CONFOEDERATIO,
RESEARCH DIVISION (CRD).

EOSCALA 1.0/VELKSCALA 0.5:

A Gridded Reconstruction of Global GDP (PPP) and Population from 10000BC to the Present.

9 March 2025 - Aust Kätzchen | austkatzchen.confoederatio@gmail.com

Abstract.

This project aims to add tooling, databases, and improved techniques for global demographic and economic change over the long run in a 5-arcminute resolution gridmap (4320x2160, WGS84 Equirectangular) from 10000BC to 2023AD, with original estimates for global population and GDP PPP (FY2000 International Dollars, 100s) per raster cell.

Both estimates were worked out from a HYDE-McEvedy hybrid database with manual adjustments and an OLS high-lambda Ridge Regression model trained on G-Econ (Kummu extended)/SEDAC data from 1990 to 2015AD. This was then worked backwards on demographic and land-use data to generate gridded base maps of potential economic activity. Resultant activity rasters were then adjusted to Nordhaus-De Long macroeconomic estimates, with Maddison (Rosés-Wolf adjusted) for regional scaling.

We present a release prototype of the accompanying model and all output data as a proof-of-concept, including Eoscala 1.0 for gridded GDP PPP and Velkscala 0.5 for gridded population estimates. Both Eoscala and Velkscala are encoded in 32-bit RGBA integer format.

Introduction.

Despite advancements in geospatial estimates of population, land use, and economics over the past 20 years, no exhaustive attempt has been made so far at producing a historical economic gridmap that can be used to inform developmental and historical studies. Such studies are often focused more on long-term ecology than on historical demographics and sociology, i.e. HYDE, Nordhaus, resulting in severe restrictions on gridded precision [1][2].

Given time constraints mean the model given is a prototype model using extant scientific and research literature data, and has not been fully synthesised to the level that it might should be in the future by running gridded population counterfactuals on other datasets in addition to manual urban and historical population adjustment. For instance, HYDE3.3 assesses Mainland China as having 14.475.479 inhabitants in 1AD, despite Han Dynasty censuses showing at least 57,67M inhabitants in 2AD [3]. This undercount is systemic, and especially pronounced amongst urban populations:

HYDE3.3 Urban Populations vs.
Mainstream Historical Estimates (1AD):

City	HYDE Population (1000s)	Estimated Population (1000s)	Discrepancy	Sources
Chengdu	3,225	250	77,519x	Modelski [4]
Luoyang	1,386	260	187,59x	Modelski [4]
Chang'an	1	246	246x	Modelski [4]
Kaifeng	1,297	100	77,101x	Modelski [4]
Taxila	0,557	150	269,299x	Modelski [4]
Madurai	1,833	50	27,277x	Chandler [5]
Pataliputra	2,808	100	35,613x	Modelski [4]
Vaishali	2,168	100	46,125x	Modelski [4]
Alexandria	0,623	400	642,054x	Chandler, Modelski [4][5]
Jerusalem	0,093	100	1075,268x	Chandler [5]
Seleucia	0,147	400	2721,088x	Modelski [4]
Rome	2,741	200	72,966x	Hanson & Ortman (City Proper), Storey, Chandler [5][6][7]
Caracol	0	100	N/A	Modelski [4]
Geomean Discrepancy:	-	-	168,569x, SD = 778,214	

Table 1. Urban population differences between HYDE and academic estimates.

The above data renders original HYDE urban estimates unusable in effect. To resolve this discrepancy, we have come up with a new population database (Velkscala 0.5) that renormalises HYDE populations to McEvedy for years before 1500AD, with manual weighting for pre-Columbian Amerindigenous populations and a fallback to base HYDE for Australian Aboriginal populations [8]. However, there is a silver lining in that there is great certainty about specific gaps in the model (see **Discussion**) in addition to methods for comprehensive redress at a later date.

Eoscala is internally consistent due to the use of scaling effects and Fermi approximation, with Rosés-Wolf adjusted Maddison being utilised for national-level GDP PPP distribution, and global GDP being adjusted to Nordhaus-De Long [9][10][11]. With the exception of 2000BC, and 10000BC (for which a proxy was used due to the lack of HYDE3.3 data for these years), all 32-bit RGBA rasters are attached below. They may be converted to their GDP (PPP) in 2000$ via the following equation:
$n = 16777216r + 65536g + 256b + a$, where n is the encoded value for each pixel.

Input Data and Wrangling.

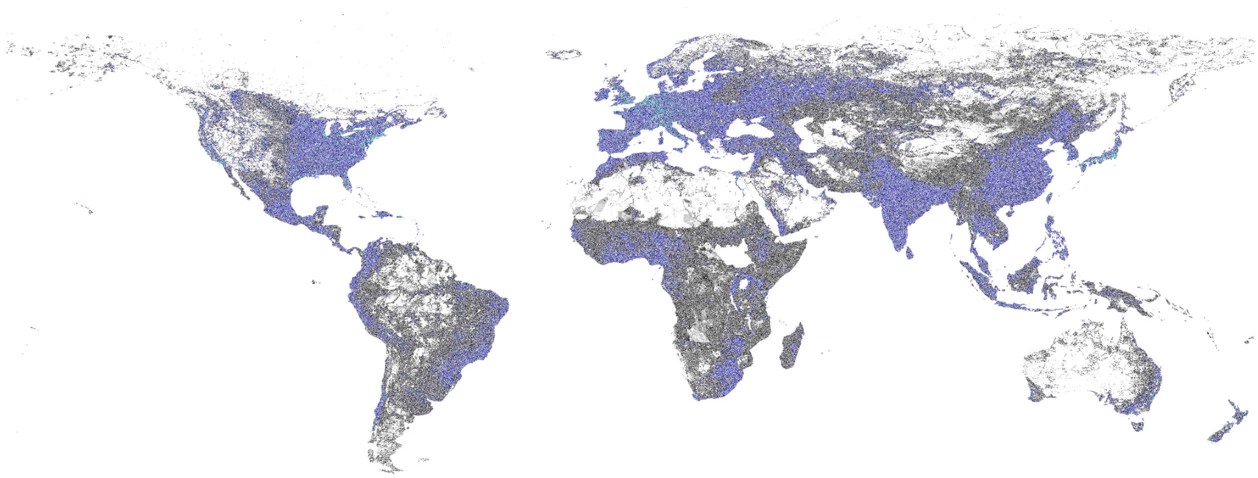

Figure 1. SEDAC, GDP PPP in FY2000 International Dollars, 100s (1990) [12].

Base input data were taken from SEDAC (G-Econ) and HYDE3.3 files respectively [13]. These were converted to .asc files, which were then converted to 32-bit positive integer rasters via $r = \frac{n}{2^{24}}\ mod\ 256,\ g = \frac{n}{2^{16}}\ mod\ 256,\ b = \frac{n}{2^{8}}\ mod\ 256,\ a = n\ mod\ 256$, where n is the integer value to encode, with the same process being applied to both historical land use and population datasets. SEDAC data was converted from 2011$ to FY2000 International Dollars by taking the World Bank deflator per national jurisdiction and applying relevant scalars [13].

For Velkscala 0.5, a raster map was derived from subdivisions mentioned in McEvedy and Jones' *Atlas of World Population History*, and all annotated population data points given attached to JSON files with corresponding RGB IDs and internal country keys [8]. To overlap them with HYDE years, cubic spline interpolation was applied for interceding years from 1AD to 1500AD as follows:

$y_q = max(y_{prev}, min(e^{S(x_q)}, y_{next})),\ \varepsilon = 10^{-6}$, where $S(x)$ is the cubic spline interpolant of log-transformed values in log-space. For global GDP (PPP) scalars, fallback linear interpolation was used to avoid redundant values during the cubic spline interpolation process. Post-1990, data was taken from the World Bank on Global GDP (PPP) in current international dollars, and converted to 2000$ [14].

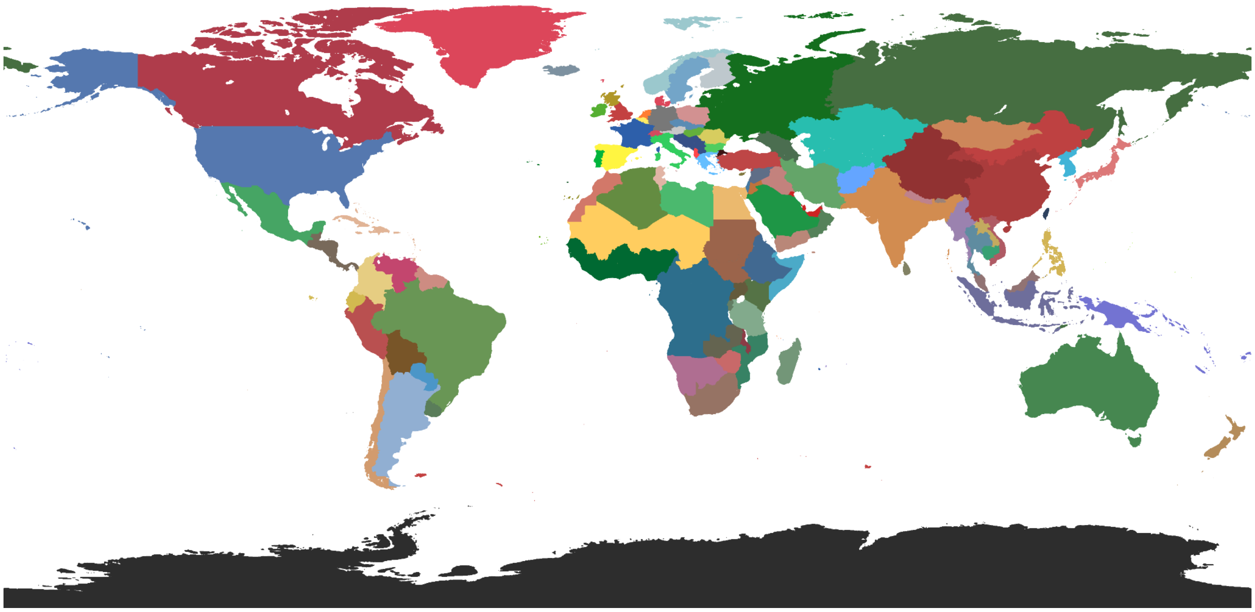

Figure 2. McEvedy Raster Subdivisions.

Velkscala 1.0 in its current form is effectively a hybridised dataset from HYDE (post-1500AD) and McEvedy and Jones (pre-1500AD). Individual estimates for indigenous populations were scaled as follows:

Country/Region	Geomean Scalar (from McEvedy)	Pop. Estimates (Millions)	Sources
Canada	3,8x	(Northern America): 3,79; 3,44; 3,5; 7, 2,5; 3,8	Denevan, Snow, Alchon, Thornton, Peros, Milner [15][16][17][18][19][20]
Caribbean	9,167x	3; 2,5	Denevan, Alchon [15][17]
Central America	6,953x	5,625; 5,5	Denevan, Alchon [15][17]
Continental USA	3,4174x	(Northern America): 3,79; 3,44; 3,5; 7, 2,5; 3,8	Denevan, Snow, Alchon, Thornton, Peros, Milner [15][16][17][18][19][20]
Mexico	6,953x	5,625; 5,5	Denevan, Alchon

			[15][17]
Australia and New Zealand	-	-	HYDE3.3 [13]

Table 2. Native American and Aboriginal population underweighting in McEvedy and Jones.

We would like to warn that Velkscala 1.0, unlike Eoscala, is not currently self-consistent due to time restrictions on current research. In terms of economic estimates, this issue was avoided by renormalisation to global GDP PPP estimates on base OLS Ridge Regression Model outputs. Additionally, 10000BC data was taken from Fermi approximated 9000BC data post-adjustment due to issues with HYDE artefacting during training.

To address the aforementioned urban underweighting, major population centres in Velkscala had their weight increased by their percentile distribution relative to the total population. This was done by taking their built-up urban area in km^2, with the maximum value being set to 100% of the relative total for each raster. Remaining urban areas were then assessed to the relative total in 0,5%-step resolution, and the end product was used as a multiplicative scalar.

Methodology.

Used datasets.

1. G-Econ/Kummu et al. (1990-2015) [12][21]

G-Econ is a spatially gridded map of global GDP PPP at 1-year intervals from 1990-2005 in its most recent iteration. The dataset was extended in 2018 to 2015 by Kummu et al. and its resolution increased from 1-degree resolution to a 5-arcminute resolution on WGS84 Equirectangular. The given datasets were deflated from 2011$ to 2000$ by World Bank jurisdiction (See **Input Data and Wrangling**).

2. HYDE3.3. [13]

HYDE is a mutually-compatible spatially explicit dataset for historical land-use patterns and population estimates. There exists a sizable discrepancy between reported regional and sum populations and summed individual cell populations as publicly accessible from Utrecht University (UU). It also excludes 2000BC, with relatively incompatible data for 10000BC.

3. McEvedy and Jones' *Atlas of World Population History* [8]

A well-known work in economic history, McEvedy and Jones provides historical roughball estimates at various jurisdictional levels for the following years: 400BC, 200BC, 1AD, 200AD, 400AD, 600AD, 800AD, 1000AD, 1100AD, 1200AD, 1300AD, 1400AD, 1500AD,

1550AD, 1600AD, 1650AD, 1700AD, 1750AD, 1800AD, 1850AD, 1875AD, 1900AD, 1925AD, 1950AD, 1975AD.

There exist significant rounding errors in McEvedy and Jones' work which has been much critiqued, alongside its underestimation of indigenous populations for which we were forced to perform manual adjustments. Cubic spline interpolation was then applied to the union set of all HYDE and McEvedy years between 1AD and 1500AD.

<u>4. Various GDP PPP Estimates.</u> [9][10][11][22]
Scalars derived from various historical GDP PPP estimates were used in finalising the gridded distribution of GDP PPP after OLS base model output. Normalisation between these estimates and post-1990 World Bank figures were drawn from OWID PPP adjustments, whilst 1990 to 2000 International Dollar conversions for Nordhaus, De Long, and Maddison + Kuznets were done by comparing World Bank SDR deflators instead (x1,2172) [13][14]. The same was done from 2021 International Dollars to 2000 International Dollars (x0,7012) [14].

This choice was deliberately made due to their scope as global datasets without clear national-level PPP weighting.

<u>4.1. Global Level.</u>
At the global level, output OLS rasters were scaled to Nordhaus due to the systemic underweighting of pre-modern GDP estimates in Maddison as noted by critics such as Cascio and Malanima, Federico, or Pritchett [23][24][25]. Though adjustment of the current Maddison Project to Rosés-Wolf yielded minimal adjustment (by $M = 7,3\%$ and $M_w = 3,1\%$ respectively), we have not yet incorporated further sourcing, i.e. Broadberry and Gupta, and aim to do so in the future.

<u>4.2. National Level.</u>
Data at the national level was taken from Rosés-Wolf adjusted Maddison post-conversion and retroactively applied after global scaling had already been done. This data was then renormalised by a second global scaling on output rasters, and was done only over the applicable domain (from first to last year for which input data existed), with bounded Newton polynomial interpolation between years.

<u>4.3. Subnational Level.</u>
Gridded subnational-level data was imputed from Eoscala's main OLS base model and formed a basis set of rasters prior to national-level and global-weighting (See **Methodology - OLS Model Training** for more information). This formed a gridmap

of regional economic activity without strict value assignments from which scaling could be applied. This is similar to the methodology of contemporary gridded economic estimates elsewhere [26].

OLS Model Training.

To create a gridded model of regional economic activity over time, an OLS Ridge Regression model, $\lambda = 10^9$, was set up and trained on various HYDE stocks from which it attempted to correlate resultant GDP (PPP) per cell in 2000$. This model was run over a yearly interval from 1990-2015, n=26, and the geometric mean of each coefficient taken to inform the final model. Multicollinearity was filtered out via a Variance Inflation Factor function and weighted down to eliminate redundancy.

HYDE Stock [13.1].	**Coefficient, 4-places, truncated.**	**Type** [13].
conv_rangeland (Converted Rangeland, km^2/cell)	0,7066	Land Use
cropland (Cropland, km^2/cell)	0,7919	Land Use
grazing (Grazing Land, km^2/cell)	0,9053	Land Use
ir_norice (Irrigated Non-Rice Cropland, km^2/cell)	1,0026	Land Use
ir_rice (Irrigated Rice Cropland, km^2/cell)	2,8066	Land Use
pasture (Pasture Area, km^2/cell)	46,3343	Land Use
rangeland (Rangeland Area, km^2/cell)	0,8791	Land Use
rf_norice (Rainfed Non-Rice Cropland, km^2/cell)	0,7924	Land Use
rf_rice (Rice Cropland, km^2/cell)	1,3376	Land Use
shifting (N/A)	0	Land Use
tot_irri (Irrigated Area, km^2/cell)	1,0028	Land Use
tot_rainfed (Rainfed Non-Rice Cropland, km^2/cell)	0,7975	Land Use
tot_rice (Rice Cropland, km^2/cell)	4,4205	Land Use
popc_ (Total Population, inh/cell)	168,538	Population

popd_ (Population Density, inh/km^2)	2,2039	Population
rurc_ (Rural Population, inh/cell)	14,573	Population
uopp_ (Built-Up Area, km^2/cell)	31.269,2372	Population
urbc_ (Urban Population, inh/cell)	58,2106	Population

Table 3. Base Model OLS coefficients per HYDE stock in terms of weighting potential economic activity.

Note that uopp_ produces exponentially more GDP PPP as it represents total built-up area (in km^2) rather than discrete demographic or land use values. It is possible that this factor is somewhat overweighted given the presence of urbanisation in informing modern economic value which may be corrected for by running rolling backwards inference models with informed growth functions, possibly distilled from Eoscala 1.0.

Cell weights were adjusted by the total land area of that cell excluding bodies of water. The base outputs of this model were taken as a proxy to inform the presence of potential historical economic activity on a global gridmap, which we refer to throughout this paper as the base model, or OLS model.

Gridded Economic Adjustment.

These weights were applied across the modified Velkscala dataset to inform centres of potential economic activity from which actual GDP could be deduced. The model was run over the years 10000BC to 1AD at 1000-year intervals, from 1AD to 1700AD at 100-year intervals, from 1700AD to 1950AD at 10-year intervals, and from 1950AD to 2023AD at 1-year intervals.

We had planned for the introduction of a rolling 10-year second-stage OLS model on Maddison data from 1820-1990 before the time domain of G-Econ, and to then infer its growth function via universal approximation theorems, but were unable to complete its training and computation in time given the challenging scope of the project. We leave this as a challenge to the reader until we are further able to pave over this gap.

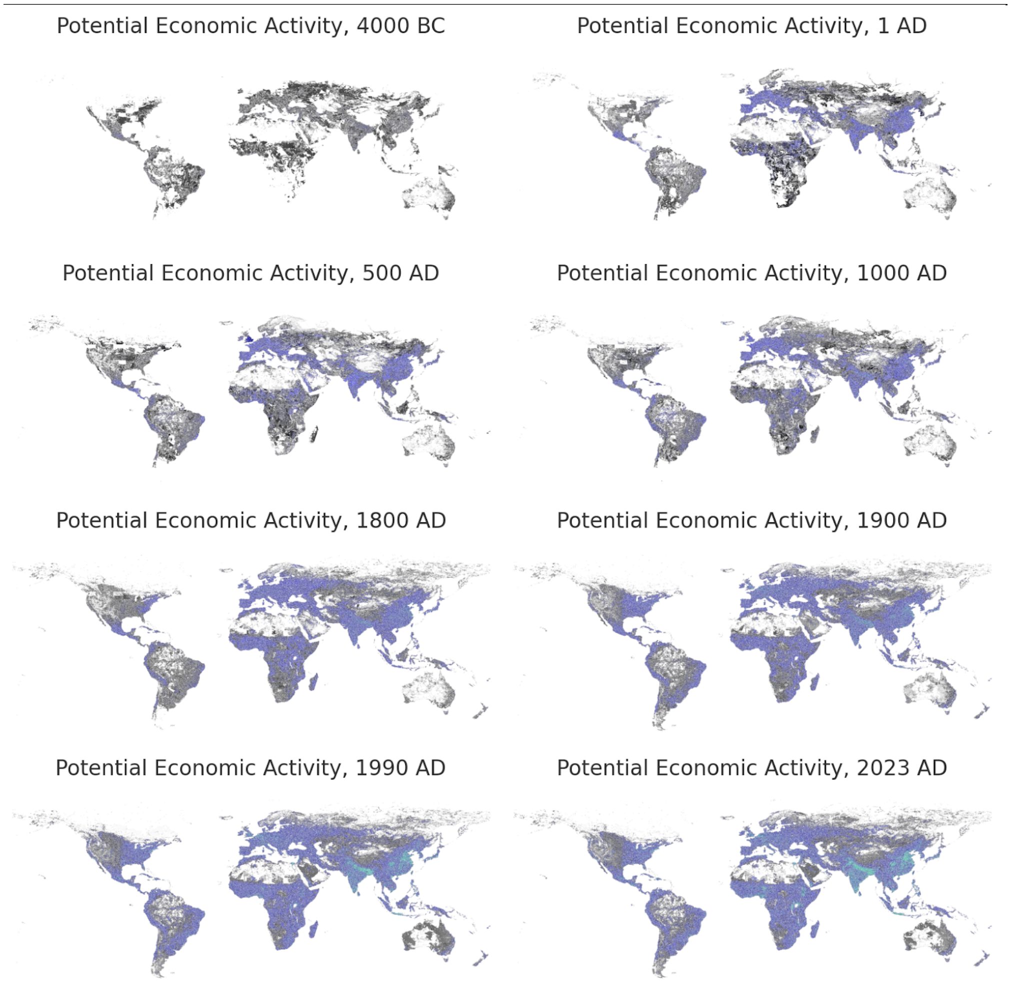

Figure 3. Gridmaps of Potential Economic Activity Over Time, 4000BC to 2023AD.

Because these rasters were not purely reflective of GDP PPP, Rosés-Wolf-Maddison scaling was applied at the national level, alongside global economic estimates to yield finished rasters. It should also be stated that there is a large discrepancy between GDP PPP and GDP nominal, particularly regarding the modern Indian Subcontinent, which has a PPP-nominal disparity ratio of nearly 3,751 for India and 4,019 for Pakistan in FY2024/2025 [27][28].

Though regionally accurate, these rasters have significant issues with pre-industrial urban economies, though this appears to normalise around 1800. Potential Economic Activity rasters are additionally attached in the Eoscala dataset and may be used as baseline proxies for additional economic datasets (i.e. poverty rate, median income) when combined with other gridded measures or statistical inference models.

Informed Estimates.

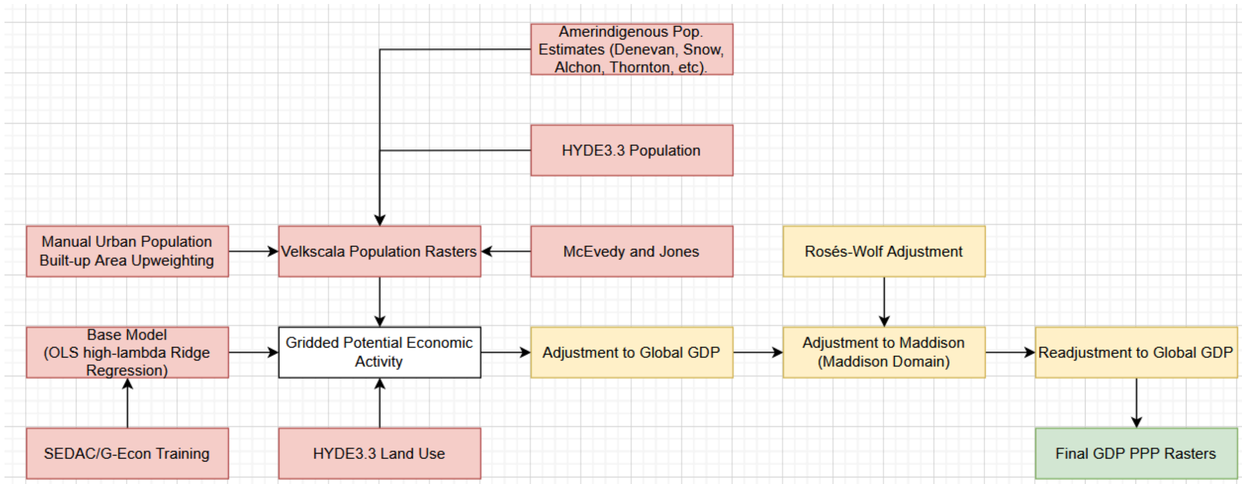

Figure 4. Diagrammatic Flowchart of Eoscala's Methodology.

Base model raster maps of potential economic activity were then weighted at the national level by Maddison, and at the global level to Nordhaus-De Long whilst being spatially informed at a subnational level, especially for years prior to 1AD. This process, where global estimates were first applied, then national estimates, then renormalised to global estimates was used to transform maps of potential economic activity into GDP PPP estimates per cell.

FY2000 International Dollars were chosen as the main measurement due to the depression of post-digital GDP service distortions given the dot-com boom that year, as 1990 International Dollars are believed to be over-inflated relative to the real economy [29]. The model also implicitly carries the assumption that built-up areas can serve as the principal proxy for urbanised GDP in both post-industrial economies as well as pre-industrial economies, an approach followed by Storey as well as Hanson & Ortman for cities in antiquity [5][6].

The relative lack of industrialisation during the pre-modern period also poses an epistemological question for the weighting of GDP PPP in urban areas, i.e. given that market towns and cities tended to be centres of commerce, particularly in terms of food distribution, which is believed to have often made up to 75% of mediaeval urban economies, and that consumers often came from other non-urban areas, should the relatively high spending on food be counted for in urban GDP PPP [30]? What of levies and taxes often imposed at city walls, such as the ferme générale or English custom duties, or other specialisms? We have decided that these impositions count, but opinions may vary.

Results.

The trends and estimates in both Eoscala and Velkscala appear to broadly align with later modern historiographic estimates of GDP by world region and population respectively. Some assumptions in the model are implicit, and we break down these major assumptions as follows:

1. Latin America (including Mesoamerica and the Caribbean) comprised a higher percentage of the world's population prior to the Bronze Age than had been estimated by McEvedy and Jones (Table 2) at ~19% of global population in 3000BC, with most modern historiographic estimates placing China at a contemporaneous population of ~2-2,1 million [31][32].
2. We also hypothesise that the relative technological equilibrium prior to the Bronze Age resulted in GDP figures reflective of agricultural activity and sedentism (i.e. in proto-cities) rather than complex trade routes, as Altaweel and Palmisano notes on roadways in the Ancient Near East: '... sites with many hollow ways (11 or more) and that are often larger suggests β is greater (0,23-0,72), but still sublinear' [33].
3. A Western Roman transition model is used rather than outright collapse, resulting in the continued, albeit, subdued growth of most economies at the local level (from $26,00B in 400AD to $36,01B in 800AD), with the continuation of many local institutions in line with modern historiography (i.e. the Kingdom of Odoacer, Carolingian Renaissance, the Papacy), in addition to relatively autonomous feudatories and the introduction of peasantry as Wickham and Caldwell suggest [34][35].

   Our modelling suggests a later GDP PPP decline for Europe between ~800-1350AD (from $38,01B to a low of $35,89B) during the Viking Era, Crusades, Mongol Conquests, and Black Death, before rebounding after the middle of the 14th century.

   It should be noted that there were significant improvements to European agricultural throughput by the Late Middle Ages (from ~10 to ~15 bushels of cereals per acre from 1250-1300) [36], though total economic throughput appears to be downweighted by the onset of the Little Ice Age and the relatively lesser impact of post-Roman urbanisation [37][38].

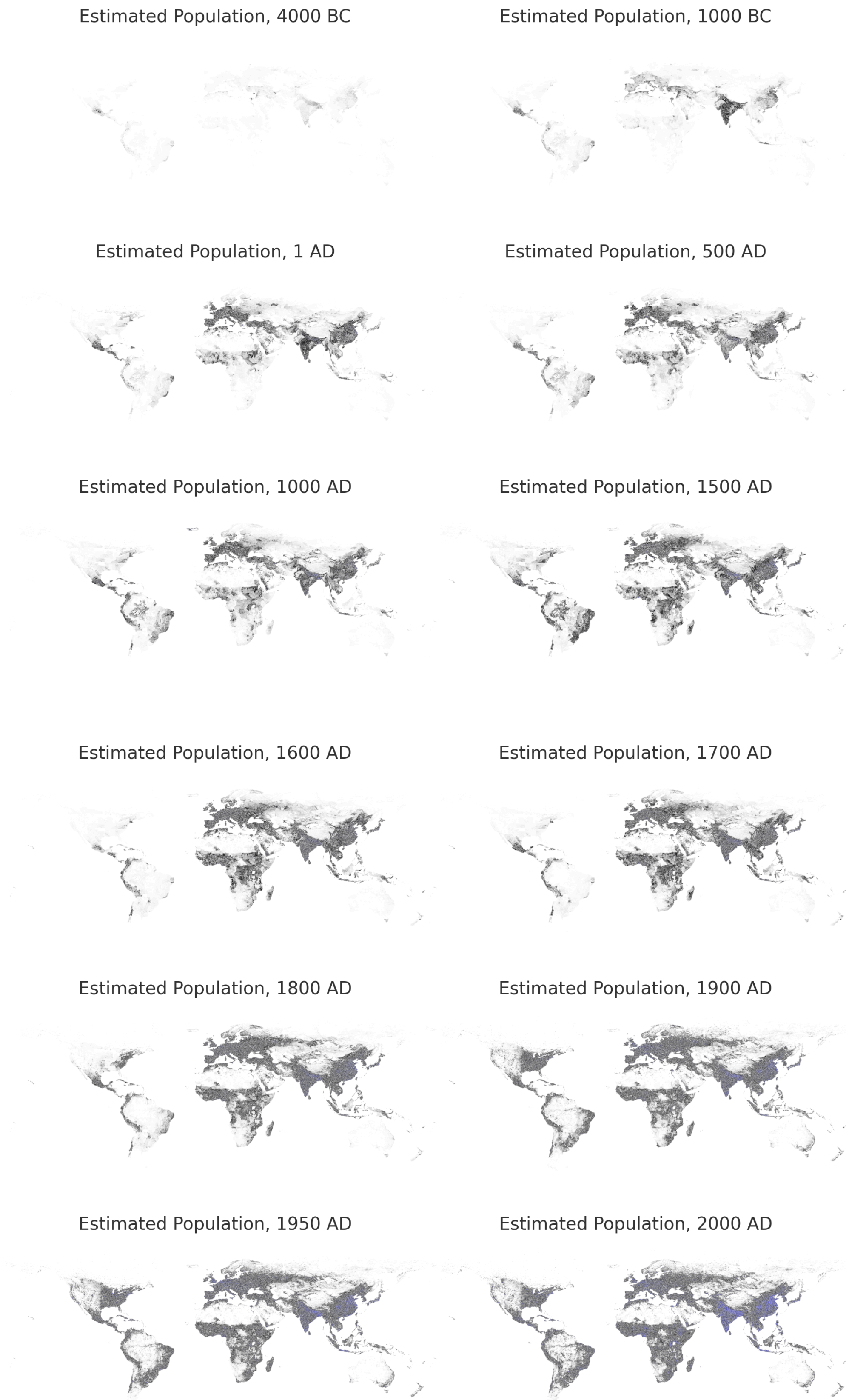

Figure 5. Estimated Velkscala population maps from 4000BC to 2000AD.

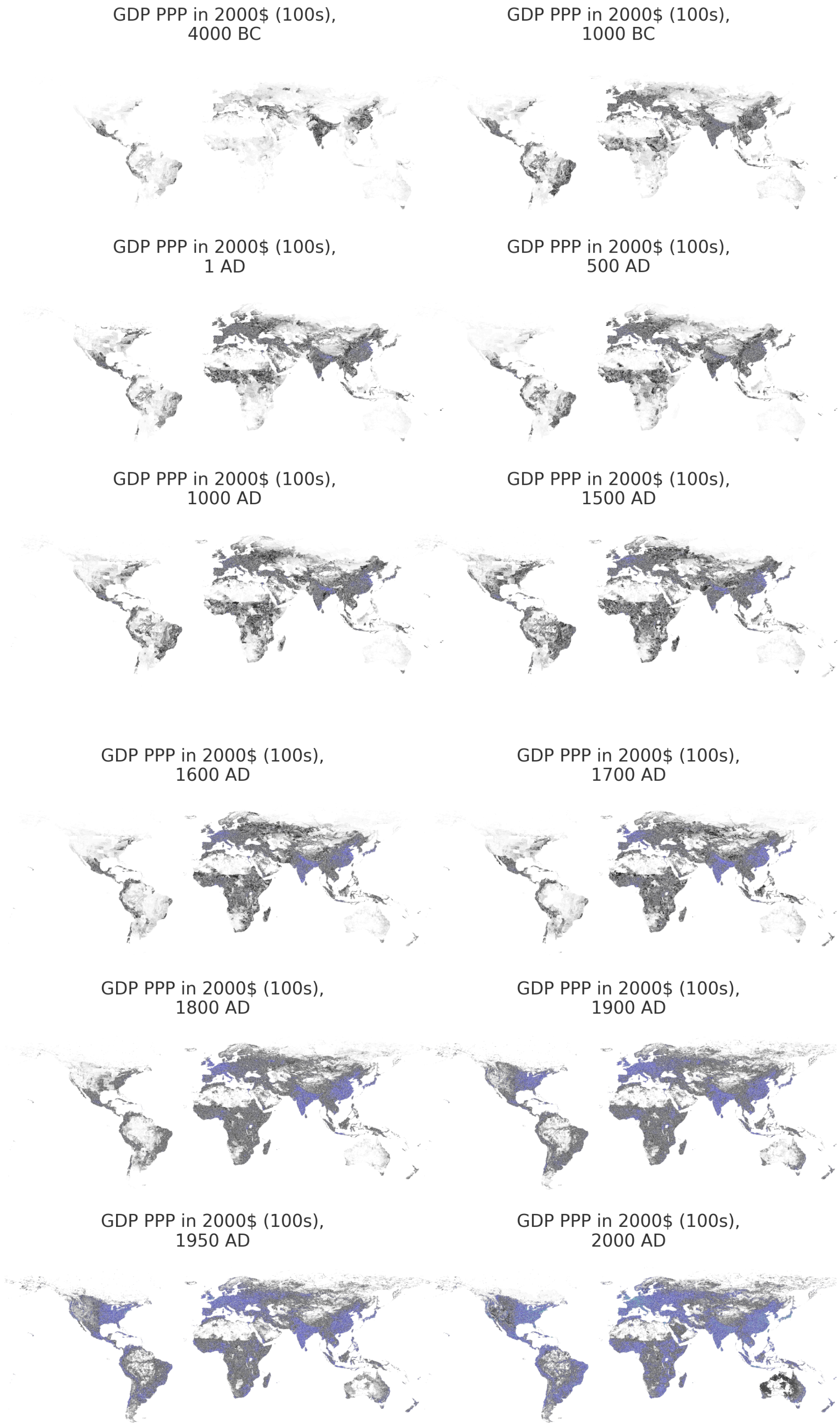

Figure 6. Estimated Eoscala GDP PPP maps from 4000BC to 2000AD.

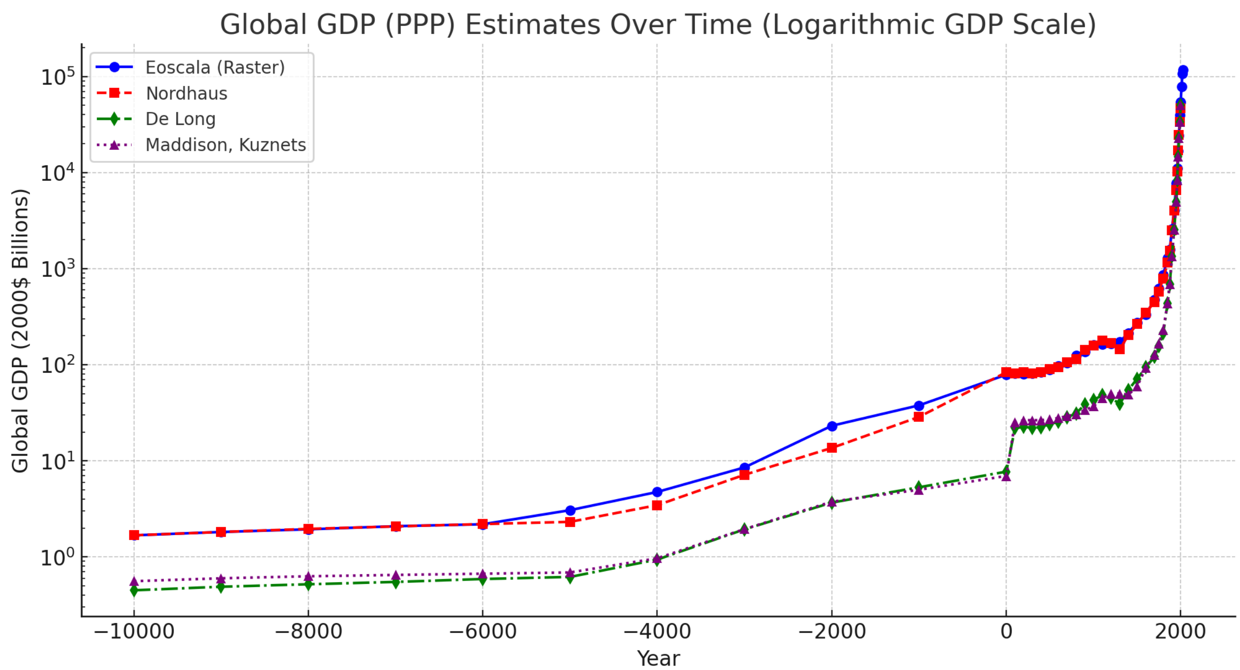

Figure 7. Long-term Eoscala Global GDP PPP estimates compared to other historical estimates.

Eoscala Global GDP (PPP) Estimates
(2000 International Dollars, Billions [Rounded], * = Linear Interpolation)

Year	**Eoscala (Raster)**	**Nordhaus** [13]	**De Long** [14]	**Maddison, Kuznets** [22]
10000BC	1,68	1,68	0,45	0,56
9000BC	1,82	1,82*	0,49*	0,60*
8000BC	1,94	1,96	0,52	0,63
7000BC	2,09	2,08*	0,55*	0,65*
6000BC	2,19	2,20*	0,59*	0,67*
5000BC	3,07	2,32	0,62	0,69
4000BC	4,75	3,46	0,94	0,97
3000BC	8,55	7,17	1,94	1,95
2000BC	23,19*	13,63	3,68	3,76
1000BC	37,82	28,66	5,31	5,01
1AD	78,87	83,56	7,73	6,97
100AD	81,19	81,20*	21,89*	25,07*
200AD	80,10	83,74	22,57	26,5
300AD	81,90	81,90*	22,07*	26,5*
400AD	83,96	83,25	22,44	26,5

500AD	88,73	89,95	24,25	27,19
600AD	97,90	94,20	25,39	27,90
700AD	104,74	105,86	28,53	29,29
800AD	124,45	115,27	31,07	30,69
900AD	137,36	143,04	38,56	33,75
1000AD	160,92	159,45	42,98	36,95
1100AD	164,26	178,82	48,20	44,63
1200AD	166,73	169,07	45,57	50,21
1300AD	173,03	144,92	39,06	50,21
1400AD	213,65	202,83	54,68	48,81
1500AD	275,29	264,91	71,41	59,28
1600AD	334,37	347,75	93,73	93,00
1700AD	474,69	450,67	121,47	127,40
1750AD	620,98	580,29	156,42	166,35
1800AD	865,62	791,30	213,30	230,05
1850AD	1.283,03	1.150,96	438,06	438,06
1875AD	1.588,03	1.528,90	691,45	691,45
1900AD	2.579,76	2.498,11	1.342,50	1.342,50
1925AD	4.048,87	4.008,20	2.559,58	2.559,58
1950AD	7.710,66	6.547,45	4.968,28	4.968,28
1960AD	10.982,95	10.263,04	8.344,05	8.344,05
1970AD	16.825,48	16.960,21	14.774,02	14.774,02
1980AD	24.387,46	24.541,67	22.905,39	22.905,39
1990AD	39.592,09	33.520,52	33.520,52	33.520,52
2000AD	54.445,52	46.595,92	49.924,56	49.924,56
2010AD	77.945,09	-	-	-
2020AD	107.611,41	-	-	-
2023AD	116.849,27	-	-	-

Table 4. Long-term Eoscala Global GDP PPP estimates compared to other historical estimates.

Eoscala Regional GDP Totals (PPP Estimates)
(2000 International Dollars, Billions [Rounded], * = Linear Interpolation)

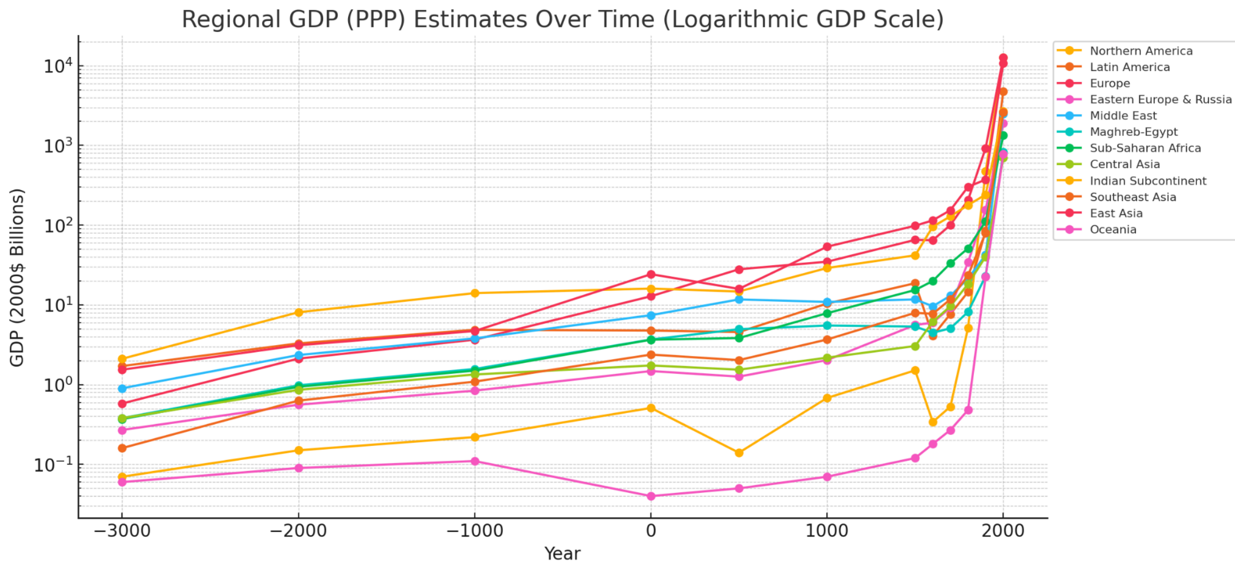

Figure 8. Estimates of Regional GDP PPP by Eoscala Region.

Region	-3000	-2000	-1000	1	500	1000	1500	1600	1700	1800	1900	2000
Northern America	0,07	0,15*	0,22	0,51	0,14	0,68	1,51	0,34	0,53	5,12	471,52	12.646
Latin America	1,71	3,29*	4,87	4,77	4,56	10,39	18,71	4,09	7,67	14,54	84,82	4.787
Europe	0,58	2,12*	3,66	12,84	27,98	34,79	65,39	64,70	100,39	206,15	926,45	12.613
Eastern Europe & Russia	0,27	0,56*	0,84	1,48	1,26	2,03	5,60	5,98	9,26	34,25	156,20	1.891
Middle East	0,90	2,35*	3,80	7,43	11,71	10,90	11,72	9,61	13,01	21,40	42,47	2.487
Maghreb-Egypt	0,38	0,98*	1,57	3,68	4,96	5,51	5,35	4,47	5,09	8,16	23,05	828,44
Sub-Saharan Africa	0,37	0,94*	1,50	3,66	3,84	7,87	15,37	19,94	33,20	51,22	111,42	1.334
Central Asia	0,38	0,86*	1,34	1,74	1,54	2,18	3,05	6,15	9,62	18,26	40,27	703,52
Indian Subcontinent	2,11	8,08*	14,05	16,02	14,72	29,00	41,83	95,73	128,90	178,27	241,74	2.687
Southeast Asia	0,16	0,63*	1,09	2,38	2,03	3,68	7,95	7,73	11,75	23,46	80,30	2.605
East Asia	1,54	3,12*	4,70	24,26	15,88	53,69	98,31	114,88	154,11	302,66	372,67	10.772
Oceania	0,06	0,09*	0,11	0,04	0,05	0,07	0,12	0,18	0,27	0,48	22,56	776,64

Table 5. Raw totals of Regional GDP PPP in FY2000 International Dollars, Billions.

Eoscala Regional GDP Percentages (PPP Estimates)
(2000 International Dollars, Billions [Rounded], * = Linear Interpolation)

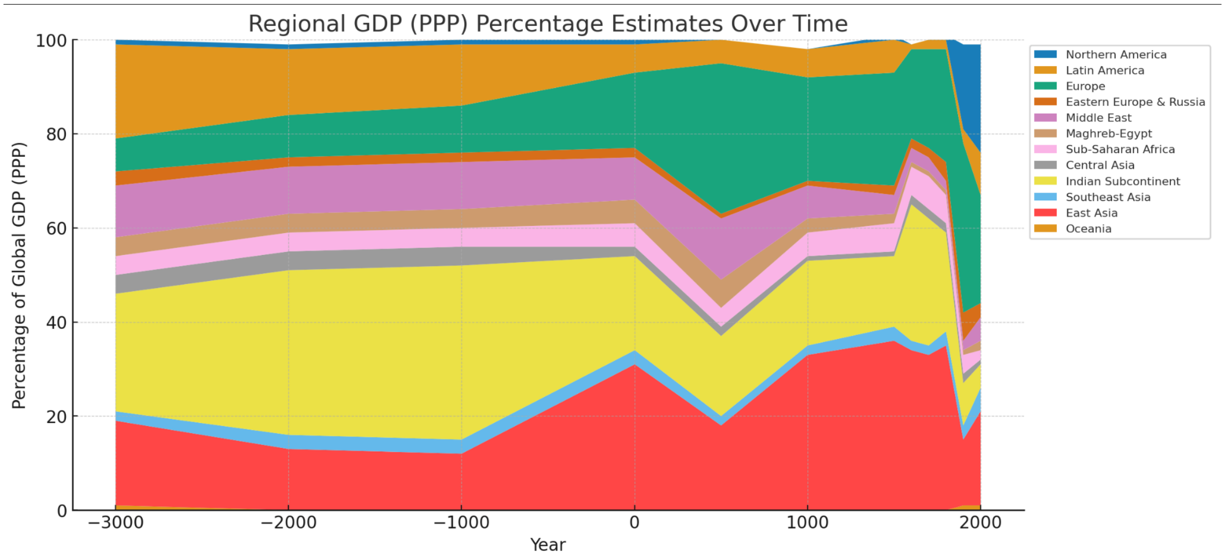

Figure 9. Regional GDP as a share of total Global GDP, 3000BC-2000AD.

Region	-3000	-2000	-1000	1	500	1000	1500	1600	1700	1800	1900	2000
Northern America	0,01	0,01*	0,01	0,01	0,00	0,00	0,01	0,00	0,00	0,01	0,18	0,23
Latin America	0,20	0,14*	0,13	0,06	0,05	0,06	0,07	0,01	0,02	0,02	0,03	0,09
Europe	0,07	0,09*	0,10	0,16	0,32	0,22	0,24	0,19	0,21	0,24	0,36	0,23
Eastern Europe & Russia	0,03	0,02*	0,02	0,02	0,01	0,01	0,02	0,02	0,02	0,04	0,06	0,03
Middle East	0,11	0,10*	0,10	0,09	0,13	0,07	0,04	0,03	0,03	0,02	0,02	0,05
Maghreb-Egypt	0,04	0,04*	0,04	0,05	0,06	0,03	0,02	0,01	0,01	0,01	0,01	0,02
Sub-Saharan Africa	0,04	0,04*	0,04	0,05	0,04	0,05	0,06	0,06	0,07	0,06	0,04	0,02
Central Asia	0,04	0,04*	0,04	0,02	0,02	0,01	0,01	0,02	0,02	0,02	0,02	0,01
Indian Subcontinent	0,25	0,35*	0,37	0,20	0,17	0,18	0,15	0,29	0,27	0,21	0,09	0,05
Southeast Asia	0,02	0,03*	0,03	0,03	0,02	0,02	0,03	0,02	0,02	0,03	0,03	0,05
East Asia	0,18	0,13*	0,12	0,31	0,18	0,33	0,36	0,34	0,33	0,35	0,14	0,20
Oceania	0,01	0,00*	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,01

Table 6. Regional GDP as a share of total Global GDP by Eoscala Region, rounded to 2 decimal places.

Conclusion.

'I take my estimates from Kremer (1993), but it would not matter if I had chosen some other authority'. - De Long, 1998

Both Eoscala and Velkscala offer relatively robust and novel statistical approaches towards the geospatial mapping of pre-industrial societies and economies. The project was done on a limited time budget of eight days by a single author, and as such, Velkscala 0.5 remains in beta with further manual corrections having to be done. In contrast, Eoscala 1.0 is internally consistent, comprehensive and reliable for research. The database and rasters given, alongside its accompanying code, are public on GitHub.

These databases are expected to be of particular use in historical demography, economics, anthropology, and sociology, and can be used to statistically ascertain the main drivers of historical economies and trade. Of particular interest would be the use of such similar gridded statistical models in testing various macroeconomic theories over the long run, particularly those offered by the Maddison Project Database (MPD) and HYDE by proxy. Despite the limitations given in this paper, Eoscala/Velkscala may also be seen respectively as the most comprehensive and statistically rigorous projects of their type.

Both Velkscala and Eoscala are expected to be maintained as projects beyond this date, with refactoring, statistical adjustment, visualisation, and novel ML techniques and distillation methods offering a large room for future improvement. All material is provided at https://github.com/Confoederatio/Eoscala-Velkscala.

Works Cited.

1. Klein Goldewijk, Kees, et al. "The HYDE 3.1 Spatially Explicit Database of Human-Induced Global Land-Use Change over the Past 12,000 Years." Global Ecology and Biogeography, vol. 20, no. 1, 11 Sept. 2010, pp. 73–86, https://doi.org/10.1111/j.1466-8238.2010.00587.x.
2. Barrage, Lint, and William D. Nordhaus. "Policies, Projections, and the Social Cost of Carbon: Results from the Dice-2023 Model." SSRN Electronic Journal, 2023, economics.yale.edu/sites/default/files/2024-03/barrage-nordhaus-2024-policies-projections-and-the-social-cost-of-carbon-results-from-the-dice-2023-model.pdf, https://doi.org/10.2139/ssrn.4413849.
3. Deng, Kent G. "Unveiling China's True Population Statistics for the Pre-Modern Era with Official Census Data." Population Review, vol. 43, no. 2, 2004, https://doi.org/10.1353/prv.2004.0014. Accessed 18 Sept. 2019.

4. Modelski, George. World Cities : 3000 to 2000. Washington, Dc, Faros. Copyright, 2000.
5. Tertius Chandler. Four Thousand Years of Urban Growth : An Historical Census. Lewiston, N.Y., St. David's University Press, 1987.
6. Hanson, J.W., and S.G. Ortman. "A Systematic Method for Estimating the Populations of Greek and Roman Settlements." Journal of Roman Archaeology, vol. 30, 15 Nov. 2017, www.cambridge.org/core/journals/journal-of-roman-archaeology/article/systematic-method-for-estimating-the-populations-of-greek-and-roman-settlements/32413192CB46847949394D750342B5D4. Accessed 9 Mar. 2025.
7. Storey, Glenn. "The Population of Ancient Rome." Antiquity, vol. 71, no. 274, 7 Apr. 1997, www.cambridge.org/core/services/aop-cambridge-core/content/view/BACD7DF32B0B77609CD6713B8AF88882/S0003598X00085859a.pdf/the-population-of-ancient-rome.pdf, https://doi.org/10.1017/S0003598X00085859. Accessed 9 Mar. 2025.
8. McEvedy, Colin, and Richard Jones. Atlas of World Population History. Harmondsworth, UK; New York, NY, Penguin, 1978, archive.org/details/atlasofworldpopu0000mcev/page/42/mode/2up. Accessed 9 Mar. 2025.
9. Wolf, Nikolaus, and Joan Rosés. Rosés-Wolf Database on Regional GDP (Version 6, 2020). 3 Nov. 2022. Rosés-Wolf database on regional GDP (version 6, 2020), cepr.org/node/424487. Accessed 9 Mar. 2025.
10. Bolt, Jutta, and Luiten van Zanden. Maddison Historical Statistics. 18 Sept. 2024. Maddison Project Database 2023, www.rug.nl/ggdc/historicaldevelopment/maddison/?lang=en. Accessed 9 Mar. 2025.
11. Nordhaus, William D. "Traditional Productivity Estimates Are Asleep at the (Technological) Switch." The Economic Journal, vol. 107, no. 444, 1 Sept. 1997, pp. 1548–1559, https://doi.org/10.1111/j.1468-0297.1997.tb00065.x. Accessed 9 Dec. 2019.
12. Nordhaus, W.D. "Global Gridded Geographically Based Economic (G-Econ) Data Set, Version 4." SEDAC, 1 Jan. 2016, www.earthdata.nasa.gov/data/catalog/sedac-ciesin-sedac-spatialecon-gecon4-4.00, https://doi.org/10.7927/h42v2d1c. Accessed 9 Mar. 2025.
13. Goldewijk, Klein. History Database of the Global Environment 3.3. 4 Oct. 2023. HYDE3.3, public.yoda.uu.nl/geo/UU01/67UHB4.html. Accessed 9 Mar. 2025.
14. De Long, J. Estimates of World GDP, One Million B.C. - Present. 1998.
15. Cook, Noble David, and William M. Denevan. "The Native Population of the Americas in 1492." The Hispanic American Historical Review, vol. 57, no. 4, Nov. 1977, p. 723, https://doi.org/10.2307/2513496. Accessed 8 Mar. 2020.

16. Snow, D.R. “Setting Demographic Limits: The North American Case | CAA Online Proceedings.” Caaconference.org, CAA, 2025, proceedings.caaconference.org/paper/35_snow_caa_2000/. Accessed 9 Mar. 2025.
17. Suzanne Austin Alchon. A Pest in the Land : New World Epidemics in a Global Perspective. Albuquerque, Univ. Of New Mexico Press, C, 2003.
18. Thornton, Russell. “Native American Demographic and Tribal Survival into the Twenty-First Century.” American Studies, vol. 46, no. 3/4, 2005, pp. 23–38, www.jstor.org/stable/40643888.
19. Peros, Matthew C., et al. “Prehistoric Demography of North America Inferred from Radiocarbon Data.” Journal of Archaeological Science, vol. 37, no. 3, Mar. 2010, pp. 656–664, https://doi.org/10.1016/j.jas.2009.10.029. Accessed 14 Oct. 2019.
20. Milner, George R., and George Chaplin. “Eastern North American Population at Ca. A.D. 1500.” American Antiquity, vol. 75, no. 4, Oct. 2010, pp. 707–726, https://doi.org/10.7183/0002-7316.75.4.707. Accessed 24 July 2020.
21. Kummu, Matti, et al. “Gridded Global Datasets for Gross Domestic Product and Human Development Index over 1990–2015.” Scientific Data, vol. 5, no. 1, 6 Feb. 2018, https://doi.org/10.1038/sdata.2018.4. Accessed 7 Mar. 2020.
22. Kuznets, Simon. “Modern Economic Growth: Findings and Reflections.” The American Economic Review, vol. 63, no. 3, June 1973, pp. 247–258. JSTOR, www.jstor.org/stable/1914358, https://doi.org/10.2307/1914358. Accessed 9 Mar. 2025.
23. Lo, Elio, and Paolo Malanima. Ancient and Pre-Modern Economies GDP in the Roman Empire and Early Modern Europe. 2011.
24. Federico, Giovanni. “The World Economy 0–2000 AD: A Review Article.” European Review of Economic History, vol. 6, no. 1, 2 Feb. 2002, pp. 111–120, ideas.repec.org/a/cup/ereveh/v6y2002i01p111-120_00.html. Accessed 9 Mar. 2025.
25. Pritchett, Lant. “Divergence, Big Time.” The Journal of Economic Perspectives, vol. 11, no. 3, 1997, pp. 3–17, www.jstor.org/stable/2138181.
26. Wu, Nan, et al. “High-Resolution Mapping of GDP Using Multi-Scale Feature Fusion by Integrating Remote Sensing and POI Data.” International Journal of Applied Earth Observation and Geoinformation, vol. 129, 9 Apr. 2024, p. 103812, www.sciencedirect.com/science/article/pii/S1569843224001663, https://doi.org/10.1016/j.jag.2024.103812.
27. World Economic and Financial Surveys: World Economic Outlook Database. Oct. 2023. World Economic Outlook Database, www.imf.org/en/Publications/WEO/weo-database/2023/October/weo-report?a=1&c=001,998,&s=NGDPD,PPPGDP,PPPPC,PPPSH,&sy=2020&ey=2028&ssm=0&scsm=1&scc=0&ssd=1&ssc=0&sic=0&sort=country&ds=.&br=1. Accessed 9 Mar. 2025.
28. “GDP, PPP (Current International $) | Data.” Data.worldbank.org, data.worldbank.org/indicator/NY.GDP.MKTP.PP.CD?most_recent_value_desc=true. Accessed 9 Mar. 2025.

29. Kraay, Aart, and Jaume Ventura. "The Dot-Com Bubble, the Bush Deficits and the US Current Account." SSRN Electronic Journal, 2005, https://doi.org/10.2139/ssrn.860864. Accessed 31 Mar. 2019.
30. Keene, Derek. "Feeding Medieval European Cities, 600-1500." Institute of Historical Research, 1 Jan. 1998. Accessed 9 Mar. 2025.
31. Song Zhenhao. 夏商社會生活史. 1994.
32. Wang Yumin. 中国人口史. 1995.
33. Altaweel, Mark, and Alessio Palmisano. "Urban and Transport Scaling: Northern Mesopotamia in the Late Chalcolithic and Bronze Age." Journal of Archaeological Method and Theory, vol. 26, no. 3, 15 Oct. 2018, pp. 943–966, https://doi.org/10.1007/s10816-018-9400-4. Accessed 2 May 2021.
34. Pohl, Walter. "Chris Wickham, Framing the Early Middle Ages: Europe and the Mediterranean, 400–800. First Paperback Ed. Oxford and New York: Oxford University Press, 2006. Pp. Xxviii, 990; 13 Maps." Speculum, vol. 85, no. 2, Apr. 2010, pp. 481–483, https://doi.org/10.1017/s0038713410000813. Accessed 20 Nov. 2021.
35. Caldwell, Craig H. "The Transformation of the Roman World, C. 450–C. 550." Manchester University Press EBooks, 7 Dec. 2020, www.manchesterhive.com/display/9781526158222/9781526158222.00006.xml, https://doi.org/10.7765/9781526158222.00006. Accessed 9 Mar. 2025.
36. Apostolides, Alexander, and Stephen Broadberry. ENGLISH AGRICULTURAL OUTPUT and LABOUR PRODUCTIVITY, 1250- 1850: SOME PRELIMINARY ESTIMATES. 2008.
37. Sinclair, Paul J J, et al. The Urban Mind: Cultural and Environmental Dynamics. Uppsala, African And Comparative Archaeology, Department Of Archaeology And Ancient History, Uppsala University, 2010, pp. 277–294.
38. Michaels, Guy, and Ferdinand Rauch. "Resetting the Urban Network: 117-2012." The Economic Journal, vol. 128, no. 608, 24 May 2017, pp. 378–412, https://doi.org/10.1111/ecoj.12424. Accessed 23 Aug. 2019.