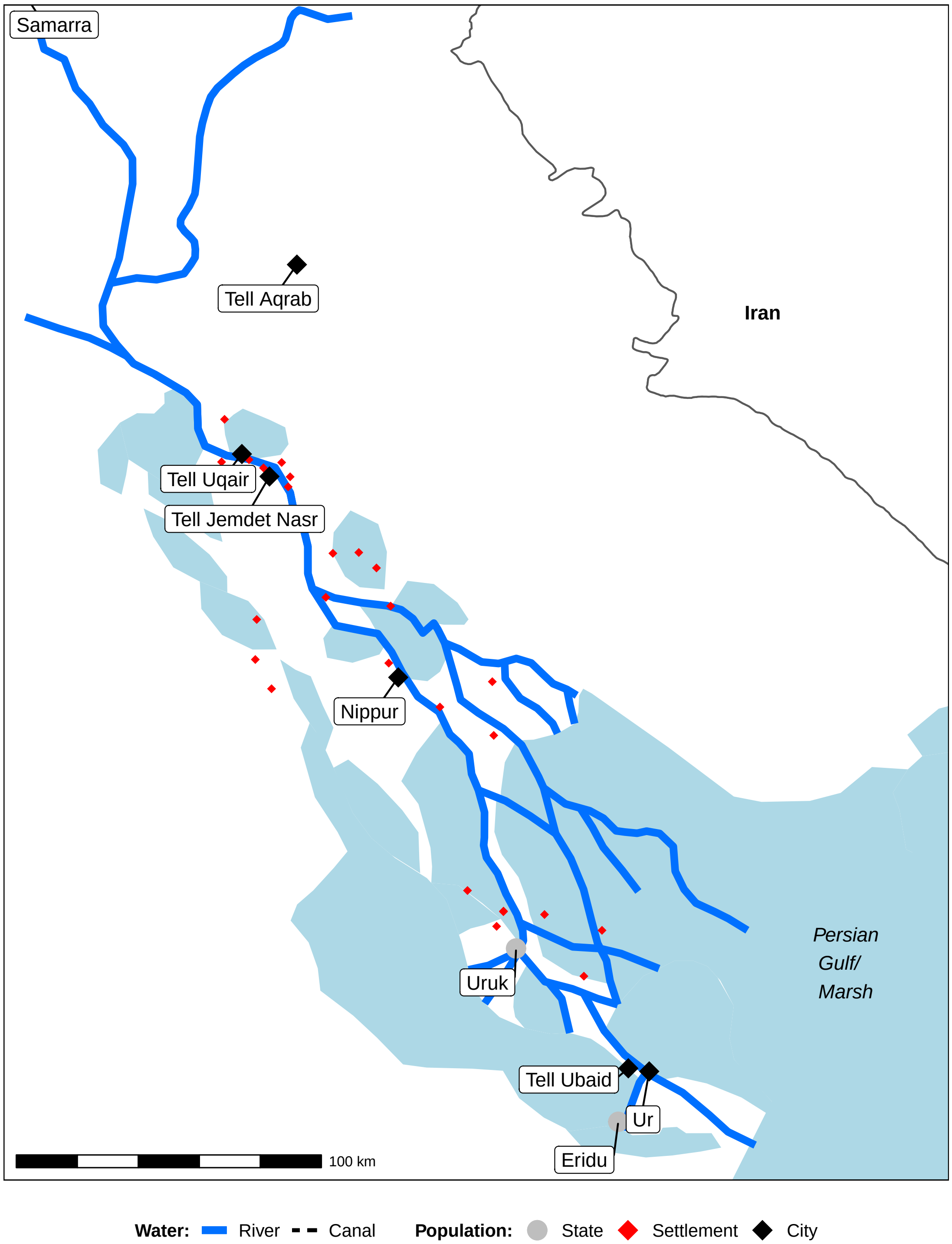


Figure AA14: Late Ubaid Period and 5000 BCE rivers

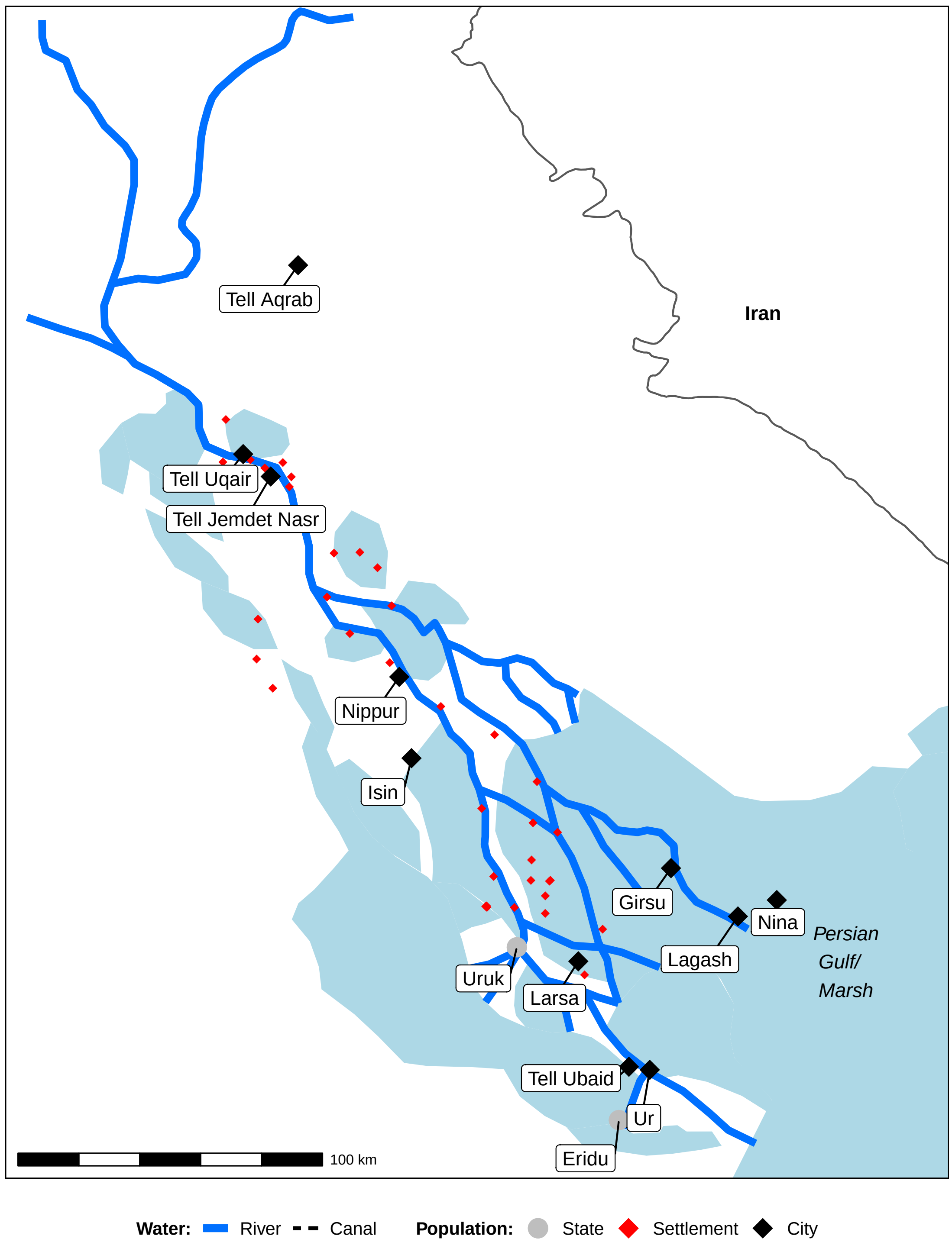


Figure AA15: Early Uruk Period and 4000 BCE rivers

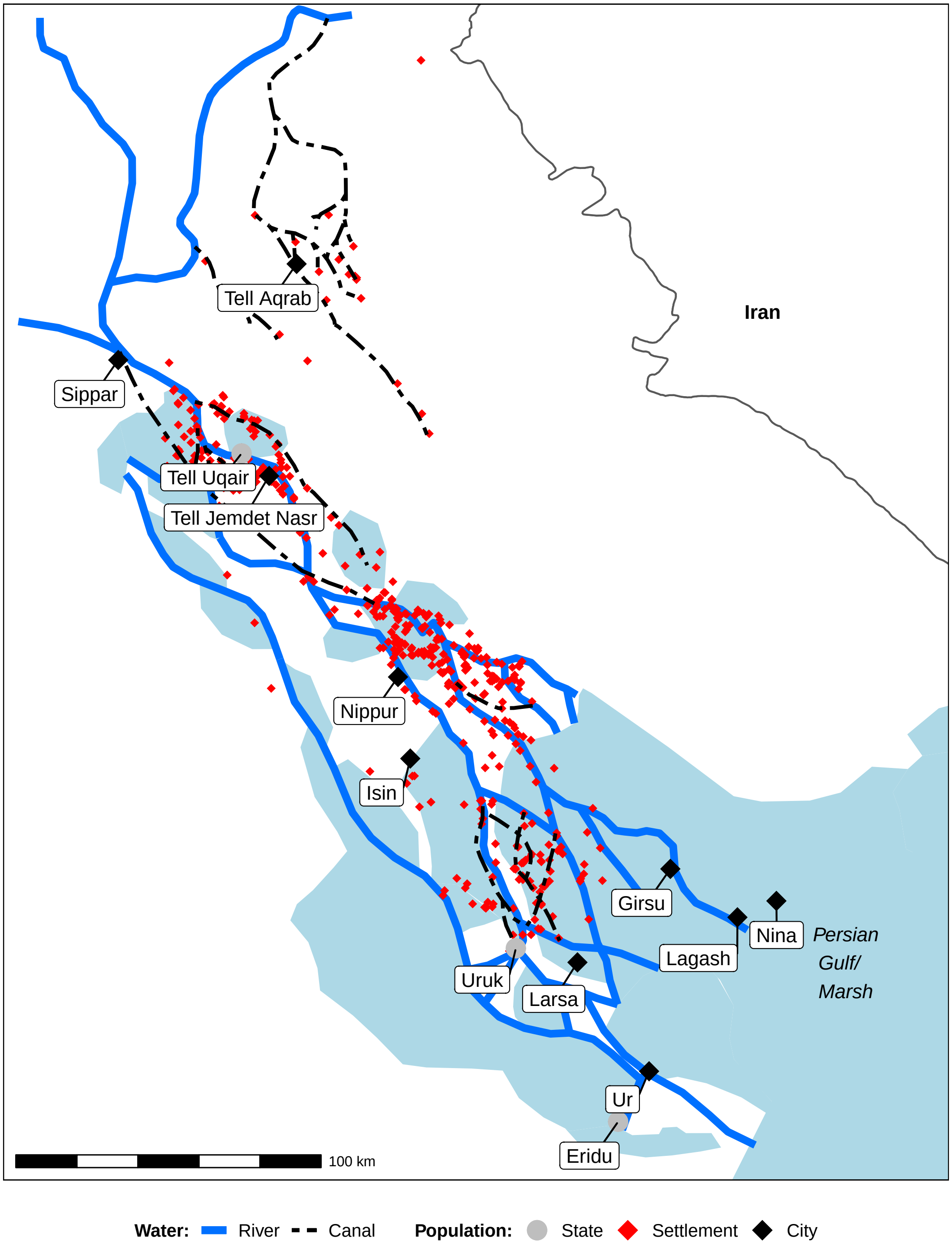


Figure AA16: Middle Uruk Period and 4000 BCE rivers

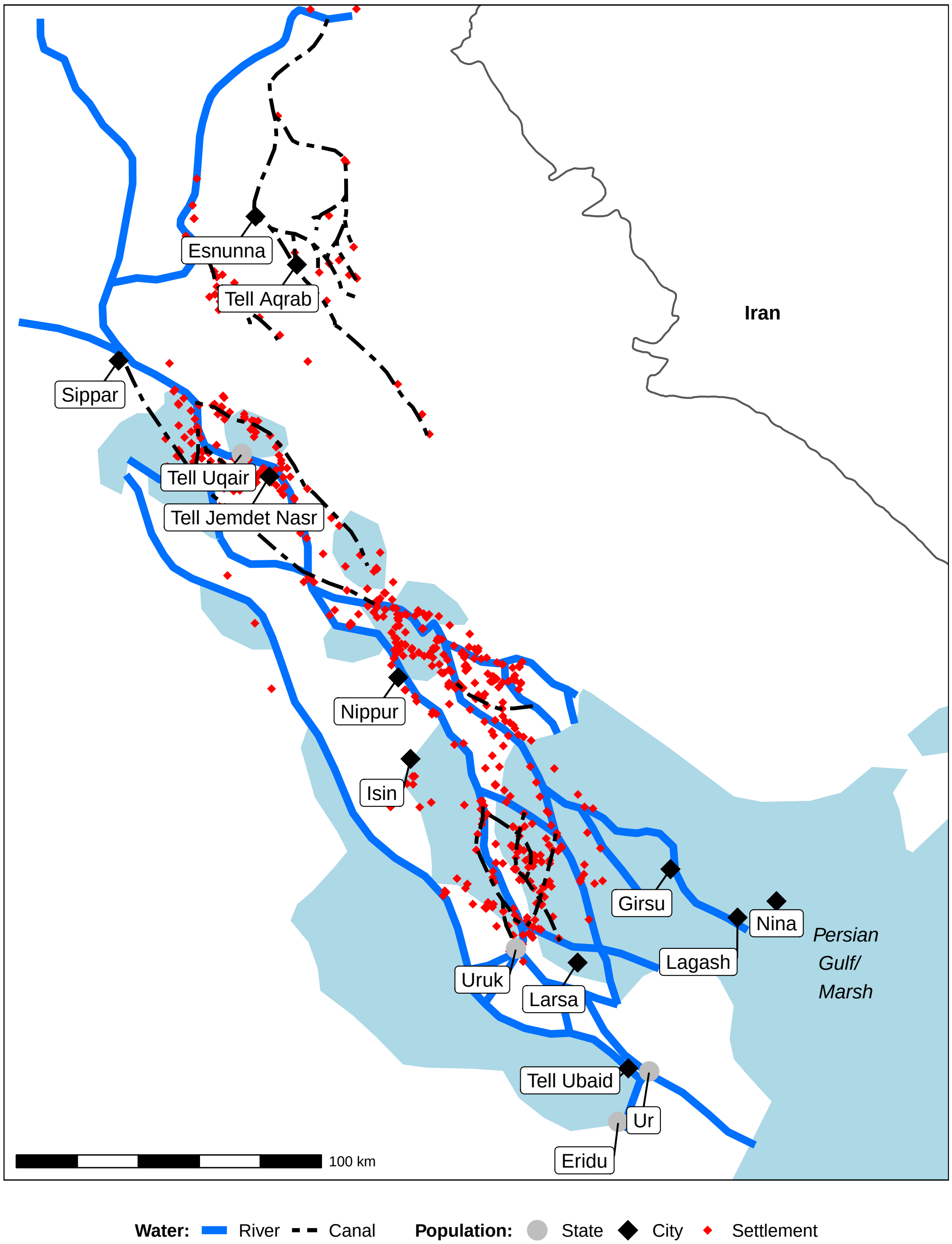


Figure AA17: Late Uruk Period and 3500 BCE rivers

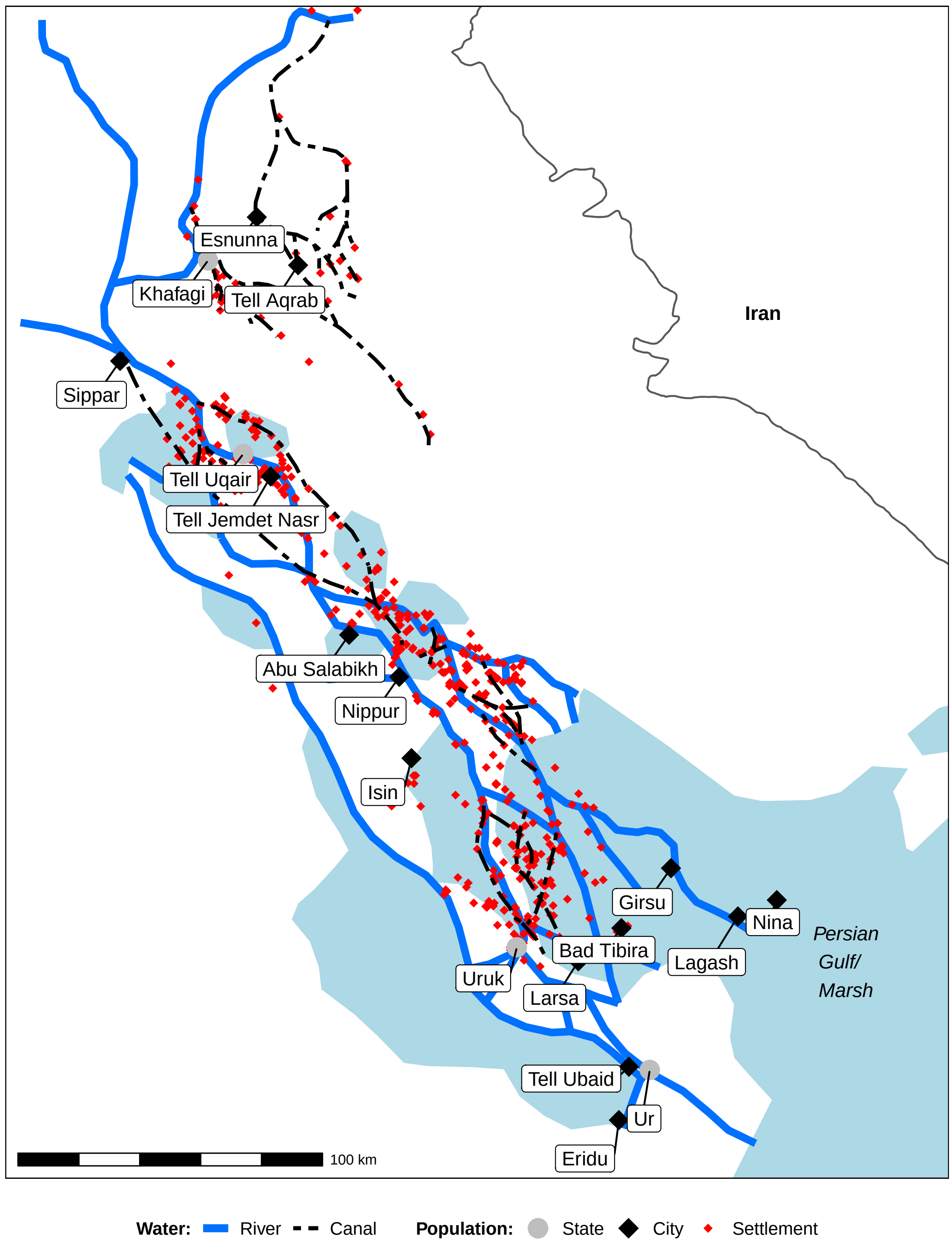


Figure AA18: Jemdet Nasr Period and 3500 BCE rivers

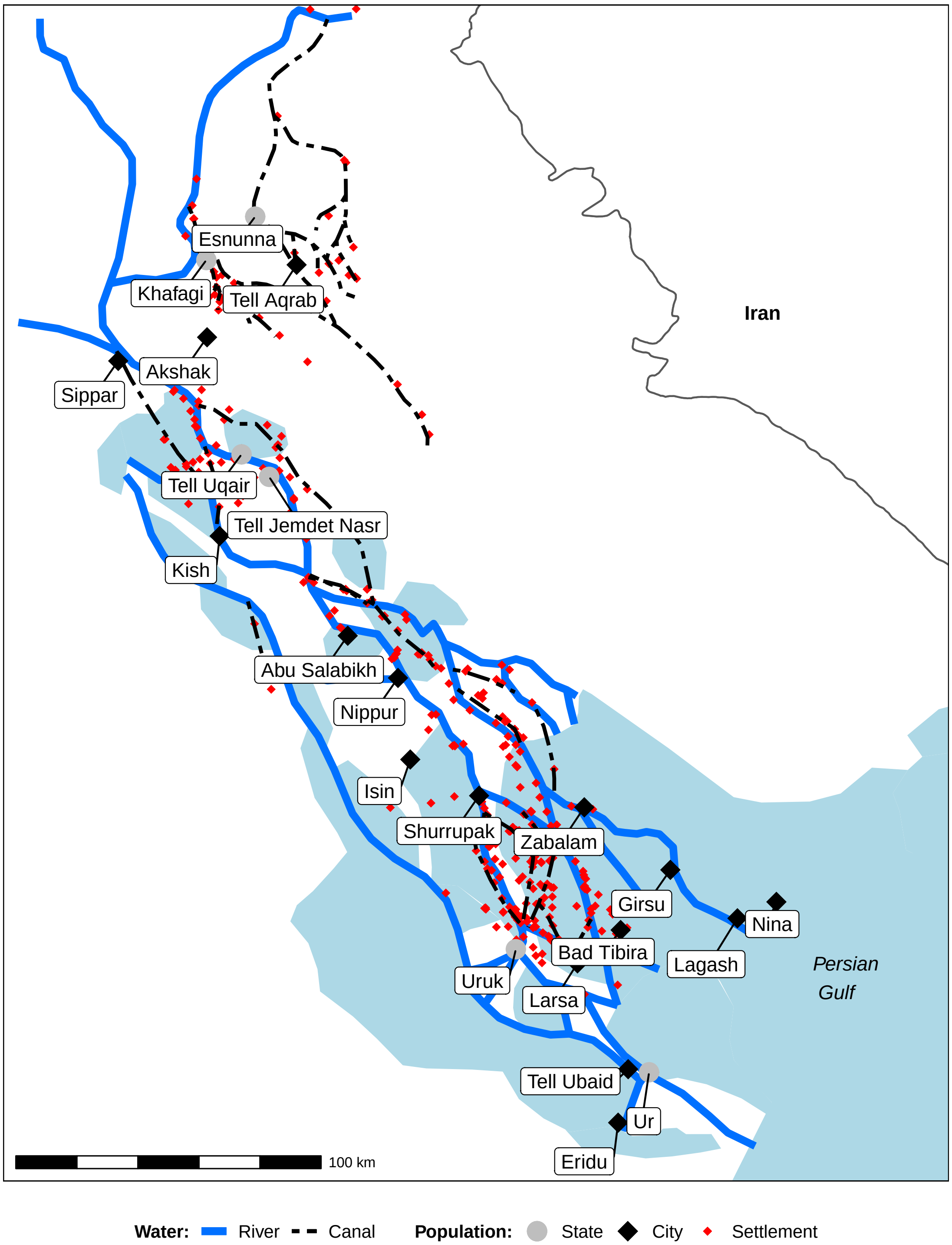


Figure AA19: Early Dynastic I Period and 3000 BCE rivers

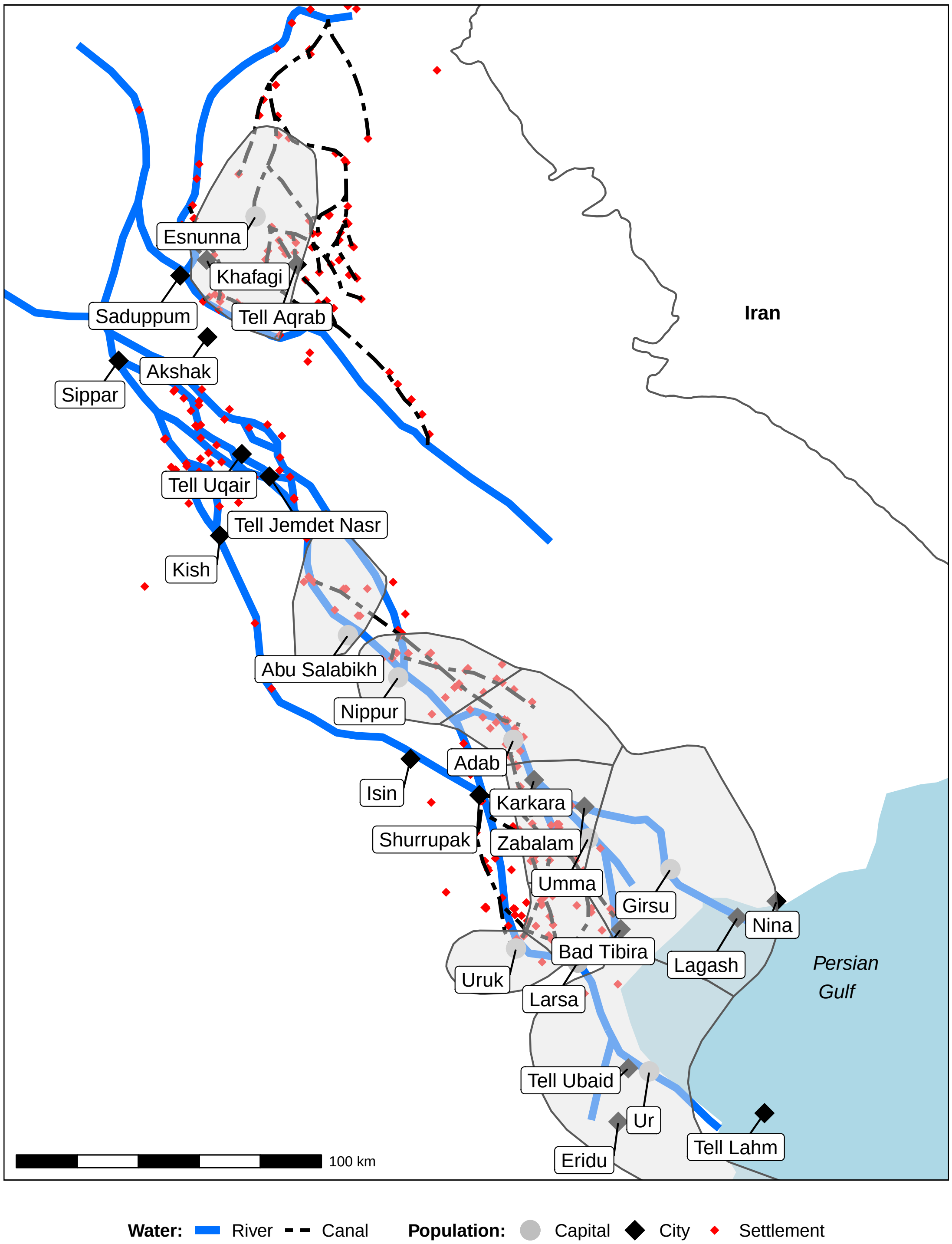


Figure AA20: Early Dynastic II Period and 2000 BCE rivers

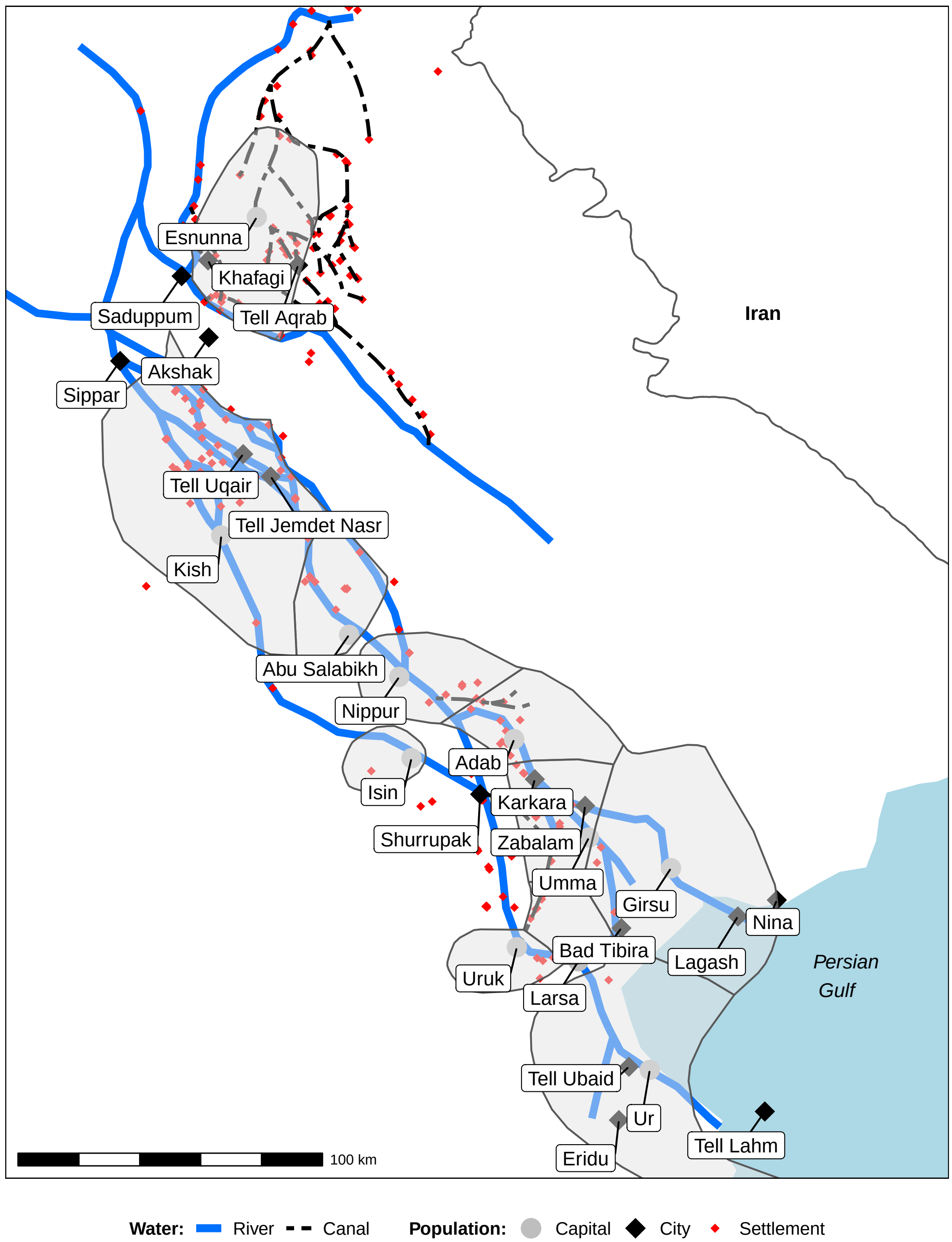


Figure AA21: Early Dynastic III Period and 2000 BCE rivers

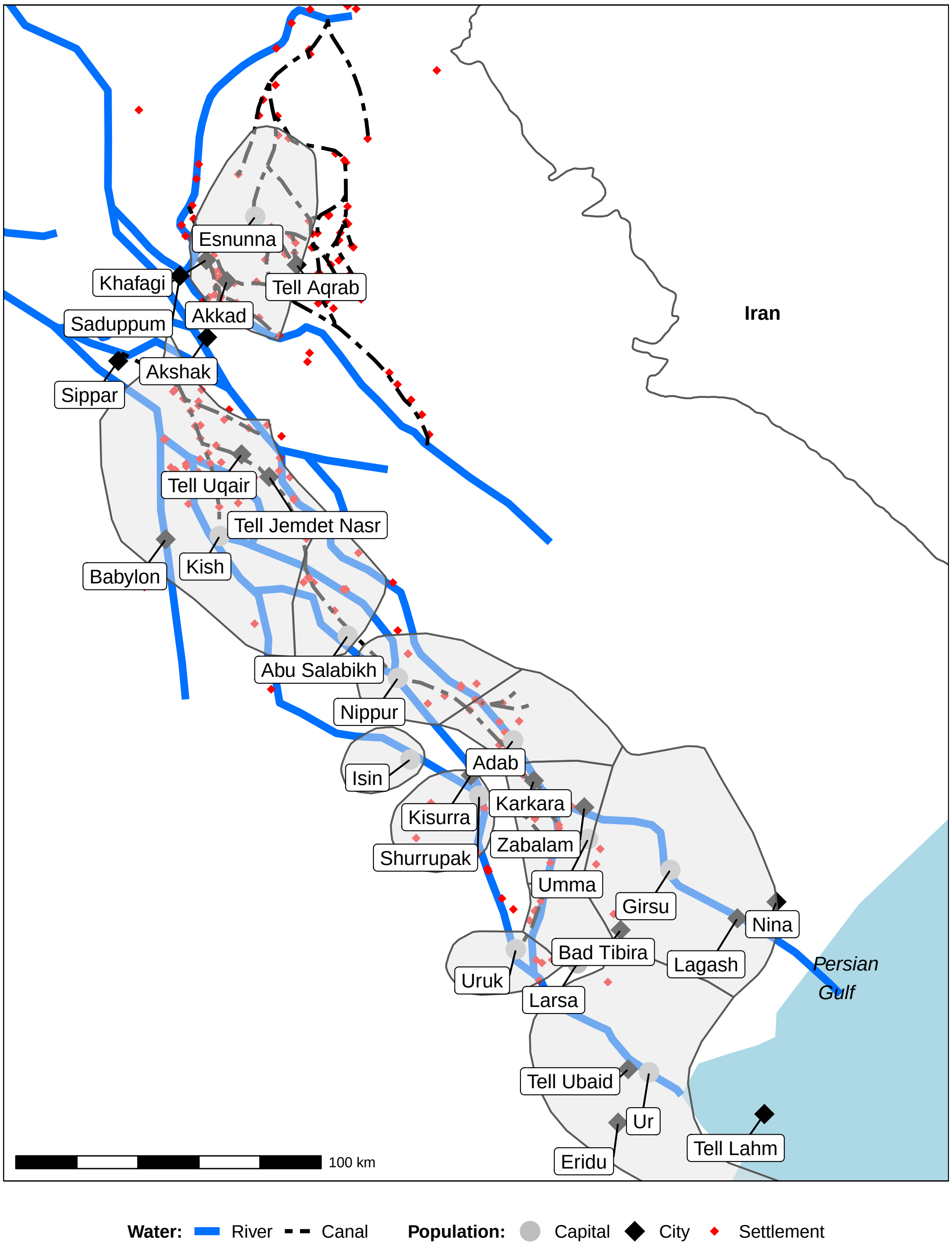


Figure AA22: Akkadian Period and 2000 BCE rivers

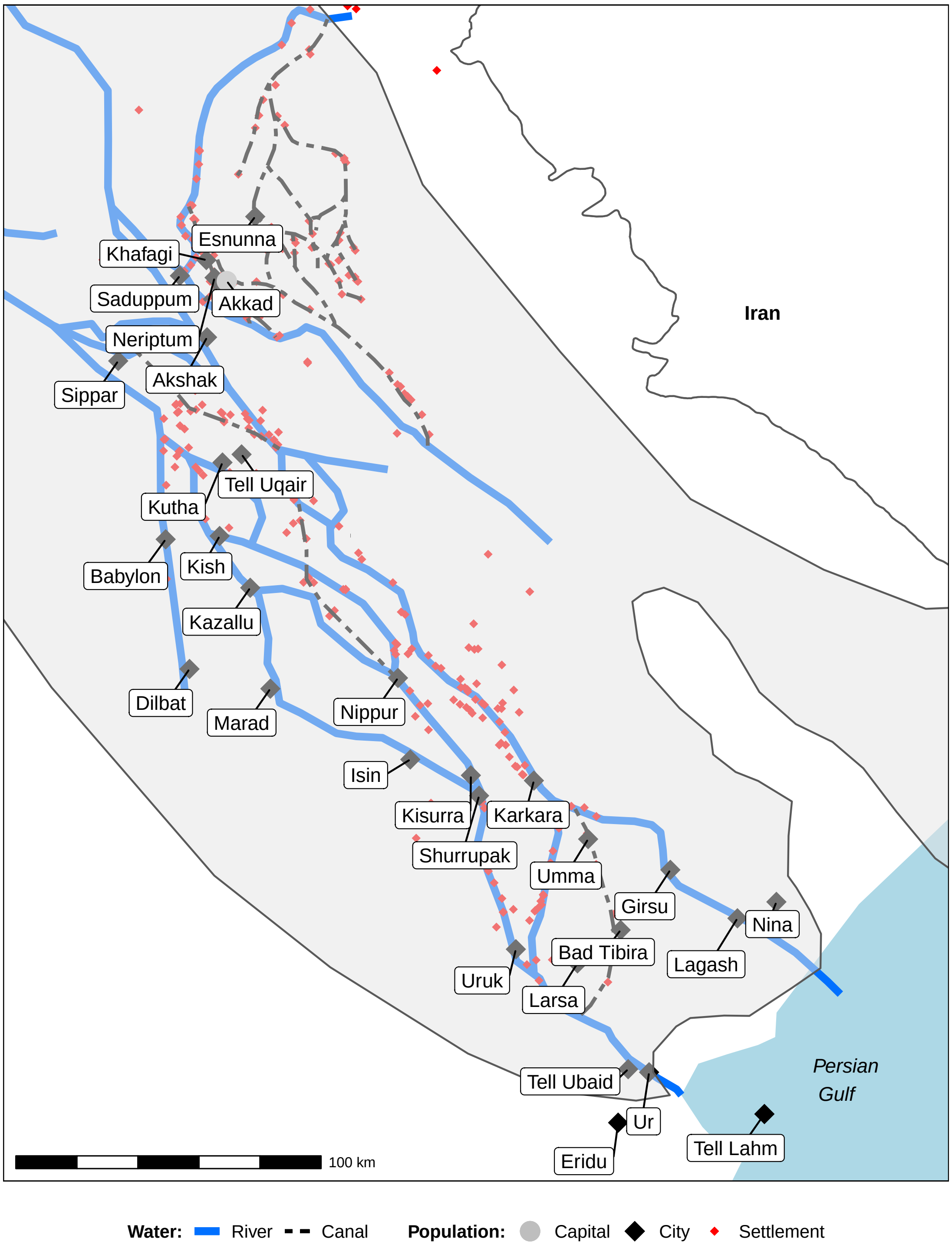


Figure AA23: Third Dynasty of UR (URIII) Period and 2000 BCE rivers

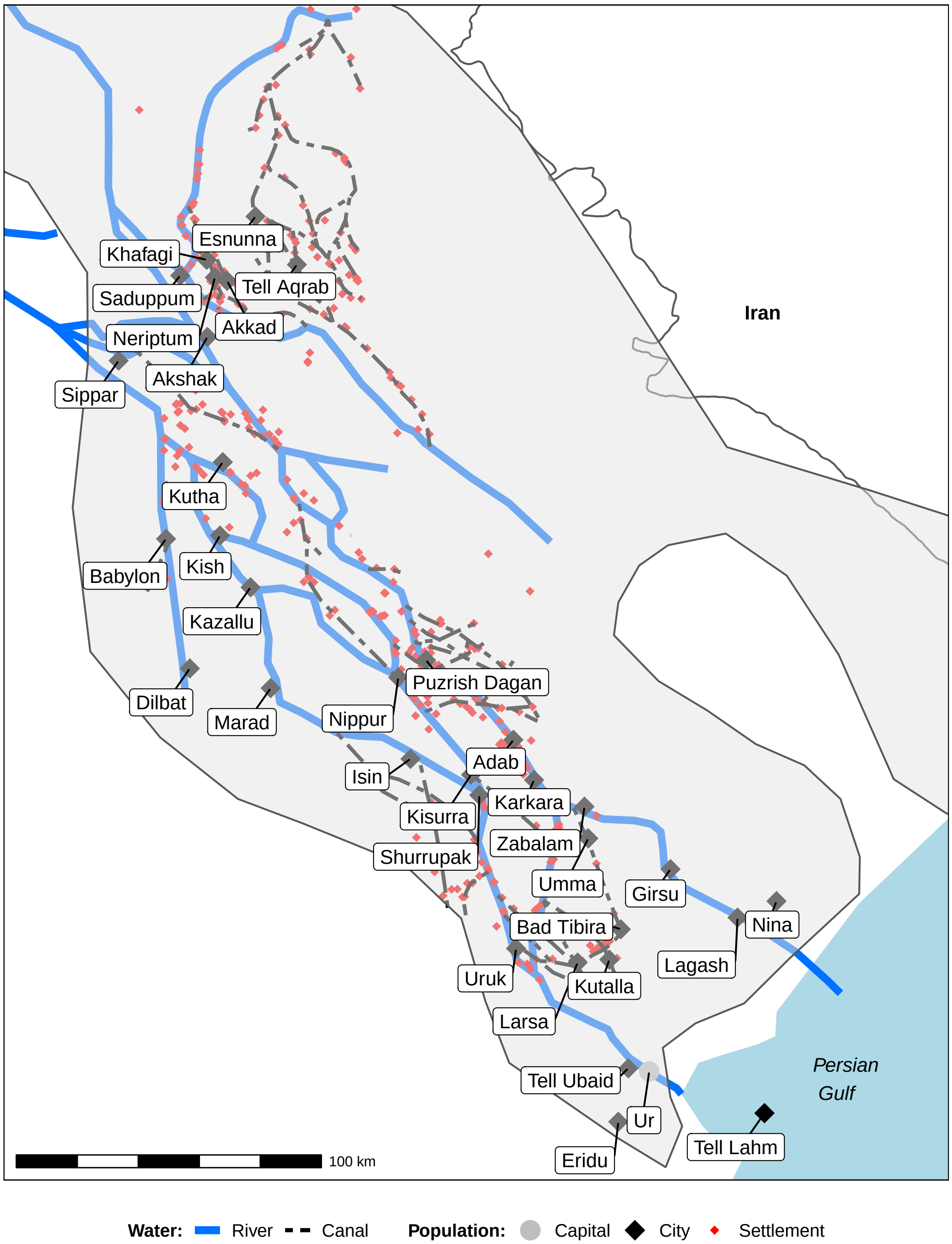


Figure AA24: Isin Period and 2000 BCE rivers

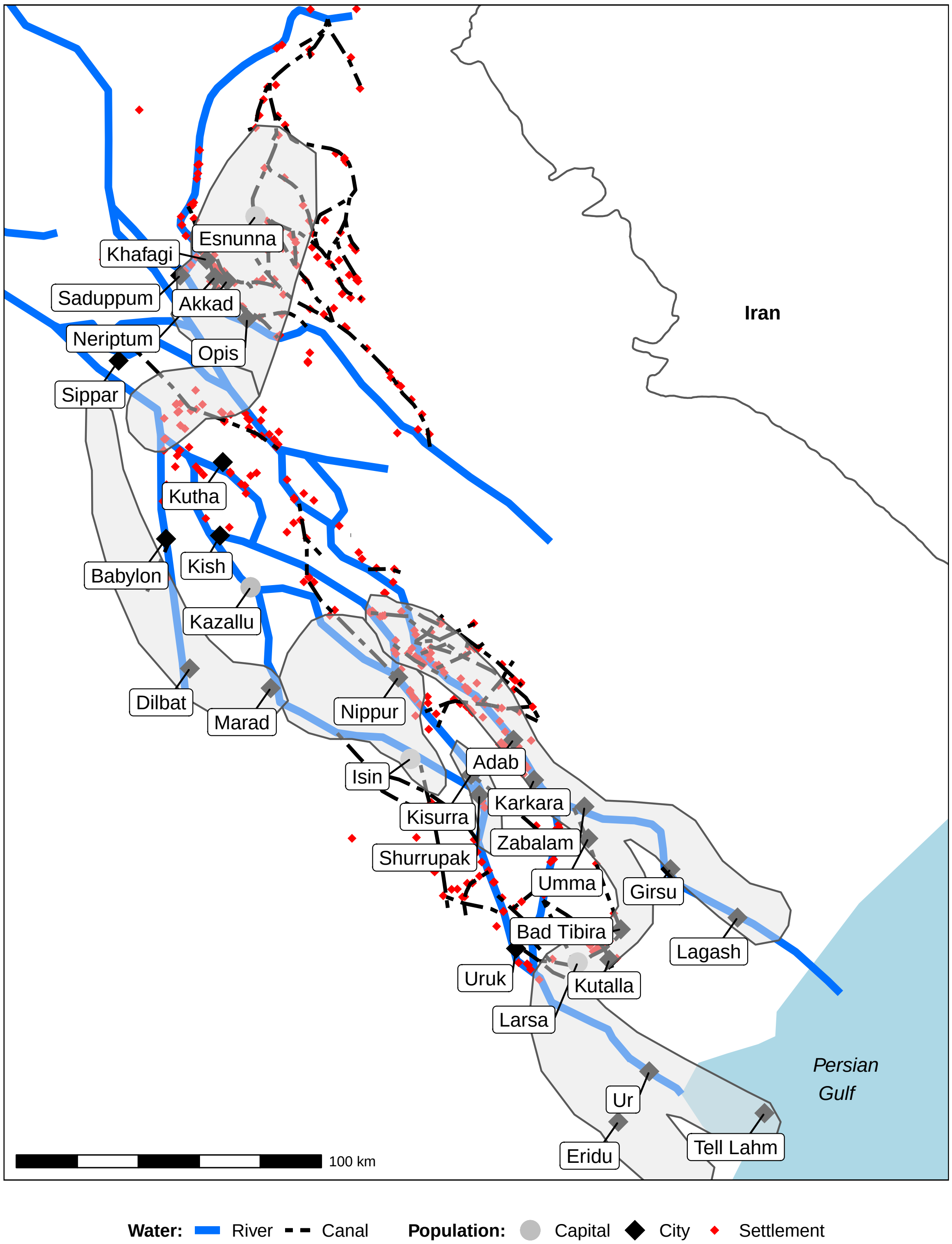


Figure AA25: Larsa Period and 2000 BCE rivers

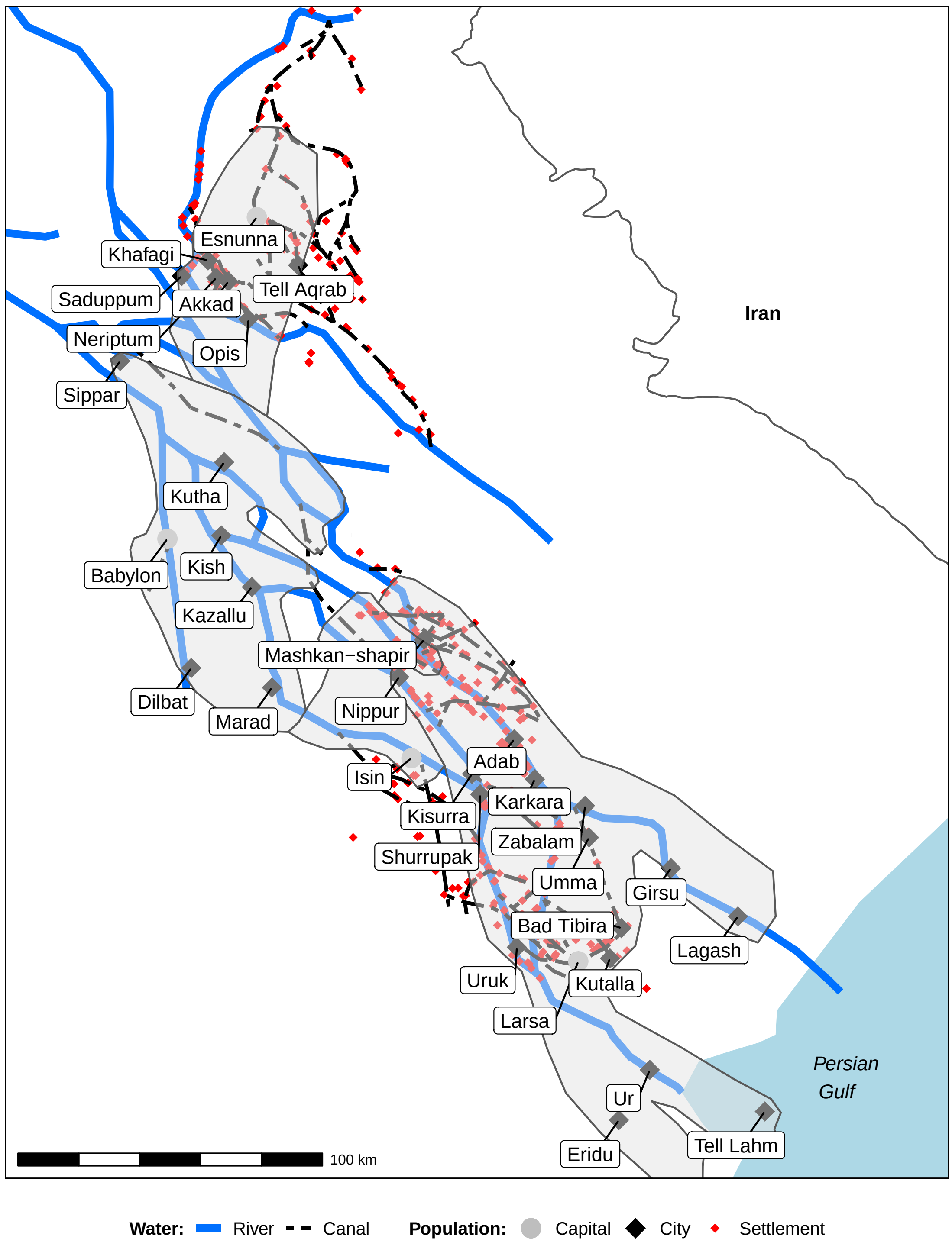


Figure AA26: Old Babylonian Period and 1500 BCE rivers

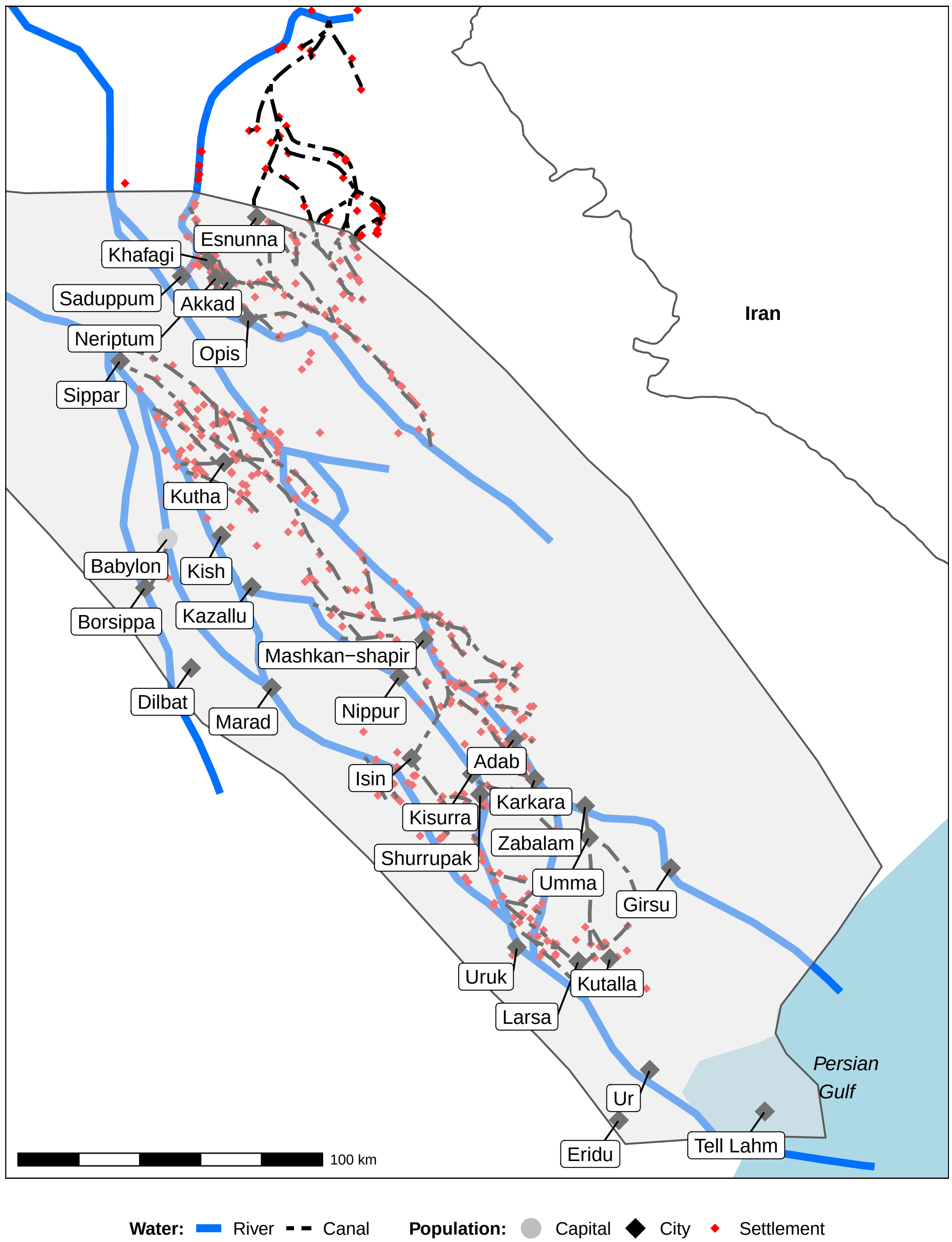


Figure AA27: Cassite Period and 1500 BCE rivers

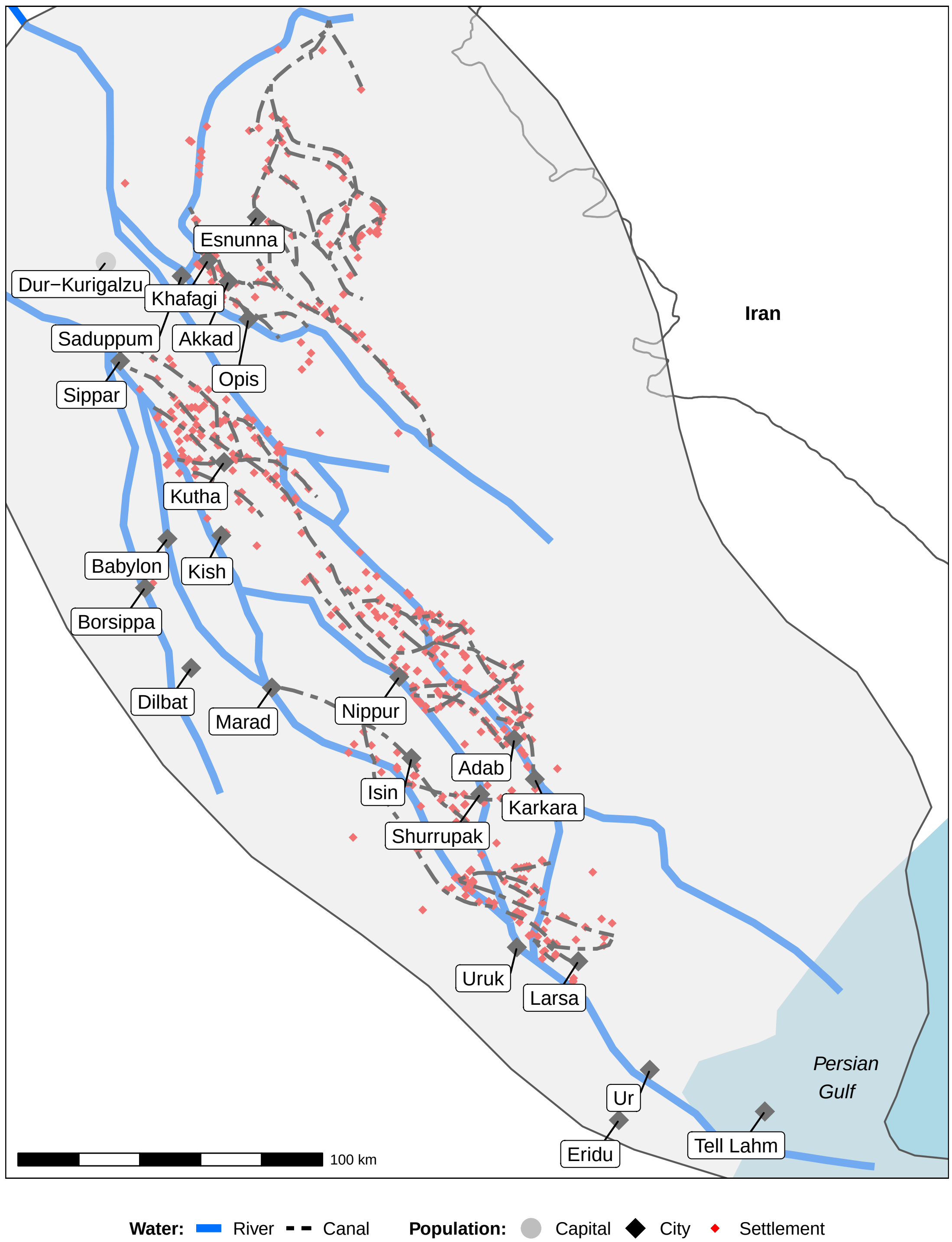


Figure AA28: Middle Babylonian Period and 1000 BCE rivers

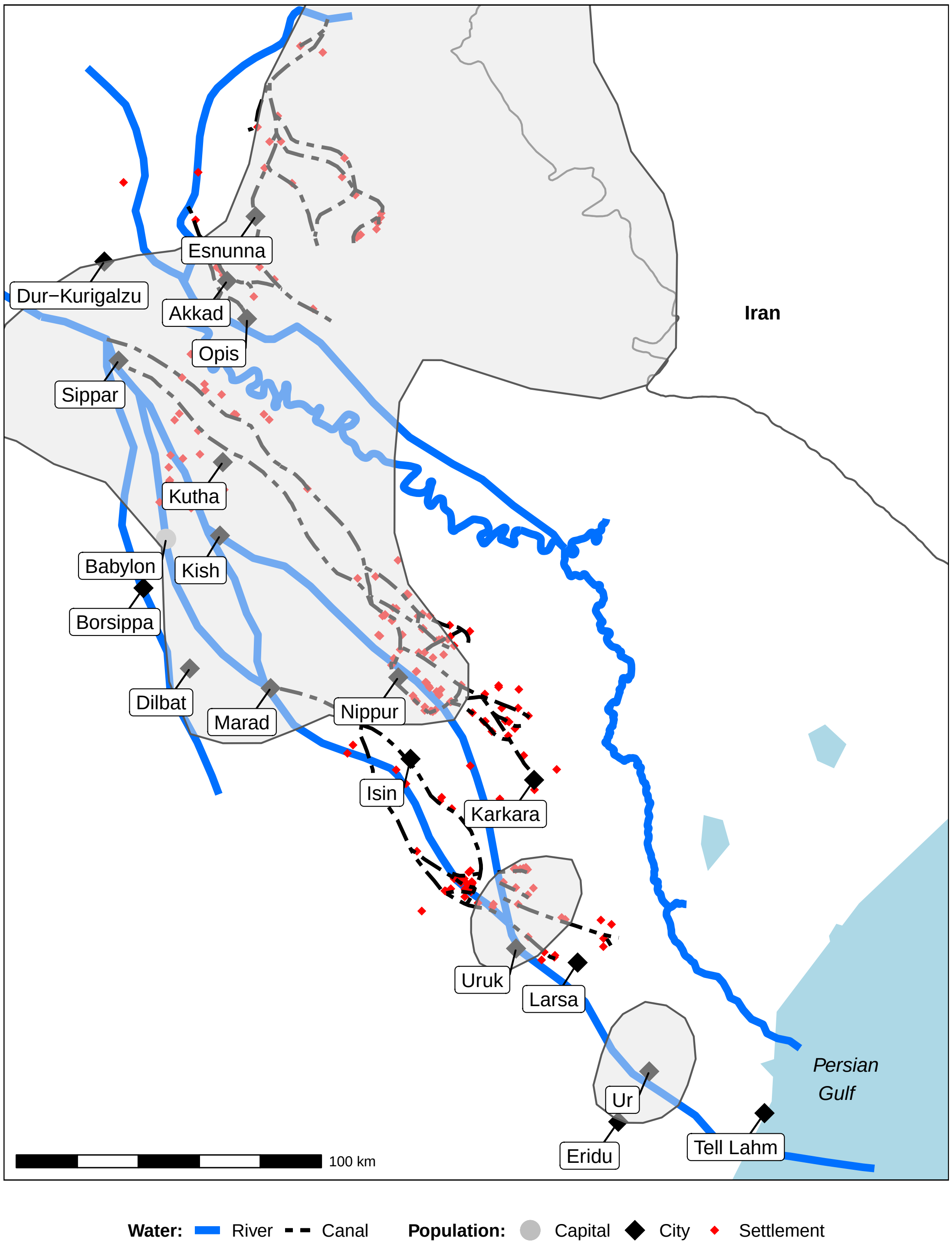


Figure AA29: Neo Assyrian Period and 1000 BCE rivers

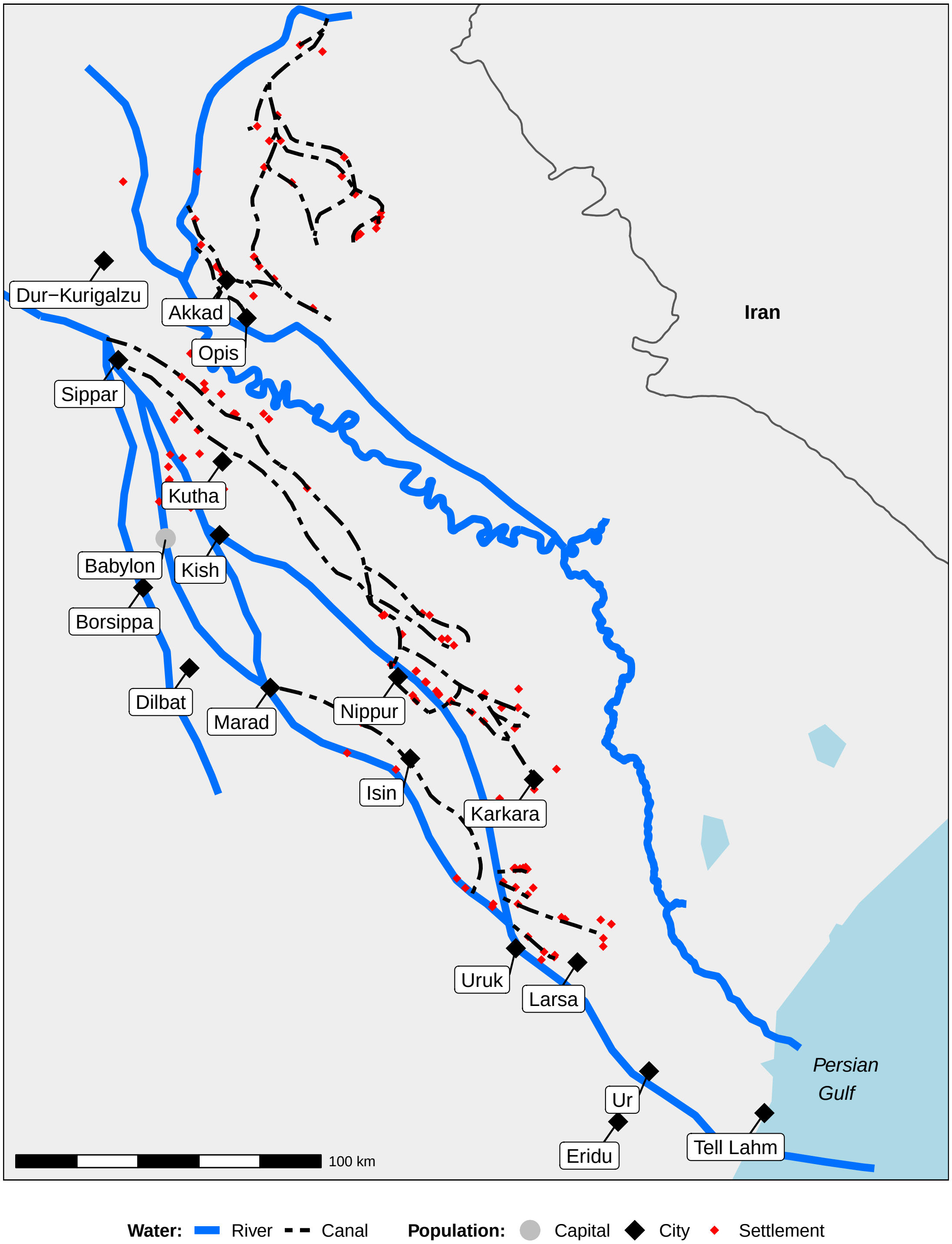


Figure AA30: Neo Babylonian Period and 0 CE rivers

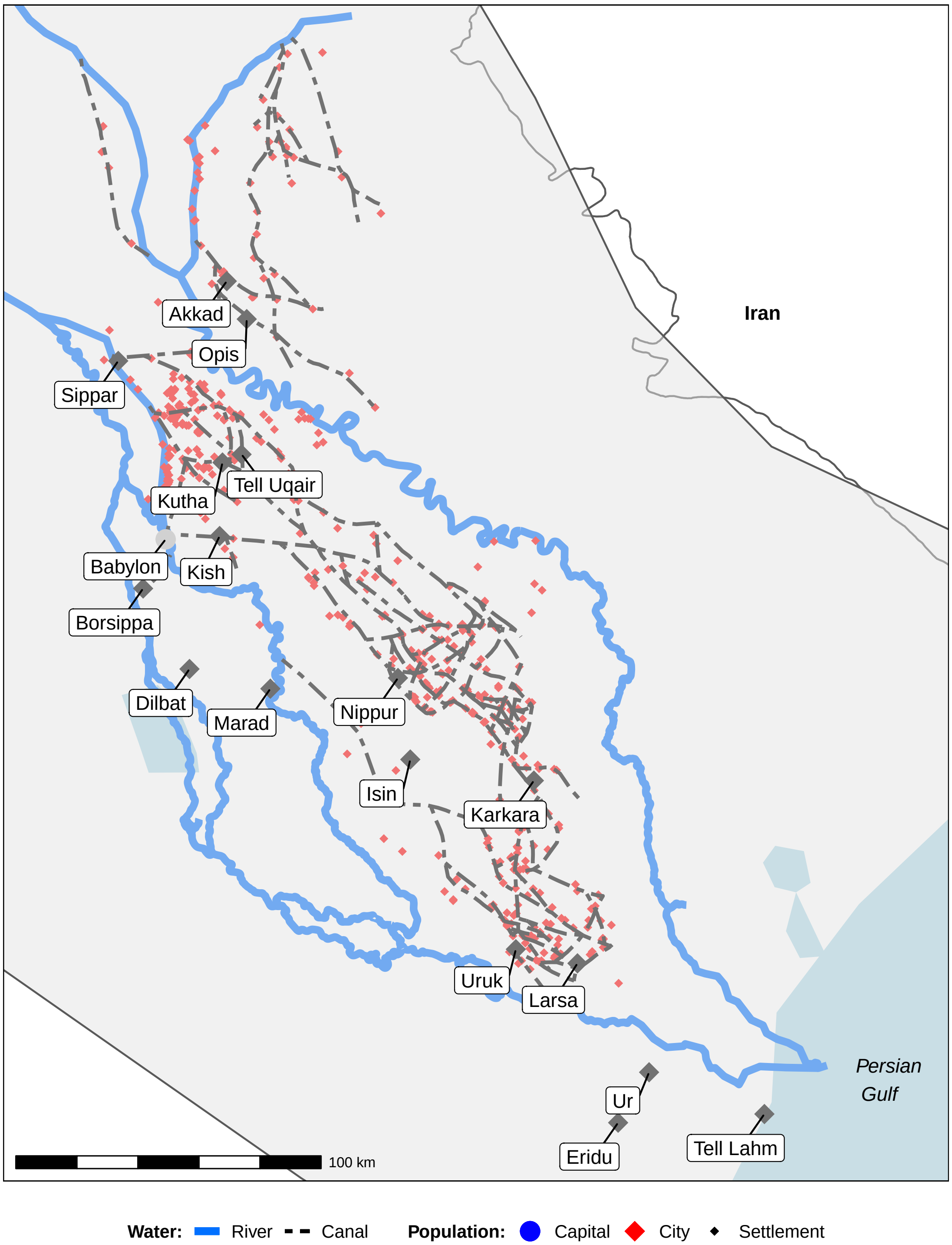


Figure AA31: Achaemenid Period and 0 CE rivers

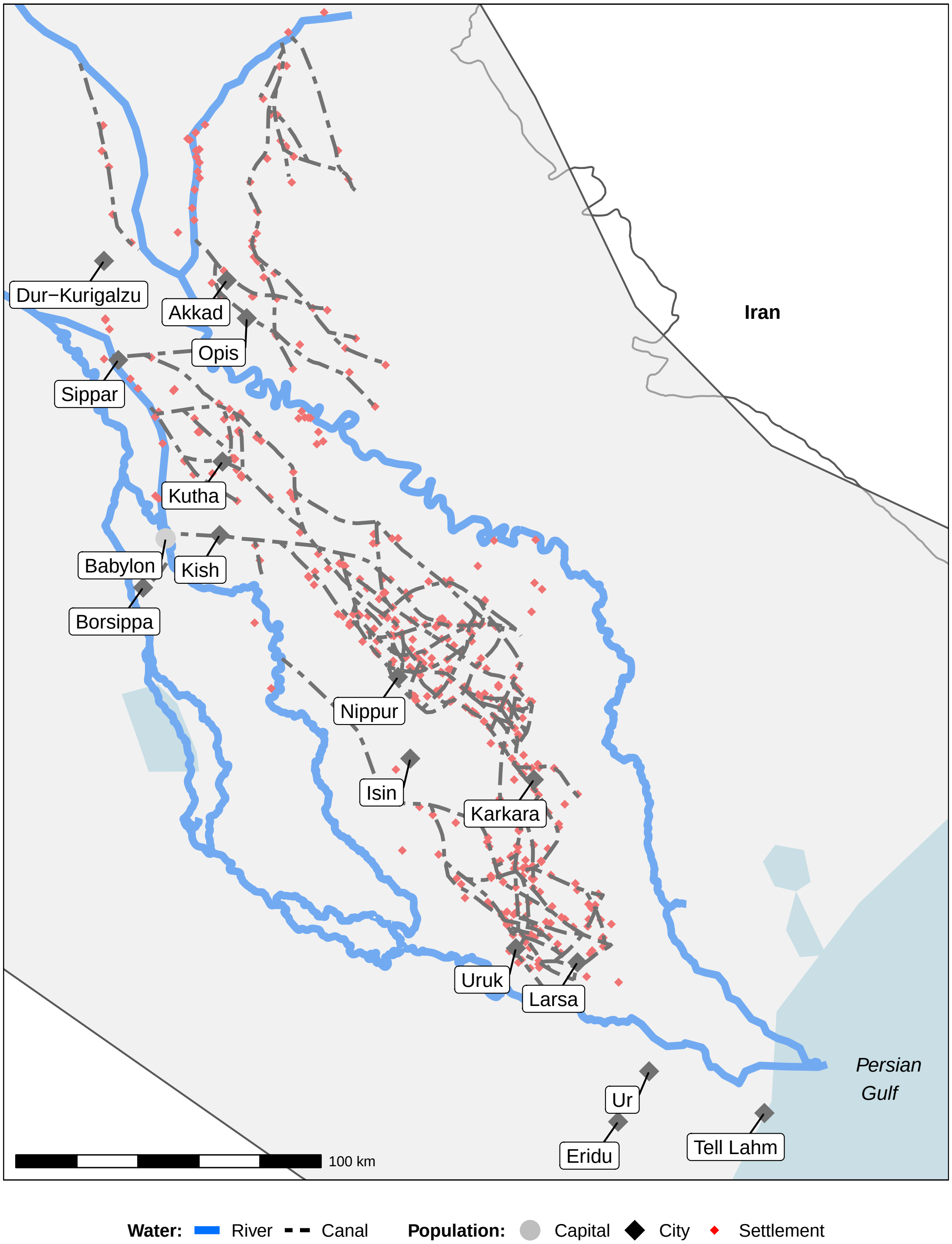


Figure AA32: Seleucid Period and 0 CE rivers

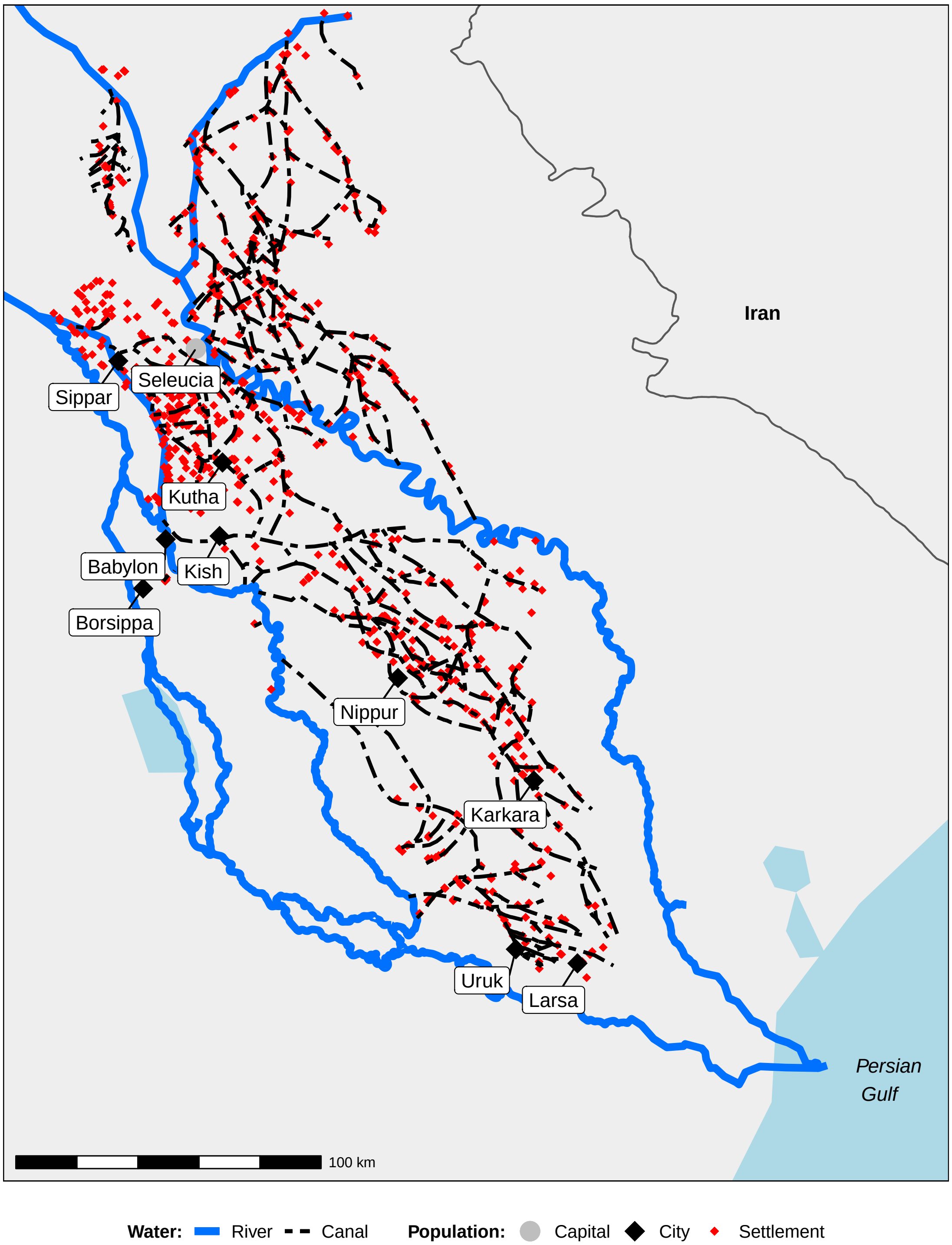


Figure AA33: Parthian Period and 0 CE rivers

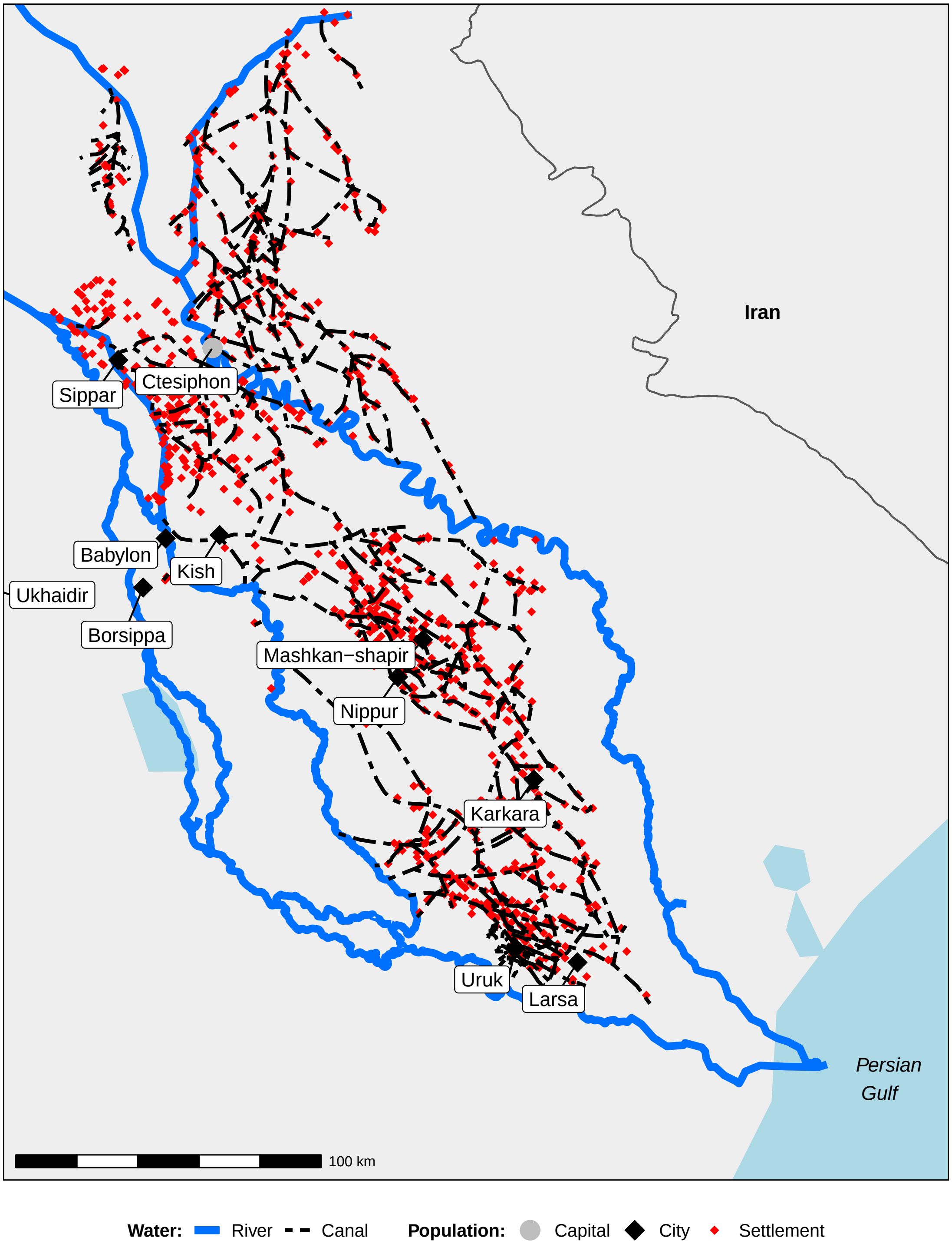


Figure AA34: Sassanian Period and 500 CE rivers

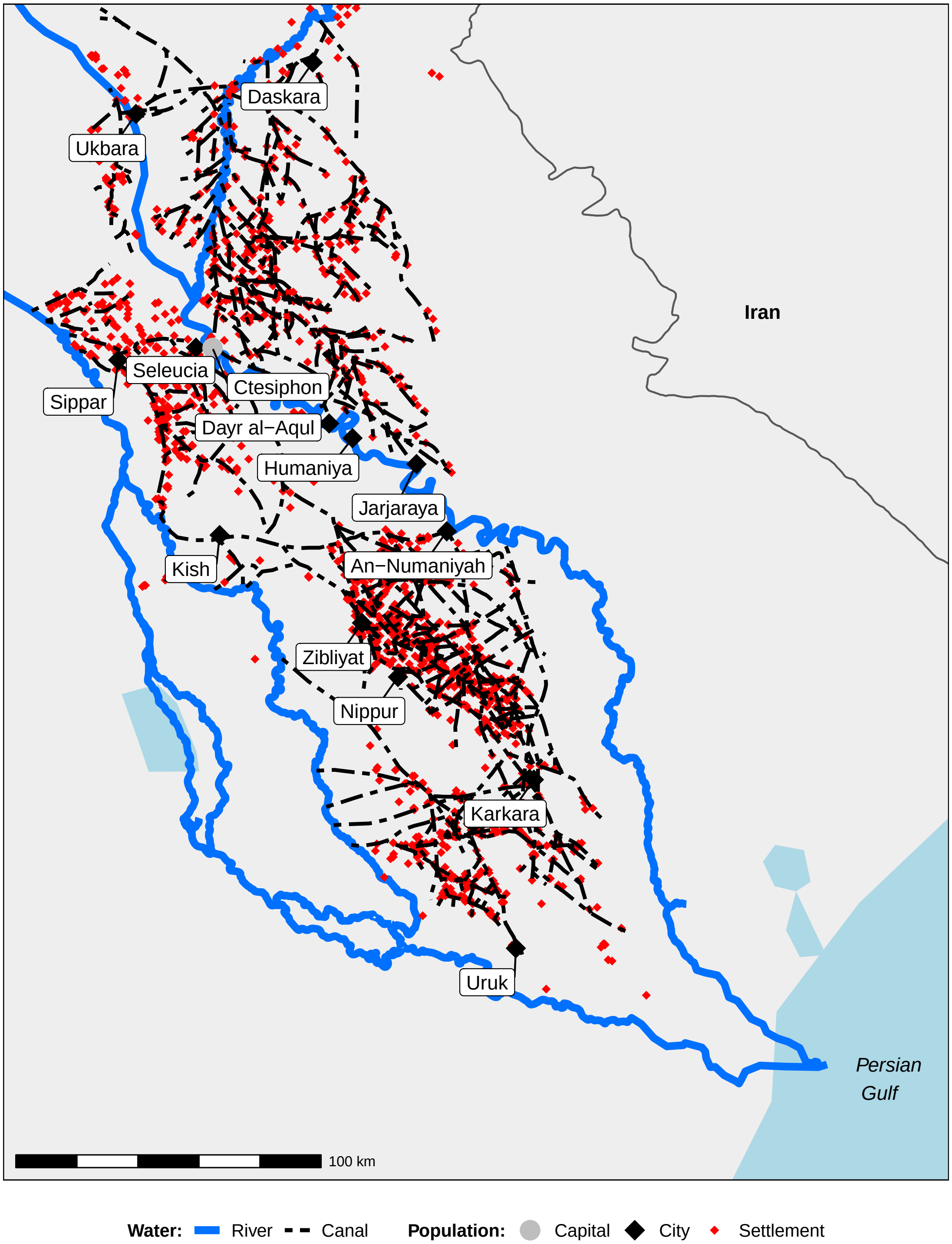


Figure AA35: Early Islamic Period and 1000 CE rivers

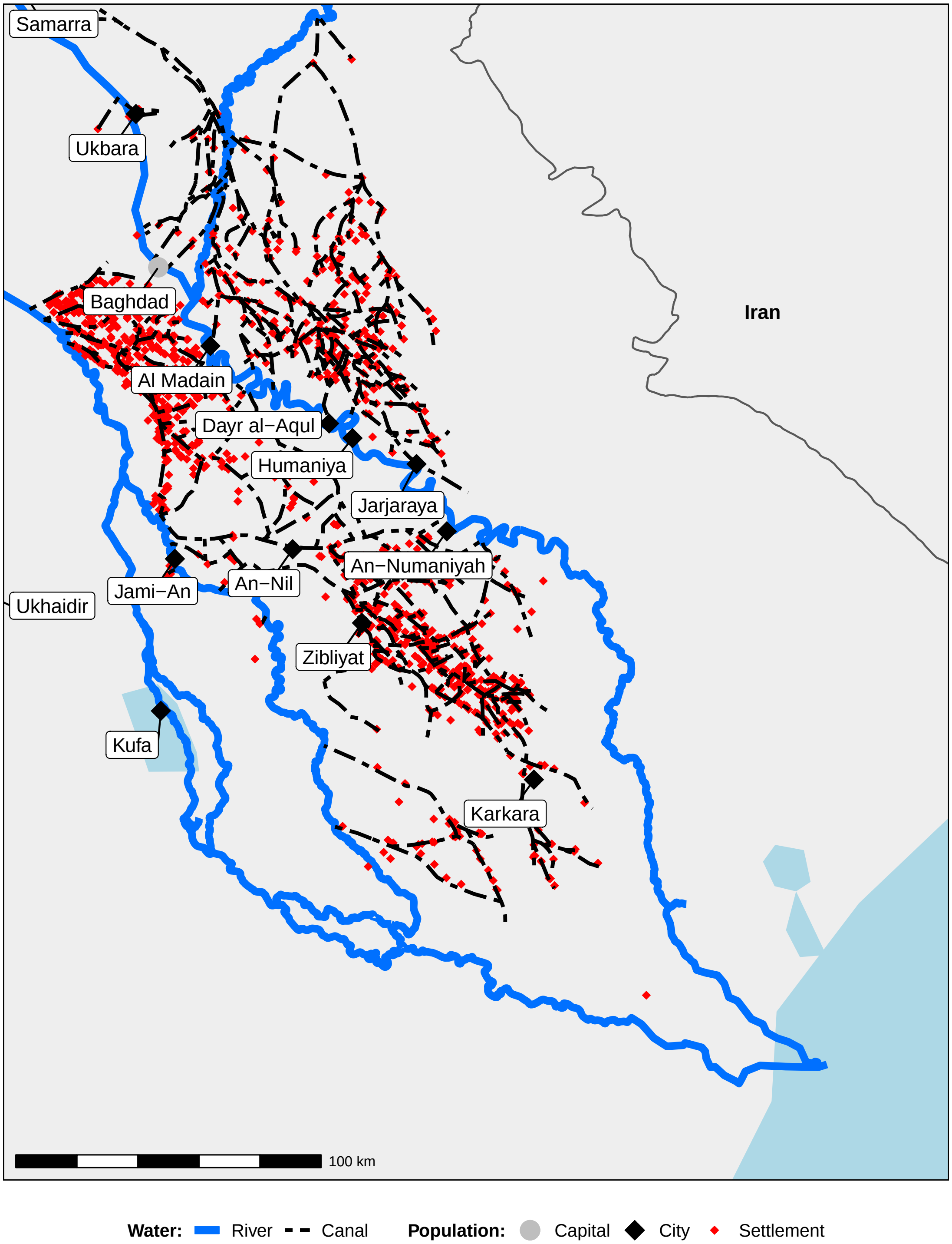


Figure AA36: Samarran Period and 1000 CE rivers

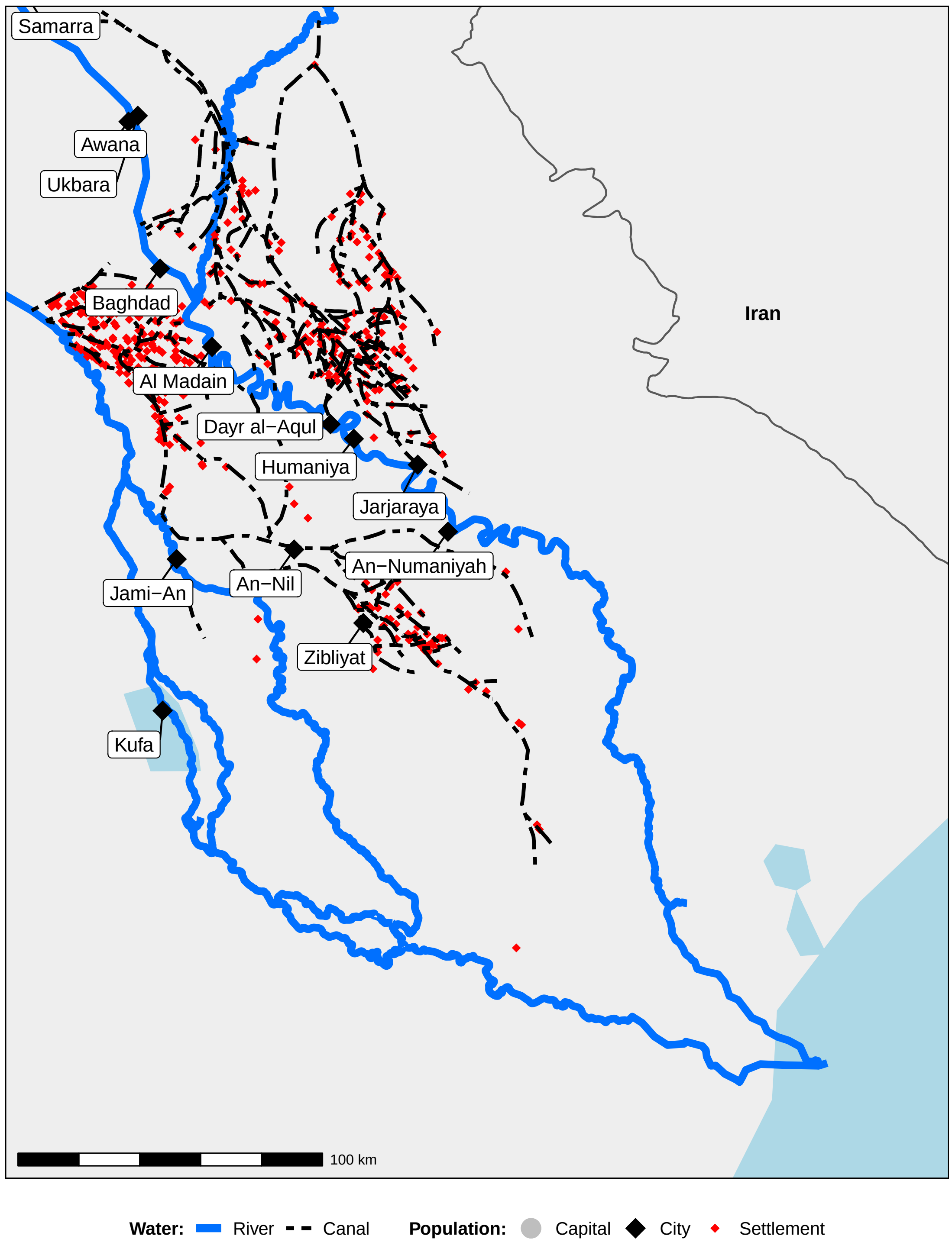


Figure AA37: Middle Islamic Period and 1000 CE rivers

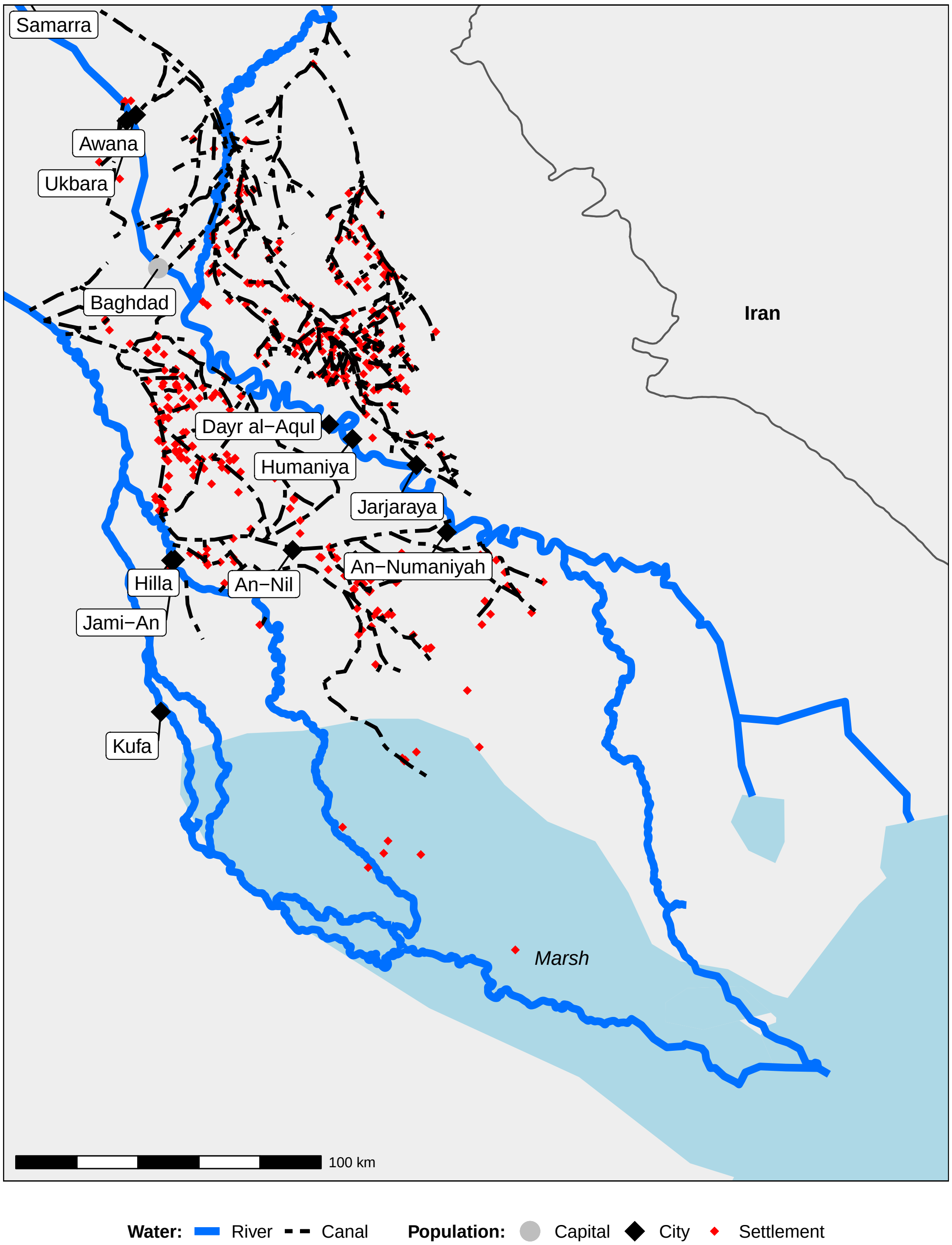


Figure AA38: Late Abbasid Period and 1000 CE rivers

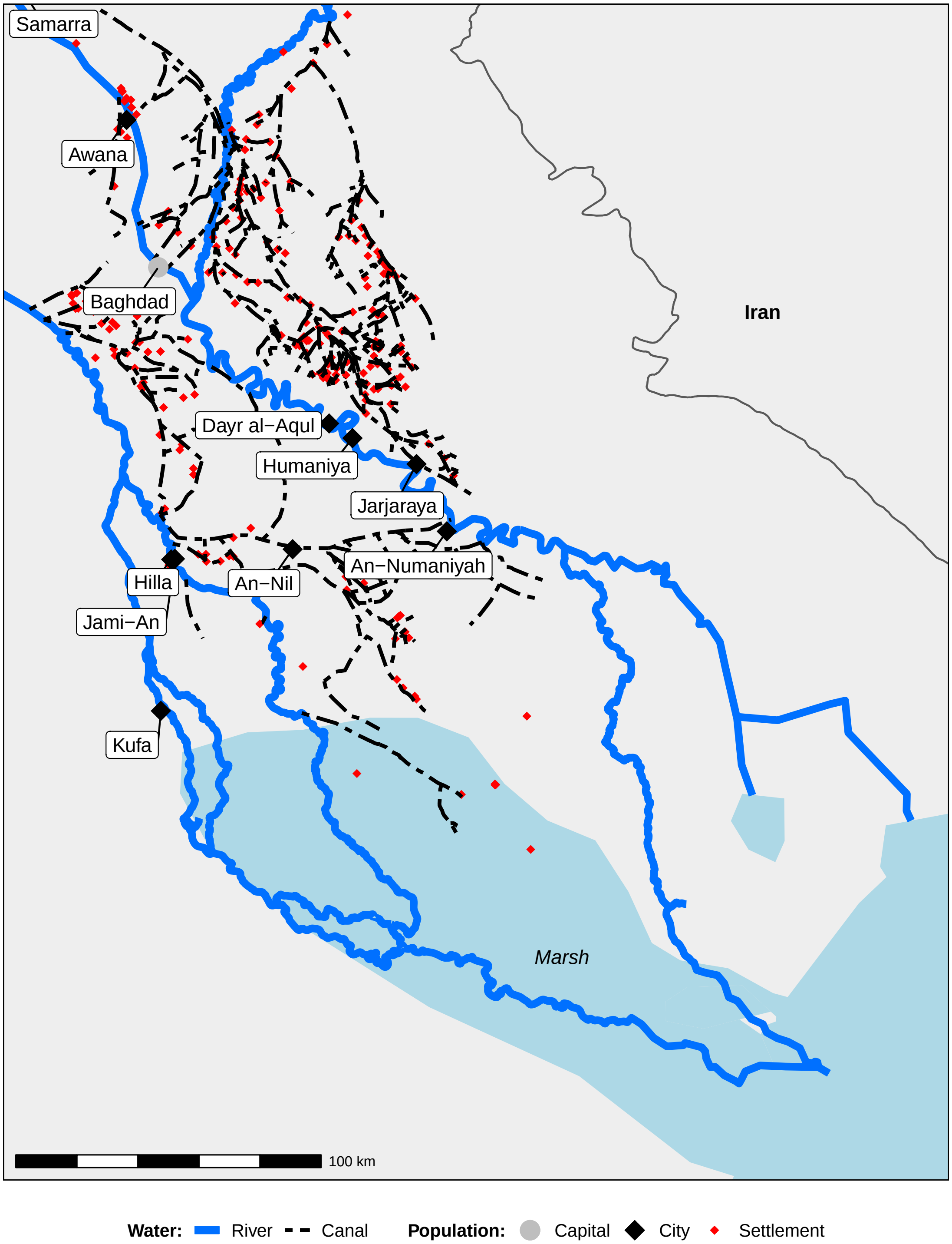


Figure AA39: Late Islamic A Period and 1000 CE rivers

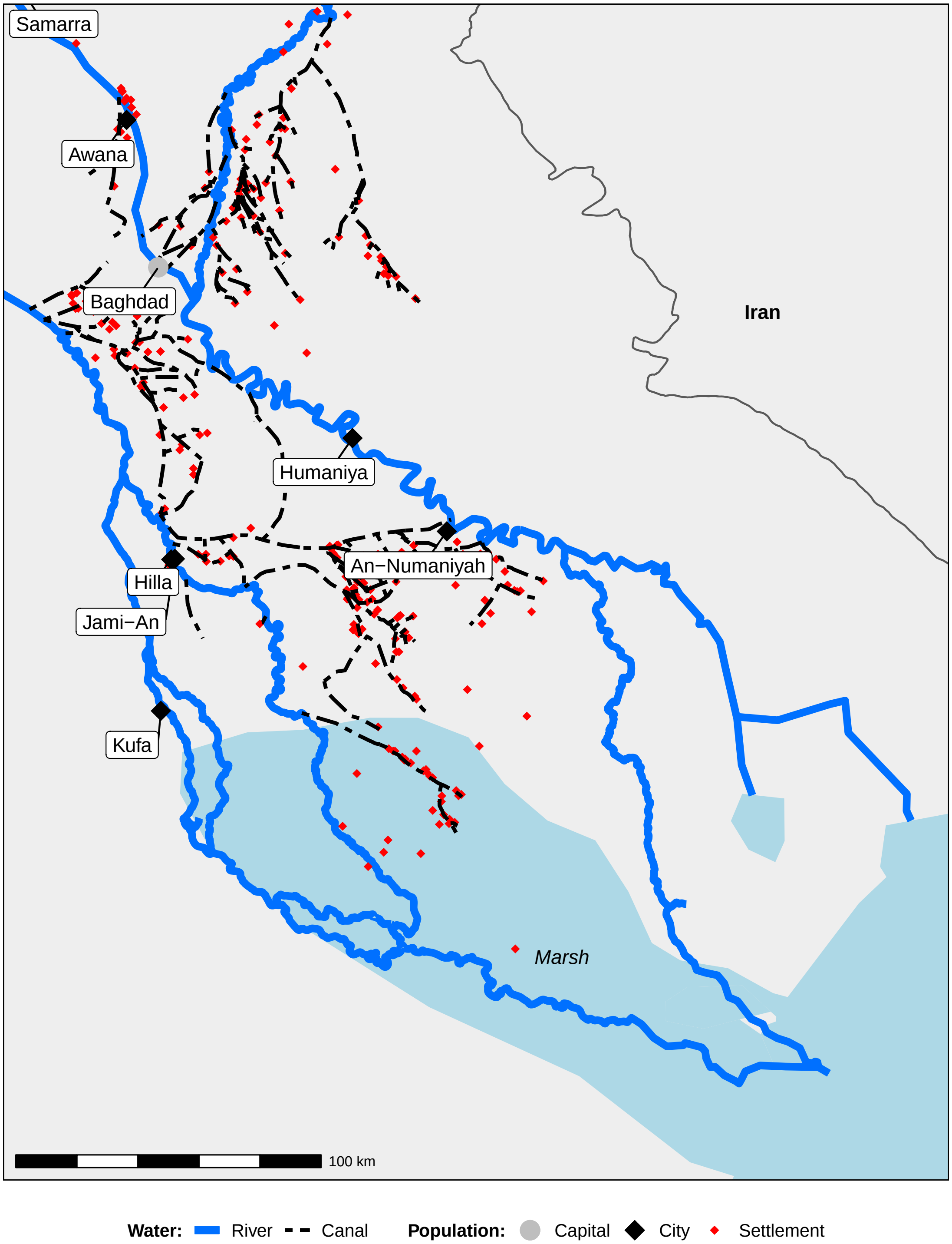


Figure AA40: Late Islamic B Period and 1000 CE rivers

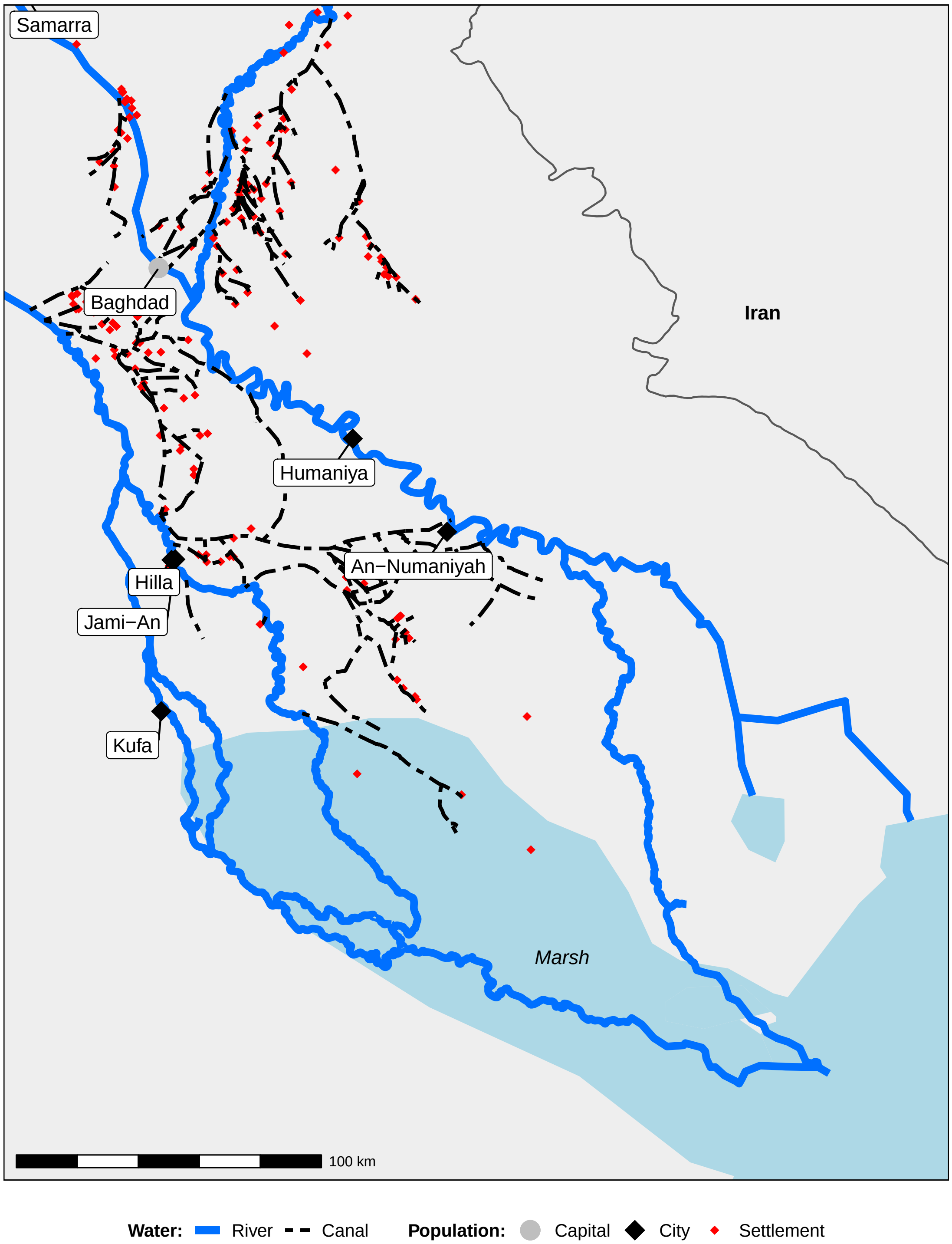


Figure AA41: Ottoman Period and 2000 CE rivers

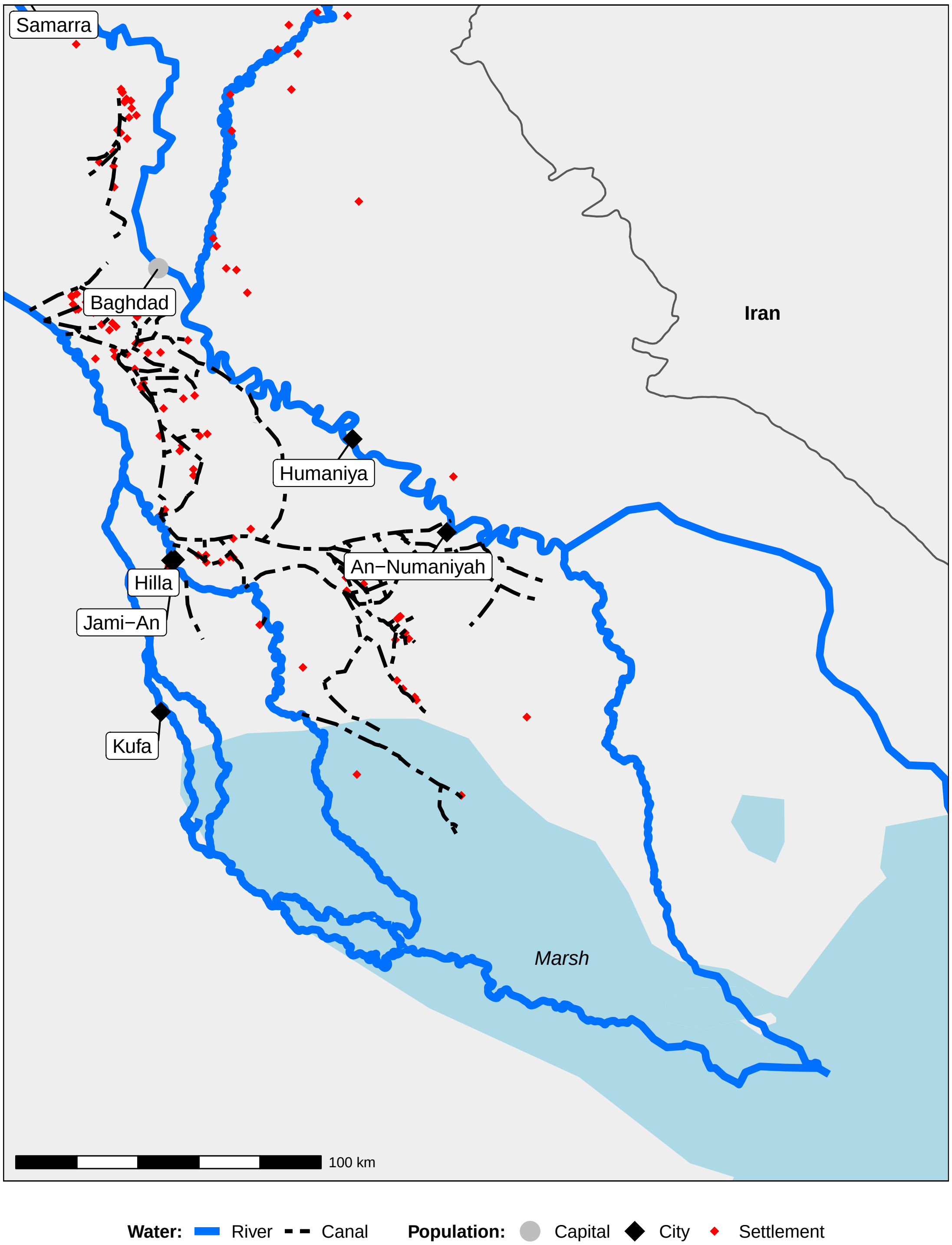


Figure AA42: Settlement in 1911 and 2000 CE rivers

Notes: The data on settlement and canals in 1911 are from War Office (1911). We restrict the data on settlement and canals to our sample area.

4 Political development

In our paper, we provide a time-series of the fraction of the southern Iraqi plain that was under a state. This summarizes the extent of the states that we map in the previous section. We now describe the political development of Mesopotamia period by period. For the periodization, see the Data Appendix.

1. **Eridu and Ubaid period(s)**: There is no evidence of political organizations above the city-level. Arguably the largest and most influential sites were Eridu and Tell Ubaid, where the distinctive pottery styles that gave the name to these periods were first excavated. Nippur was also an important religious center in the region. There was full decentralization across cities and very little evidence of city states.

2. **Uruk period(s)**: Uruk was the most important and influential city at the time, although it did not control any territory outside the immediate vicinity of the city. However, Uruk was the leader of a trade alliance (Cline and Graham, 2011, pp.15-6) and probably had economic influence even beyond the southern Iraqi plain. There was strong interdependence between cities and the countryside, which allowed the creation of more stratified societies (Roaf, 1990, p.58). While Uruk probably had cultural and commercial prominence, cities were independent political units and form small city states. We code each city with at least one administrative building as a capital city.

3. **Jemdet Nasr period**: This period is named after the site of Tell Jemdet Nasr, where the particular type of pottery that named the period was first identified. Tell Jemdet Nasr probably assumed a more prominent cultural and political role across the plain between the end of the 4th and the beginning of the third millennium. By contrast, Uruk probably lost part of its influence over the region, although it remained an important commercial and religious center (Roaf, 1990, p.68). As for the previous Uruk period(s), we code each city with an administrative building as an independent polity in this period.

4. **Early Dynastic I**: This period was characterized by the emergence of several new independent city states that started exercising a firmer control over the countryside (Nissen, 1988) and by the establishment of the first royal dynasties (Roaf, 1990, p.79). A new commercial and political league likely formed and was centered around the city of Nippur. The latter was the cultural and religious capital of southern Iraq and was the location of the temple of the god Enlil, the most powerful of the Sumerian pantheon (Cline and Graham, 2011, 15-6). Nippur, however, only had cultural, religious and (probably) commercial prominence over the other city-states. We code each city with an administrative building as a city state in this period. The size of the territories of these first city states was

still quite limited, as each of them typically only controlled the countryside surrounding the capital city. We rely on Lafont et al. (2017, p.107) to trace the extension of the territory of different city states during the Early Dynastic I period. Most city states only included one capital city. In a few isolated cases larger states (i.e. Esnunna) could control multiple cities with administrative buildings.[2]

5. **Early Dynastic II**: Nippur maintained its religious prominence, while city states remained independent. The first confidently recognized royal palace dates from this period and was excavated in the city of Kish. We code each city with an administrative building as a city state in this period. We rely on Lafont et al. (2017, p.107) to determine the extension of the territory of the different city states also during the Early Dynastic II period.

6. **Early Dynastic III**: This was a dynamic and complex period that witnessed significant fighting between city states and the emergence of the first regional powers. Kish seems to have played a prominent political role in first half of the period, as suggested by the fact that "King of Kish" became the ceremonial title of later rulers. Sargon of Akkad, for instance, was originally from Kish and used the title of "King of Kish" throughout his reign to underline his status and power well after he had established his vast empire across the Middle East. The king of Kish had direct control over the northern part of our study area and would intervene to settle disputes in the south, as for the case of the long-lasting conflict between the states of Umma and Lagash (Podany, 2013, p.36). Uruk and Ur had independent dynasties, so probably wielded some level of regional power as well. Nippur maintained its religious prominence and independent government (Roaf, 1990, pp.81-4). The state of Lagash expanded its territory by the end of Early Dynastic III period, when King Eannatum defeated Umma, Ur and Uruk (Roaf, 1990, p.88). Similarly, Umma, under king Lugalzagesi expanded and sacked Lagash by the end of the period. We disregard short-lived changes of boundaries linked to conflicts in the last few decades of the period. We code each city with an administrative building as a city state in this period. We rely on Lafont et al. (2017, p.107) to determine the extension of the territory of the different city states during the Early Dynastic III period.

7. **Akkadian period**: The Akkadian empire was created by Sargon of Akkad and consolidated by his son Naram-Sin. It is generally considered the world's first empire, based on the recorded attempts to establish professional bureaucracy and the desire the define clear boundaries and regions for tax collection purposes. At its maximum extent, the Akkadian empire controlled the entire southern Iraqi plain, having conquered all the independent city-states that had characterized the political

[2]Kish possibly had started playing a political role in the northern part of the alluvium from this period. However, as we do not have any administrative buildings in this city for the Early Dynastic I period, we only code it as a state from the subsequent Early Dynastic II period (see Section 7 in the Data Appendix for more detail).

landscape of the Early Dynastic era. While the control that the Akkadian empire exerted over the study area faded under the last rulers of the dynasty, we code all cities as being under the control of one state until the end of the period, which was marked by severe droughts and an invasion of the Gutian people that seized parts of the territory. The city of Akkad (or Agade), the capital of the empire, has not yet been precisely located. Nevertheless, there is a convincing evidence that this city was located nearby Baghdad (Meyers, 1997). Akkad is coded as the only political capital in our sample area for this period.

8. **Ur III period**: Ur controlled the entire sample area. Shortly before Ur III dynasty had established its control over the entire plain, the state of Lagash under Gudea managed to briefly assert itself as a regional military power in the southern part of the alluvium. Given the short duration of this kingdom, however, we code Ur as the only capital for the entire period. The Ur III empire created a capillary administrative system across the study area and was responsible for several ambitious building (see section 7 in the Data Appendix) and canalization plans in Nissen (1988, p.194)). The Ur III empire collapsed, after a few decades of decay, due to the Elamite invasion of 2004 BCE.

9. **Isin period**: In this period, a new dynasty from Isin asserted its control over large parts of the earlier Ur III empire, albeit only for a few decades. Its power was challenged early on by the city states of Kazallu in the north and Larsa in the south, while Esnunna retained control of the Diyala plain over the entire period. Uruk had an independent dynasty for parts of the Isin and the later Larsa periods, but often fell under the influence of one of the other two major players. For simplicity, we code Uruk as being under the direct control of Isin during the Isin period (Roaf, 1990, pp.109-11).[3] We code Isin, Larsa, Esnunna and Kazallu as regional capitals in this period, with Isin controlling the majority the city in the alluvium.

10. **Larsa period**: During the Larsa period, the city of Larsa took control over large parts of the plain, but only managed to conquer its rival Isin at the very end of the period under the leadership of king Rim-Sin. Isin remained otherwise independent throughout (normally also controlling the important city of Nippur), but with a reduced territory compared to the previous Isin period. Babylon emerged as a regional power in this period. It controlled the former territories of Kazallu and wielded power in the area surrounding the city of Kish. Esnunna remained independent and exerted control over the Diyala plain throughout the period. We code Esnunna, Babylon, Isin and Larsa as regional capitals.

[3] And under Larsa during the Larsa period.

11. **Old Babylonian period**: At the beginning of the period, Babylon under king Hammurabi (a member of the Amorite dynasty that ruled Babylon in the Larsa period), expanded its territory after several victorious campaigns and achieved full control over the entire southern alluvium, thus ending Larsa's supremacy across the sample area. Esnunna was the last independent regional state to fall. Hammurabi set up a capillary administrative apparatus and issued his famous legal code which, among other things, contained articles regarding irrigation and canal maintenance. Despite some territorial losses during the last decades of the Old Babylonian dynasty, the latter maintained full control of sample area for most of the period. We therefore code Babylon as the only capital in this period.

12. **Cassite period**: After a few decades of decay, the Old Babylonian empire was eventually destroyed by the Hittites, who sacked Babylon in 1595 BCE (Roaf, 1990, p.123). When the Hittites left, the Cassites, a foreign population probably from Iran, filled the power vacuum. After settling in the northern part of the sample area, they created a kingdom that encompassed all the the southern Mesopotamian territories of the Old Babylonian empire, including the Diyala plain (Roaf, 1990, p.142). Despite showing several elements of cultural and political continuity with the previous Amorite empire, the Cassite dynasty led to a geographical shift in the political center of the empire. After a few generations, the Cassite king Kurigalzu I moved the capital to Dur-Kurigalzu, a newly founded city located north of Sippar and near Baghdad, probably in the middle of the Cassite tribal areas. Babylon only retained a ceremonial and cultural role after this event. Despite both cities acting as capital for parts of the Cassite period, we code Dur-Kurigalzu as the only capital, as the latter played the role of capital for a longer period of time and because no change of dynasty took place with the shift of capital.

13. **Middle Babylonian period**: The resources of the Cassite kingdom were exhausted by a series of conflicts against Assyria and Elam, that culminated with the defeat against the Elamites, who sacked Babylon and took the last Cassite king prisoner around 1150 BCE. This event marked the end of the Cassite period. During the Middle Babylonian period, southern Iraq was frequently invaded and at times subject to the formal control of foreign powers, Elam and Assyria in particular. Phases of foreign occupation and puppet rulers alternated with independent local dynasties, often emerging from the bureaucratic cadres or tribal leadership. Southern Mesopotamia was also exposed to continuous attacks from nomadic tribes. As a consequence of this instability, the political landscape was extremely fragmented and most cities regained substantial independence from the central Babylonian power (van de Mieroop, 2015, pp.218-219). In other words, Babylon maintained a cultural,

religious and formal political prominence, but several tribal capitals emerged and wielded power over smaller stretches of land (Beaulieu, 2017). The irrigation system was severely affected by this lack of central leadership and political instability (see Roaf (1990, p.198) and van de Mieroop (2015, p.209)). Given its continued formal role, we code Babylon as capital but with a much reduced and fragmented territory. Even cities under the formal control of the capital would have experienced a large degree of independence in this period.

14. **Neo Assyrian period**: The political instability that characterized the Middle Babylonian period was violently put to an end by the Assyrians, who took formal control of southern Mesopotamia and started to appoint Babylonian rulers, often selected from within the Assyrian ruling family. King Tiglath-Pileser first asserted complete control over the area in the eighth century BCE, while the Assyrian empire reached its maximum extension and power under king Sargon II. Assyrian rulers had faced several rebellions in southern Mesopotamia, which led to repression and to the destruction of Babylon by Sennacherib, in 689 BCE. The Assyrian Empire regained influence and power in the area under Esharaddon (who re-built Babylon) and Ashurbanipal. Given this political situation, the Assyrian capital of Niniveh[4] would be the center of power for southern Mesopotamia as well. However, as the Assyrian viceroys ruled from Babylon, we code the latter as the capital during this period.

15. **Neo Babylonian period**: Under the kings Nabopolassar and Nebuchadnezzar, Babylonia regained her former glory. After defeating the Assyrians and sacking Niniveh in 612 BCE, Nabopolassar went on to build a large empire that stretched all the way to the Mediterranean sea (Roaf, 1990, p.198). Babylon was thoroughly rebuilt and regained its role of imperial capital. The administrative capacity of the empire formed the basis for a resurgence of large canalization works in the sample area. We code Babylon as the only capital in this period.

16. **Achaemenid period**: Cyrus the Great conquered Babylon in 539 BCE and deposed the last Neo Babylonian king Nabonidus. He thus ended the Neo-Babylonian dynasty, but made Babylon the capital of the Persian-Achaemenid empire. We code Babylon as the political capital in this period.

17. **Seleucid period**: Alexander the Great entered Babylon in 331 BCE, after defeating the last Achaemenid emperor, Darius, in a series of battles. Under his successors, Mesopotamia formed, together with Syria, the core territory of the Seleucid empire. The Greek conquest effectively marked the end of the Mesopotamian civilization and of its distinct cultural identity. The newly built city of Seleucia,

[4]Although the Assyrian emperors sometimes moved the royal court to other capitals, such as Dur-Sharrukin and Ashur

for a time the capital of the entire Seleucid empire, acted the regional capital during this period. The adoption of a location on the Tigris river as capital marks a historical shift in the political center of power, as capitals tended to be located on the Euphrates up to this point. We code Seleucia as the only capital in the period.

18. **Parthian period**: The Parthians defeated the Greeks after a few decades of continuous fighting, took control of southern Mesopotamia and founded a new capital at Ctesiphon, which was also located on the Tigris near Seleucia. The continuous military confrontation that opposed the Parthians and the Romans made Iraq, especially during the second century CE at the peak of the conflict, a heavily militarized frontier region and generated a power vacuum that eventually translated into a lack of centralized administration. Towards the end of the period, this situation affected the functioning of the irrigation network and trade in the sample area (Adams, 1981, p.200). We code Ctesiphon as the only capital in this period.

19. **Sassanian period**: The Sassanian (or Sassanid) dynasty from Iran succeeded in defeating the already weakened Parthian empire in 224 CE. After asserting their control over Mesopotamia, the Sassanian rulers started to use Ctesiphon as the regional (and often imperial) capital. While under the Sassanian rule the complexity and efficiency of the irrigation system across the sample area reached its peak, it was only towards the end of the fifth century CE that the Sassanian administrative apparatus was fully developed. During the first two centuries of Sassanian rule, instead, the area was not actively managed by the state (Adams, 1981, p.201). We code Ctesiphon as the only capital for this period.

20. **Islamic period(s)**: The Sassanian empire was repeatedly defeated by the Islamic armies that took control of southern Mesopotamia in 651 CE. Caliph Al-Mansour founded a new capital on the Tigris, Baghdad, which remained the political capital of Iraq until present. The only short-lived shift in the location of the capital took place in the Samarran period, when the Abbasid court moved to the city of Samarra, located 40 kilometers north of Baghdad and along the banks of the Tigris. During the Ottoman period, while Baghdad retained the functions of a regional capital, the center of the administrative power moved to Istanbul. The Islamic periods witnessed a progressive decline in the extension of the irrigation system relative to the Sassanian period and, in particular between the Middle Islamic and the Ottoman periods. We code Baghdad as the capital from the Early Islamic period until today, with the only exception of the Samarran period.

5 Cities and buildings

The list below provides a brief archeological history of the main cities included in our dataset. The basis for our data is the work of Ernst Heinrich (1982, 1984). We supplement and expand his work with data from other comprehensive *compendia*, mainly Meyers (1997) and Bryce (2009). Only on a few occasions, namely when the cited works do not provide sufficiently detailed information (for instance due to insufficient detail on the life-span or the size of a building), we refer directly to more specific reports from archeological campaigns and local studies.

1. **Abu Salabikh**: Identified with the ancient city of Eresh. Not included in Heinrich's catalog. Meyers (1997) reports a temple for the EDI, EDII and EDIII periods, which we include in the dataset.

2. **Adab**: Heinrich (1984) only reports a palace in the Old Babylonian period, which we code as being in existence between the EDIII and the Cassite periods based on Meyers (1997). The latter also records the existence of a ziggurat and a temple between the EDI and the Cassite periods, which we add to the dataset.

3. **Akkad**: The city of Akkad (or Agade, the capital of the Akkadian empire created by Sargon), has not been precisely located and no archeological excavations have taken place. From textual sources, we know that the city, which was likely located at the confluence of the Diyala and Tigris rivers, survived the end of the Akkadian Empire in the late third millennium BCE (Meyers, 1997). Based on the discussion in Meyers (1997), which relies on textual sources, we include the existence of a palace and a ziggurat for the Akkadian period alone, as there is no evidence that these survived the end of the Akkadian empire.

4. **Akshak**: Uncertain location and not included in Heinrich's catalog. From textual sources, we know that this city was located near the junction of the Diyala and Tigris rivers. As excavations have not taken place, data on buildings are missing for the entire life-span of the city (Jemdet Nasr to URIII).

5. **Al Madain**: Medieval city of Islamic foundation near ancient Ctesiphon. No data on buildings.

6. **An-Nil**: Medieval city of Islamic foundation 25 km to the East of ancient Kish. No data on buildings.

7. **An-Numaniyah**: Medieval city of Sassanian foundation, located on the contemporary course of Tigris North of ancient Nippur. No data on buildings.

8. **Awana**: Medieval city of Islamic foundation, located North of Baghdad. No data on buildings.

9. **Babylon**: The data in Heinrich (1982) and Heinrich (1984) are incomplete due to repeated flooding of the Old Babylonian part of the city which largely destroyed the archeological evidence for the period. We complement Heinrich's data with information from Beaulieu (2017), who compares archeological records with textual sources that allow to trace the evolution of public buildings in Babylon from its foundation.

   The textual sources mention how Nebuchadnezzar refurbished the "Sudburg", or South Palace, (Beaulieu, 2017, p.9). This palace is likely the royal residence that had been built by Hammurabi and Samsu-Iluna in the Old Babylonian period (Beaulieu, 2017, p.6). The Neo-Babylonian king also built two new palaces. All three palaces are reported by Heinrich (1984), albeit for the Neo-Babylonian period alone. We assign the South Palace to all periods between the Old Babylonian and the Neo Babylonian ones, with the exception of the intervening Middle Babylonian and Neo Assyrian periods, when the sources report repeated destructions by invading foreign armies, such as the Assyrian and the Elamite ones. The Neo-Babylonian palaces continued to be used during the Achaemenid period and fell out of use during the Seleucid period (Beaulieu, 2017, p.11).

   Heinrich (1982) only reports one ziggurat between the Old Babylonian and the Middle Babylonian periods, the so called Old Ziggurat, along with the Neo-Babylonian Etemenaki Ziggurat and several coeval temples from the seventh century BCE. Meyers (1997) suggests that two temples, namely the Esagila and Ninmah ones existed from the EDIII period and were only destroyed during the Assyrian sack of the city in the Neo Assyrian period. Sargon destroyed the city in 2340 BCE, but the city was quickly re-built. Several new temples were built in the Old Babylonian period. Thus the city counted 5 active temples and a ziggurat between the Old Babylonian and the Middle Babylonian periods and 6 temples and a ziggurat between the Neo Babylonian and the Seleucid periods. After the Seleucid era, the city declined and all buildings eventually collapsed in the Parthian period Meyers (1997).

10. **Bad Tibira**: The city is not included in Heinrich's catalog, but this was an important urban center of Jemdet Nasr foundation that reached its peak during the Early Dynastic era. Archeological excavations in the area are limited, but textual sources report the existence of a temple between the EDIII and the Larsa periods. As it is unclear whether the latter had been founded earlier, temples are set to missing between the Jemdet Nasr and the EDII periods. Due to limited excavations, palaces are also set to missing between the Jemdet Nasr and the Larsa periods. Throughout its history, the city

was often under the control of the kingdom of Lagash.

11. **Baghdad**: Medieval city of Early Islamic foundation, capital of the Abbasid Caliphate between 750 and 1258 and current capital of Iraq. The Islamic period is not covered by Heinrich, but we interpolate administrative buildings based on Meyers (1997) and Le Strange (1905). We include three palaces between the Early Islamic and the Abbasid periods, but no palace is coded for the Samarran period when the capital moved to Samarra. Al-Mansur's mosque is included between the Early Islamic and the Ilkhanid periods, with the exception of the Samarran period when Baghdad decayed, following the shift in capital location.

12. **Borsippa**: Heinrich (1982) only reports a temple and a ziggurat in the Neo Babylonian period. The archeological evidence from excavations is limited, but Bryce (2009) suggests that both the Nabu temple and the Eurmeiminanki Ziggurat (both part of the Ezida complex) had been built in the Old Babylonian period and restored by later rulers. Restoration works were carried out until the Seleucid period, after which the city decayed.

13. **Ctesiphon**: City of Parthian foundation, for a time capital of the Parthian empire and later adopted as capital of the Sassanian empire. The city was built next to Seleucia, the Hellenistic capital of the Seleucid empire, on the banks of the Tigris. The city is not included in Heinrich's catalog. Invernizzi (1994) reports the existence of a royal palace between the Parthian and the Sassanian periods, which we add to the dataset.

14. **Daskara**: City of Sassanian foundation in the northern part of the Diyala plain. The city was politically important at the time as it featured a royal residence, which we only code for the Sassanian period. The city collapsed soon after the Islamic conquest.

15. **Dayr al-Aqul**: Medieval city of Sassanian foundation, located on the Tigris between Al Madain and Humaniya. No data on buildings.

16. **Der**: Important city of Old Babylonian foundation, located in the Diyala area along one of the trade routes to Elam. Not included in Heinrich's catalog. Limited archaelogical evidence on the city exists, we do not have any recorded monumental buildings in the dataset, although it probably served as temporary royal residence during the Middle Babylonian and Neo Assyrian periods (Bryce, 2009; Beaulieu, 2017).

17. **Dilbat**: The city achieved urban status during the Old Babylonian period, although the site is already attested in the Akkadian period. It remained one of the most important urban centers of the

area until the Neo Babylonian period. The site has only been partially excavated. The city is not included in Heinrich's catalog. We add a temple between the Old Babylonian and the Neo Babylonian periods to the dataset based on Bryce (2009).

18. **Dur-Kurigalzu**: Capital of the Cassite kingdom, founded by Kurigalzu I. We fully rely on Heinrich for the number and size of the buildings. We assign extant buildings to the Cassite period alone, as the city quickly decayed after the end of the Cassite period (Bryce, 2009).

19. **Eridu**: We largely rely on Heinrich, who provides a detailed account of the excavated buildings in Eridu. The latter was one of holiest sanctuaries in southern Mesopotamia over our study period and arguably the oldest city in the area. The site was extremely long-lived, as its existence is attested between the Eridu and Achaemenid periods. Some lack of clarity remains on the life-span of the monumental buildings described in Heinrich. The ziggurat was built in the URIII period and certainly survived the collapse of the URIII empire at the end of the third millennium BCE. Probably destroyed during Assyrian invasions of the Middle Babylonian period, it was re-built in the Neo Babylonian era (Meyers, 1997). Textual evidence suggests that some of the pre and proto-historic temples were still in use during the Old Babylonian and Cassite periods (Bryce, 2009). Archelogical evidence, however, does not support this possibility. Administrative buildings from the Early Dynastic era were also located at the site.

20. **Esnunna**: Heinrich provides a detailed list of the monumental buildings in this important city which, before the rise of the Old Babylonian empire, was the capital of a powerful and independent regional kingdom. From Meyers (1997), we know that Hammurabi's army destroyed all buildings at the beginning of the second millennium BCE, when Esnunna's status was reduced to provincial capital.

21. **Girsu**: Girsu was for a time the capital of the kingdom of Lagash, which gained political importance in the second half of the third millennium BCE, just before the rise of the Akkadian empire. Archeological evidence is limited for this site. The city was abandoned in the Old Babylonian period. Based on Meyers (1997), we update the data from Heinrich by extending the life-span of the main temple from the Early Dynastic III period until the Old Babylonian one, with the only gap being the Akkadian period when the city was in severe decline after having been sacked at the end of the conflict with rival city state of Umma. Following Meyers (1997) we also add a second temple between Early Dynastic III and Old Babylonian periods. A palace possibly existed in Early Dynastic III, when the city enjoyed political prominence in southern Mesopotamia, but such a structure has not yet been

clearly identified by the archeologists and it is therefore not included in our dataset.

22. **Hilla**: Medieval city of Middle Islamic foundation, located on the homonymous branch of the Euphrates. No data on buildings.

23. **Humaniya**: City of Sassanian foundation, located on the Tigris South of Baghdad. No data on buildings.

24. **Isin**: Heinrich reports several remains of administrative buildings from the Isin period, but does not specify for how long these were active. We assign these buildings to the Isin period alone, consistent with Meyers (1997). The Gula temple, reported by Heinrich (1982) for the Cassite period only, was continuously refurbished and maintained between the EDII and the Neo Babylonian periods (Meyers, 1997).

25. **Jami-An**: Medieval city of Early Islamic foundation, located near Hilla on the opposite bank of the Euphrates. No data on buildings.

26. **Jarjaraya**: City of Sassanian foundation, located on the Tigris south of Humaniya. No data on buildings.

27. **Karkara**: The city was founded in the EDI period and it is not included in Henrich's catalog. It remained an important urban center until the Early Islamic period, when it was known as Jidr. Recent excavations have located a temple dating from the URIII period and a fortress, active between the Parthian and Sassanian periods, which we add to the dataset (Bryce, 2009).

28. **Kazallu**: The city is first attested in the Akkadian period and lastly mentioned in textual sources from the Old Babylonian one. It is not included in Heinrich's catalog. Archeological evidence on monumental buildings does not exist, nor buildings (other than city walls) are reported in textual sources (Bryce, 2009). The data are set to missing for the entire life-span of the city.

29. **Kesh**: Modern Tell Wilaya. City of Jemdet Nasr foundation, located on an ancient branch of the Tigris. The site has not been fully excavated. Heinrich (1984) reports two administrative buildings from the EDIII and Akkadian periods. We set religious buildings to missing, due to limited excavations.

30. **Khafagi**: The city is also known as Tutub, and experienced continuous occupation between the Jemdet Nasr and the Cassite periods. Archeological data are unchanged from Heinrich (1982) and Heinrich (1984), apart from the addition a temple from the Old Babylonian period based on Bryce (2009).

31. **Kish**: Important city that rose to prominence during the Early Dynastic era, seat of the first post-diluvian royal dynasty. The city was continuously occupied between the Jemdet Nasr and the Sassanian periods. The information from Heinrich is detailed and we fully rely on his catalog. The importance of Kish during the Early Dynastic periods is reflected in the discovery of two large administrative palaces and a ziggurat that fell out of use by the end of the third millennium BCE, probably during the Akkadian period. Other religious monumental complexes date from the Old Babylonian and Neo Babylonian periods. While we rely on Heinrich's dating of palace A to the EDII period, it is possible that its construction had started earlier so that the latter might actually date back to the EDI period (Bryce, 2009). Results are robust to this additional robustness check.

32. **Kisurra**: The city is first attested in the URIII period and only gained political autonomy for a short period of time during the Larsa period. The city is not included in Heinrich's catalog. Archeological evidence is limited but no significant monumental buildings have been located (Bryce, 2009).

33. **Kufa**: City of Middle Islamic foundation, located on the western branch of the Euphrates. No data on buildings.

34. **Kutalla**: The city was founded in the URIII period and was a satellite, provincial center of the city state of Larsa. Heinrich does not include Kutalla in his catalog, but a temple between the Larsa and the Old Babylonian periods is attested from textual sources (Bryce, 2009). As limited excavations were carried out, we set data to missing between the URIII and Isin periods.

35. **Kutha**: The city is attested between the Akkadian and the Achaemenid periods and was an important religious center in southern Mesopotamia. The site has been poorly excavated and it is not included in Heinrich's catalog. The temple of the city's god Nergal is however attested from textual sources, so we add this temple for the entire life-span of the city (Bryce, 2009).

36. **Lagash**: The city of Lagash was for a time the capital of the powerful kingdom of Lagash, that raised to prominence in the EDIII period. Based on Meyers (1997), we add a temple, the precursor of the Bagara complex, which is reported by Heinrich (1982) for EDIII only, between EDI and EDII. In EDIII, the Inanna temple was also built. We extend the life-span of both the Bagara complex and the Inanna temple to the Old Babylonian period, with a gap during the Akkadian period, when the city experienced widespread abandonment after being conquered and destroyed by its rival Umma. Remains of an administrative palace, dating between the EDIII and the Old Babylonian periods, were also excavated (Meyers, 1997). We add this building to our dataset.

37. **Larak**: The city emerged in the Jemdet Nasr period and was probably located on an old branch of the Tigris. While the location of ancient Larak has been plausibly identified, the site has not been excavated. Data are therefore missing for the entire life-span of the city, which is not included in Heinrich's catalog.

38. **Larsa**: Heinrich does not report any palaces in Larsa before the Old Babylonian period, but only a ziggurat between the URIII and the Cassite periods. However, the city was the capital of the kingdom of Larsa, the dominant power across the sample area before the expansion of the Old Babylonian empire. We complement Heinrich's data by adding the Nur-Adad palace for the Larsa period based on Meyers (1997). Larsa was also an important city-state during the Early Dynastic era. A large administrative building from the third millennium BCE has been recently identified (Meyers, 1997). We include this building in our dataset and we code it as a palace for the EDI, EDII and EDIII periods. For temples, we follow Heinrich (1982), with the only change being the extension of the life-span of the Samas temple to Neo Babylonian period (Meyers, 1997).

39. **Marad**: The city of Marad is not included in Heinrich's catalog. First attested in the Akkadian period, it never held political power over southern Mesopotamia but became an important religious center in the Old Babylonian period. We only add the Lugal-Marada temple between the Akkadian and the Cassite periods to the dataset (Bryce, 2009).

40. **Mashkan-shapir**: The city became an important commercial center during the Larsa period, and it was abandoned after the Old Babylonian era. The city is not included in Heinrich's catalog, but we add a temple for the Larsa and Old Babylonian periods based on Bryce (2009) and Stone and Zimansky (1994).

41. **Neriptum**: Also Nerebtum. The city is first attested in the Akkadian period and probably declined in the Old Babylonian period. Limited excavation works were carried out at the site. We rely on Heinrich who reports a temple and a secular building from the Old Babylonian period.

42. **Nina**: Nina was an important city of the kingdom of Lagash. The site is being currently excavated and it is not included in Heinrich's catalog. Settlement dates back to the Ubaid period, reached its peak in the EDIII period and declined probably in the URIII period (Bryce, 2009). We include two temples that were recently excavated, dating from the EDIII and URIII periods, respectively.[5]

43. **Nippur**: The city was an important religious center located in the middle of the sample area. We expand the data from Heinrich by adding a governor's palace from the Cassite period and a fort

[5] See http://www.tellsurghul.org/History.html, last accessed on 8/6/2020.

from the Parthian one. The excavated remains of Nippur's ziggurat and of the temple of Enlil were part of the larger Ekur complex (literally *the house is a mountain*). The structure belongs to the URIII period and was built by King Ur-Nammu; parts of an Akkadian layer were also found underneath. The Ekur complex remained operational until the Old Babylonian period. While the Early dynastic structure of the Ekur complex has not been found at present (as it was probably destroyed during the URIII reconstruction), textual evidence suggests that the complex existed since the early third millennium BCE, when the city started to play a central role in Mesopotamian politics as the center of diplomacy (conflict resolution and water management) and royal legitimation. The Ekur complex, therefore, appears to have been the center of Mesopotamian political life since the EDI period (Neumann, 2006). Throughout the city's history, the priesthood of the Enlil temple (possibly together with other temples) played a central role in the administration of the territory of Nippur, in particular, with respect to irrigation management and organization of the agricultural labor (Leick, 2002, p.159). We also increase the life-span of most temples reported in Heinrich (1982) so to last until the Parthian period, when the city declined (Meyers, 1997). Furthermore, we include the North and the Gula temples based on Meyers (1997). Despite showing continuous occupation from the Middle Uruk period, actual evidence of religious buildings on the site of the Inanna temple are attested from the EDI period only. New temples were subsequently built on top, until the last addition in the Parthian era. The Inanna temple was greatly expanded during the URIII, probably by Ur-Nammu, within the context of the renovation works implemented by the new dynasty of Ur. The Ninurta temple mentioned in clay tablets possibly coincides with the Gula temple.[6] Several large private houses were also excavated (Old Babylonian and Cassite periods), but these are not included in the dataset.

44. **Opis**: Also Upi. It was a city located on the Tigris, probably founded in the Isin period. It was abandoned by the end of the Achaemenid period. The site has been located but not excavated, so that data on buildings are missing for the entire period of occupation.

45. **Puzrish Dagan**: The city was founded in the URIII period ans served as a tax collection and logistic center of the URIII empire. The site has not been properly excavated, but there is no evidence of monumental buildings dating from the URIII period (Bryce, 2009).

46. **Saduppum**: Also Shaduppum. The city was an administrative center of the kingdom of Esnunna between the Larsa and Old Babylonian periods. We expand the life-span of the two temples reported in Heinrich (1982) back to include the Larsa period, when the kingdom of Esnunna was at the peak

[6]See http://cdli.ox.ac.uk/wiki/doku.php?id=nippur_mod._nuffar

of its power (Bryce, 2009). The city was then burnt to the ground in the Old Babylonian period, so no buildings survive after that period.

47. **Samarra**: The city is located outside of sample area and it is not included in Heinrich's catalog. It was built from scratch after the Islamic occupation of Mesopotamia and served as capital city of the Abbasid Caliphate during the Samarran period. We include all public buildings from this period, namely a mosque and three palaces, based on Stierlin (2002).

48. **Seleucia**: City founded in the Seleucid period. For a time, it served as capital of the Seleucid empire. It is located on the Tigris near Ctesiphon. The site is not included in Heinrich's catalog, but we incorporate data on the administrative buildings and temples for the Seleucid period only based on Invernizzi (1994).

49. **Shurrupak**: Modern Tell Fara. The city was the capital of an important city-state in the Early Dynastic era. It was destroyed at the end of the EDIII period and it is not included in Heinrich's catalog. Based on Martin (1988), we add a palace in the EDIII period and we include a temple between the EDIII and the Akkadian periods.

50. **Sippar**: Heinrich (1982) reports two large religious buildings, namely the Shamash Temple in the Ebabbar complex and a ziggurat, for the Neo Babylonian period. Meyers (1997) suggests that these buildings were only refurbished in the Neo Babylonian period, based on earlier structures dating back to the Akkadian one. Therefore, we code both buildings as in existence between the Akkadian and Neo Babylonian periods. The twin city of Der (also Sippar-Anunnitu) was located a few kilomers away of the main mound of Sippar. The two initially separated settlements grew in the Old Babylonian period so to merge into one large city. Thus we code Sippar as only one city in our dataset. Der was supposedly the center of the cult of Anunnitu, but several excavations campaigns have failed to locate the corresponding temple (Bryce, 2009). We therefore do not code any additional monumental buildings for Der.

51. **Tell Aqrab**: Also Tell Agrab. The city is of Ubaid foundation and witnessed a complete abandonment at the end of the EDIII period, followed by a temporary resettlement in the URIII and Larsa periods (Bryce, 2009). Heinrich (1982) reports the existence of two temples between the EDI and the EDIII periods.

52. **Tell Jemdet Nasr**: Important urban settlement, whose pottery style was used to name the homonymous archeological period. It probably played an important cultural role at the end of the 4th mil-

lennium BCE. Heinrich (1984) reports a palace from the Jemdet Nasr period, where a significant amount of administrative tablets was located. We also add a Parthian fort (Bryce, 2009).

53. **Tell Lahm**: Most southern city of the area, identified with the ancient city of Kissik. The site is not included in Heinrich's catalog and, despite its significant size, no monumental buildings have been located in different excavation campaigns (Bryce, 2009).

54. **Tell Ubaid**: The pottery style that was found at the site gave the name to the Ubaid period, employed in Mesopotamian chronology to designate the 5th millennium BCE. The large temple on platform (proto-ziggurat), which is reported by Heinrich (1982) for the EDIII period alone, is actually attested between the EDIII and URIII periods and we extent its life-span accordingly. While we know that the temple complex was refurbished under king Mesannipadda of Ur in EDIII and then by king Shulgi in URIII, its foundation date is uncertain (Meyers, 1997).

55. **Tell Uqair**: City located next to Tell Jemdet Nasr. Heinrich (1982) reports the existence of two temples and a proto-ziggurat (large temple on platform) dating between the Early Uruk and Jemdet Nasr periods.

56. **Ukbara**: City of Sassanian foundation, located on the Tigris North of Baghdad. No data on buildings.

57. **Ukhaidir**: Early Islamic fortress that served as royal residence for a short period of time during the Early Islamic period. We add a palace for the Early Islamic period (Michell, 1995, p.251).

58. **Umma**: The city is not included in Heinrich's catalog. Umma, however, played an important political role during the Early Dynastic era and recent archeological excavations confirm the presence of monumental buildings from this period (in particular at the Umm-al-Quarib site) (Bryce, 2009; Oraibi Almamori, 2014). We add two temples and a palace for the EDI, EDII and EDIII periods (Oraibi Almamori, 2014). The site was abandoned after the Old Babylonian period. The city of Umma was for some time incorrectly identified with the nearby site of Tell Jokha, which instead corresponded to the small satellite city of Kissa. Given their proximity, we code the two mounds as one city and attribute all public buildings to Umma (site of Umm-al-Quarib).

59. **Ur**: The city was continuously occupied between the Ubaid and the late Achaemenid periods. It features monumental buildings from several construction phases. The central political role that the city played throughout Mesopotamian history is reflected in the large number of monumental buildings that were located at the site. We rely on the very detailed catalog from Heinrich. We only improve on

Heinrich (1982) by extending the life-span of the Early Dynastic ziggurat to the Middle Uruk, Late Uruk and Jemdet Nasr periods. The Early Dynastic structure, in fact, was probably a refurbished version of a religious complex dating from the Uruk period that featured a proto-ziggurat with a temple on a high platform. The city and its buildings were probably destroyed in the Akkadian period by king Rimush (Bryce, 2009). The URIII dynasty made Ur the capital of a large empire and this prominent political status was coupled with ambitious construction plans. The visible remains of the monumental ziggurat date from the URIII era. Substantial destruction of public buildings occurred during the Elamite invasion of 2004 BCE (although the kings of Isin rebuilt most public buildings a few decades after) and following the rebellion against the Babylonian empire of 1750 BCE, when the city was attacked and destroyed in retaliation. Important refurbishment works of URIII religious buildings took place in the Cassite and Neo Babylonian periods, after which the city eventually declined and was abandoned. The archeological records allowed to identify only two royal/administrative palaces from the URIII period (Meyers, 1997).

60. **Uruk**: Heinrich provides a detailed description of the excavated buildings for the city of Uruk. The city remained important, albeit perhaps not as prominent, after the transition from the Late Uruk to the Jemdet Nasr and the Early Dynastic period. By contrast, population declined during the Early Dynastic II period. The city recovered in the Early Dynastic III period under king Lugalezi and declined again after his defeat against Sargon in the Akkadian period. Intensive construction plans (including a ziggurat on top of the Early Dynastic terrace) were implemented in the Ur III period. Monumental constructions continued until the Seleucid period. The Sassanian period marked the eventual decline and abandonment of the city (Bryce, 2009). We only make small adjustments on Heinrich (1982), for instance by extending the life-span of the Steinstift and Kalkstein temples to the Middle-Uruk period and the Ningizzidatemple to between the Middle Babylonian and the Neo Babylonian periods. Based on Meyers (1997), we add a cult-house for the Ubaid period, for which there is clear recent evidence. We also extend the life-span of the Eanna ziggurat to between the URIII (when it was built) and the Achaemenid periods. This building, in fact, was consistently refurbished after the URIII period, as opposed to what Heinrich (1982) suggests. The only gap corresponds to the Middle Babylonian period when the ziggurat decayed. The latter was then rebuilt by the Assyrians during the Neo Assyrian period (Meyers, 1997).

61. **Zabalam**: The city was founded in the Jemdet Nasr period and abandoned by the end of the EDIII one. It is not included in Heinrich's catalog. We add the Ishtar temple, attested between the Akkadian and Old Babylonian periods, to the dataset (Bryce, 2009). As the precise date of its foundation

is unclear, we set temples to missing between the Jemdet Nasr and the EDIII periods. The city was a dependency of the powerful city of Umma during the Early Dynastic era.

62. **Zibliyat**: City of Sassanian foundation, that reached its peak in the Early Islamic period, and located 20 km north of Nippur. No data on buildings.

References

Adams, R. M. (1965). *Land Behind Baghdad*. Chicago: University of Chicago Press.

Adams, R. M. (1974). *The Evolution of Urban Society: early Mesopotamia and prehispanic Mexico*. London: Weidenfeld and Nicholson.

Adams, R. M. (1981). *Heartland of cities*. Chicago: University of Chicago Press.

Algaze, G. (2008). *Ancient Mesopotamia at the Dawn of Civilization: the Evolution of an Urban Landscape*. Chicago: University of Chicago Press.

Beaulieu, P.-A. (2017). Palaces of Babylon and Palaces of Babylonian Kings. *Journal of the Canadian Society for Mesopotamian Studies 11-12*, 5–14.

Bryce, T. (2009). *The Routledge Handbook of the Peoples and Places of Ancient Western Asia: The Near East from the Early Bronze Age to the Fall of the Persian Empire*. Abingdon: Routledge.

Cline, E. H. and M. W. Graham (2011). *Ancient Empires: From Mesopotamia to the rise of Islam*. Cambridge: Cambridge University Press.

Cole, S. W. (1994). Marsh formation in the Borsippa region and the course of the lower Euphrates. *Journal of Near Eastern Studies 53*(2), 81–109.

Cole, S. W. and H. Gasche (1998). Second- and first-millennium BC rivers in northern Babylonia. In H. Gasche and M. Tanret (Eds.), *Changing Watercourses in Babylonia*, pp. 1–64. Ghent: University of Ghent.

Cole, S. W. and H. Gasche (2007). Documentary and other archaeological and environmental evidence bearing on the identification and location of the rivers of lower Khuzestan and the position of the head of the Persian Gulf ca. 1200 BC-200 AD. *Akkadica 128*, 1–72.

Gasche, H., M. Tanret, S. W. Cole, and K. Verhoeven (2002). Fleuves du temps et de la vie Permanence et instabilité du réseau fluviatile babylonien entre 2500 et 1500 avant notre čre. *Annales. Histoire, Sciences Sociales 57*(3), 531–544.

Gibson, M. (1972). *The city and area of Kish*. Miami: Field Research Projects.

Heinrich, E. (1982). *Die Tempel und Heiligtümer im alten Mesopotamien: Typologie, Morphologie und Geschichte*. Berlin: de Gruyter.

Heinrich, E. (1984). *Die Paläste im alten Mesopotamien*. Berlin: de Gruyter.

Invernizzi, A. (1994). Hellenism in Mesopotamia. A view from Seleucia on the Tigris. *Al-Rafidan, XV*, 1–24.

Lafont, B., A. Tenu, F. Joannes, and P. Clancier (2017). *La Mésopotamie. De Gilgamesh à Artaban 3300-120 av. J.-C.* Paris: Belin.

Le Strange, G. (1905). *The lands of the eastern Caliphate: Mesopotamia, Persia, and central Asia, from the Moslem conquest to the time of Timur*. Cambridge: Cambridge University Press.

Leick, G. (2002). *Mesopotamia : the invention of the city*. London: Penguin.

Martin, H. P. (1988). *Fara: a reconstruction of the ancient Mesopotamian city of Shuruppak*. Birmingham: Chris Martin.

Meyers, E. (Ed.) (1997). *The Oxford Encyclopedia of Archaeology in the Near East. 5 Volumes*. Oxford: Oxford University Press.

Michell, G. E. (1995). *Architecture of the Islamic world : its history and social meaning*. London: Thames and Hudson.

Morozova, G. (2005). A review of Holocene avulsions of the Tigris and Euphrates rivers and possible effects on the evolution of civilizations in lower Mesopotamia. *Geoarchaeology 20*(4), 401–423.

Neumann, H. (2006). Nippur.

Nissen, H. J. (1988). *The early history of the ancient Near East, 9000-2000 B.C.* Chicago: Chicago: Chicago University Press.

Oraibi Almamori, H. (2014). The Early Dynastic monumental buildings at Umm al-Quarib. *Iraq 76*, 149–187.

Paepe, R. (1971). Geological approach of the tell ed-der area, mesopotamian plain, iraq. In *Tell ed-Der I*, pp. 9–27. Louvain: Editions Peeters.

Podany, A. H. (2013). *The Ancient Near East: A Very Short Introduction*. Oxford: Oxford University Press.

Roaf, M. (1990). *Cultural atlas of Mesopotamia and the ancient Near East*. New York: Facts on File Inc.

Stierlin, H. (2002). *Islam: early architecture from Baghdad to Cordoba*. Köln ; London: Taschen.

Stone, E. and P. Zimansky (1994). The Tell Abu Duwari Project, 1988-1990. *Journal of Field Archaeology 21*(4), 437–455.

van de Mieroop, M. (2015). *A History of the Ancient near East, Ca. 3000-323 BC*. New York: John Wiley and Sons.

Verkinderen, P. (2015). *The Waterways of Iraq and Iran in the Early Islamic Period: The Changing Rivers and Landscapes of the Middle East*. London: IB Tauris.

War Office (1911). *Lower Mesopotamia. Between Baghdad and the Persian Gulf (Map)*. London: Great Britain.