National Technical University of Athens
School of Civil Engineering
Department of Water Resources and Environmental Engineering

Issues of prosperity:

Stochastic evaluation of data related to environment, infrastructures, economy and society

G.-Fivos Sargentis
Ph.D. Thesis

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Stochastic evaluation of data related to environment, infrastructures, economy and society

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Issues of Prosperity:
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Ζητήματα Ευημερίας:
Στοχαστική αξιολόγηση περιβαλλοντικών, τεχνολογικών, οικονομικών και κοινωνικών δεδομένων

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Στην μνήμη του μακαριστού,
Γέροντά μου Γρηγορίου Ιερομονάχου

Contents

Preface

“γνώσεσθε τὴν ἀλήθειαν, καὶ ἡ ἀλήθεια ἐλευθερώσει ὑμᾶς”
Καινή Διαθήκη Κατά Ιωάννη 8.32

“ye shall know the truth, and the truth shall make you free”
New Testament, John 8:32

Eight years ago, Prof. Demetris Koutsoyiannis suggested me to begin this PhD thesis.

The topic was defined in 2015 and the research started in 2017 which coincides with my departure from the School of Architecture and I finally found myself in a creative environment under the guidance of Demetris Koutsoyannis, and also the cooperation of knowledgeable colleagues (Panayiotis, Any and Romanos); in this workplace I formulated the thoughts reflected in this PhD thesis.

This research started with the target to defend the dominant narrative of sustainability as I was fascinated by the small scale and I was considering that the support of this issue would be the originality of the thesis.

As Prof. Koutsoyannis is passionate with rationality, he demanded a systematic documentation from me, so I followed his prompting. Doing this research, in the processing of data collection, I was surprised when I found that many of them, although publicly available, are withheld by many reports as selected timeseries are chosen to suit in a dominant narrative.

As I went deeper and deeper in my research, it became clearer to me that many of the arguments of sustainable development had formed a "politically correct" perception even if there were not supported by evidence. I was shocked when I found out that in this narrative, the man has the role of a parasite that needs to be contained (overpopulation).

This work is targeting to human’s prosperity and I rationally processed various parameters and data that contribute to this direction. I have also used stochastic tools which were originally developed for this processing. In the case studies I explored, distinguishing several issues, I came up with specific suggestions. Finally, I argued that it is impossible to make progress for the humanity with misinterpretations that shape the current “politically correct” dominant narrative.

The PhD thesis is completed at this point; however, I would like to point out that my experiences on Mount Athos have shown me that prosperity is not limited to the material world, which is the subject of this thesis. People have the potential to live prosper when they meet their spiritual needs, which in the end, are probably more important than the issues addressed in this thesis.

Acknowledgments

I am grateful to my beloved wife Matina and my beloved daughters Maria-Artemis and Eleni-Angelina for their patience. This thesis is my apology for the time I did not spend with them doing my research. In addition, I thank my mother Eleni and my wife's parents, Dimitris and Chrysoula for supporting my family all these years.

I am grateful to the supervisor of this thesis, my beloved friend, mentor and professor Demetris Koutsoyiannis who guided this journey. The effects of my training under his supervising are obvious by the publications in scientific journals and the citations of my work as his student the past years. I have to note that my collaboration with Demetris was the most creative, luxury (in scientific terms) and happy (in cooperative relations) period in my career until now. As Demetris dedicated a lot of his personal time for my training, I am also thankful to his wife, my beloved friend Anna Patriciou for stealing his presence from her, at several times.

I am grateful to the late beloved friend, mentor, professor Themistocles Xanthopoulos; for our daily collaboration and the endless conversations we had for the presentation of his book "Requiem with Crescendo? Homo Sapiens the Ultimate Genus of Human" during the period of this thesis. In this context I defined my political way of thinking which was crucial for the formulation of this thesis.

I am also grateful to the late beloved friend, Giorgos Aidinis for our endless conversations. His thoughts had defined also my political way of thinking.

I am thankful to my university, the National Technical University of Athens (NTUA), which provides my salary and I had the time to complete this thesis. This research was also supported by two research projects of European Union (OPTARCH and ADDOPTML) which gave me the additional funding, new experiences, and the necessary background to complete it. I am thankful to EU for this support and I am mostly thankful to Prof. Nikos D. Lagaros which was the leader of these research projects. As Prof. Lagaros is also in the advisory committee in this thesis, I have to note that I had a wonderful and creative cooperation with him and I am grateful for that.

I would like to thank the third member of advisory committee, Prof. Kimon Hadjibiros, for his contribution and his helpful comments.

I would like to thank my beloved friends and colleagues Panayiotis Dimitriadis, Theano (Any) Iliopoulou. Our cooperation during this thesis was extremely creative and I had wonderful time with them as they are mature scientists. Even if I had already a PhD and I am about 15-20 years older than them, many times during this thesis I had the role of a student in front of them and I've learned many things from them. I would like to note that they are great teachers and I am thankful for their time and patience. I would also like to thank my beloved friend and colleague Romanos Ioannidis with whom I had a unique contact and wonderfool and creative cooperation.

I would like to thank Prof. Nikos Mamasis. Our enjoyable cooperation in the lesson "Laboratory for Humanitarian Studies" in the School of Civil Engineering was an inspiring issue which triggered this thesis.

I would like to thank the co-authors of the papers related to this thesis (alphabetically): Andreas Angelakis, Ioannis Bairaktaris, Michalis Chiotinis, John Christy, Panos Defteraios, Panayiotis Dimitriadis, Andreas Efstratiadis, Evangelia Frangedaki, Theano (Any) Iliopoulou, Romanos Ioannidis, Georgios Karakatsanis, Demetris Koutsoyiannis, Nikos Lagaros, Nikos Mamassis, Georgia-Konstantina Sakki, Paraskevi Siamparina, Stavroula Sigourou and Anastasios Tsonis. I would also like to thank the anonymous reviewers of the papers related to this thesis, and I own special thanks to Evangelia Frangedaki, Michalis Chiotinis and Theano (Any) Iliopoulou for English editing of this document.

I would like to thank Dr. Giuseppe Leonardo Cascella and Mr. Stefanos Camarinopoulos for their cooperation and the hospitality in their companies IDEA75 (Bari) and RISA (Berlin) during the research period in the frames of OPTARCH and ADDOPTML projects.

I would also like to thank the School of Architecture. Even if I had done my first PhD there and I've served as teaching stuff for several years, I've never felt as an organic part of this school. This was a critical element to take the decision to change the orientation of my career in my 40s moving to School of Civil Engineering and doing this thesis.

I would like to thank late Dr. Andreas Makris who had a significant role in the beginning of this thesis.

It is probably obvious from the Preface that a part of myself is rested constantly in Dochiariou Monastery in Mount of Athos even if some periods I do not often visit this place. I would like to thank the elders of Dochiariou Monastery as they have inspired my life. I am grateful for their prayers. I am especially grateful to the abbot, elder Amphilochios and prior-abbot, elder Gavriil for their guidelines, their holistic support in every part of my life and their prayers. In addition, I would like to thank my beloved friend Spyros Theofilatos who is also a precious link to the monastery.

In my beliefs, the issues of prosperity are not controlled by us. Therefore, I would like to close this chapter with the wish:

Υπεραγία Θεοτόκε, φύλαξον ημάς υπό την σκέπην σου.

Athens, 14 June 2022
G.-Fivos Sargentis

Notational conventions. The book follows the *Guidelines for the use of units, symbols and equations in hydrology*[I]. In turn, these guidelines are based on (i) the Système International (SI) brochure[II]; (ii) the ISO 80000-2 Standard, *Mathematical Signs and Symbols to Be Used in the Natural Sciences and Technology*; and (iii) Unicode Technical Report #25, *Unicode Support for Mathematics*.[III] We list some of the conventions here for the reader's convenience.

Physical dimensions and units

(a) All quantities are dimensionally consistent. In particular, arguments of functions such as exp( ) and ln( ) are dimensionless.
(b) We use s, min, h, and d for second, minute, hour and day respectively. We do not abbreviate week, month or year, which are non-SI units.[IV]
(c) Multiplication of units is indicated by a space, e.g. N m, and division either by negative exponents (e.g. m s^{-2}) or by use of the solidus (oblique line, e.g. m/s^2); however repeated use of the solidus (e.g. m/s/s) is not permitted.
(d) Prefixes of units such as M (mega = 10^6) and μ (micro = 10^{-6}) have no space between (e.g. μs, MW). According to the SI, the prefix for kilo is lower case k (e.g. km—K is the symbol of the kelvin).
(e) For areas and volumes, we use m^2 and m^3; the hectare (ha) and the litre (L) are also allowed in SI. A million m^2 is denoted as square kilometre (1 km^2 = 10^6 m^2). A million m^3 is denoted as cubic hectometre (1 hm^3 = 10^6 m^3—not 1 Mm^3 because 1 Mm^3 = 10^{18} m^3; note that in SI any power to a unit applies also to the prefix); a billion m^3 is denoted a cubic kilometre (1 km^3 = 10^9 m^3).
(f) All units are typeset in upright (Roman) fonts, not italic or bold.
(g) Numerals are also typeset in upright fonts. The symbol for the decimal marker is the dot. To facilitate reading, numbers are divided in groups of three using a thin space (e.g. 12 345.6). (Note that neither dots nor commas are permitted as group separators). A space is used to separate the unit from the number (e.g. 10 m).

Symbols and equations

(a) We prefer single-letter variables (if necessary, with subscripts, e.g. E_{RMS}) over multi-letter ones. Single-letter variables or parameters and user-defined function symbols are italic (e.g. x, Y, β, $f(x)$). Multi-letter variables, if cannot be avoided, are typeset in upright, not italic (e.g. RMSE).
(b) Common, explicitly defined, functions are not italic, whether their symbols are single-letter (e.g. $\Gamma(x)$ for the gamma function, $\mathrm{B}(y, z)$ for the beta function) or multi-letter (e.g. $\ln x$, $\exp(x + y)$).
(c) Textual subscripts or superscripts are not italic (e.g. x_{max}, T_{min} where 'max' and 'min' stand for maximum and minimum, respectively).
(d) Mathematical constants are upright (e.g. e = 2.718…, π = 3.141…, $\mathrm{i}^2 = -1$). Also, mathematical operators are upright (e.g. $\mathrm{d}x$ in integrals and derivatives, $\Delta\gamma$ for the difference operator on γ).
(e) Vectors, matrices and vector functions are bold and, for single-letter variables, italic. In particular, vectors are usually denoted with lower case letters (e.g. $\boldsymbol{x}$, $\boldsymbol{\omega}$ as vectors; $\boldsymbol{f}(\boldsymbol{x})$ as a vector function of a vector variable) and matrices with upper case letters (e.g. $\boldsymbol{A}$ as matrix; $\boldsymbol{AB}$ as the product of matrices $\boldsymbol{A}$ and $\boldsymbol{B}$, $\boldsymbol{A}^{\mathrm{T}}$ as the transpose of $\boldsymbol{A}$, $\det \boldsymbol{A}$ as the determinant of a square matrix $\boldsymbol{A}$).
(f) We use nested parentheses for grouping (e.g. $\ln(a\ (b + c))$ rather than $\ln[a\ (b + c)]$
(g) To distinguish between stochastic variables from regular variables we use the Dutch convention[V], i.e., we underline the stochastic variables. Further, we use the curly brackets for sets (e.g. $P\{\underline{x} \le x\}$ for a scalar x or $P\{\underline{\boldsymbol{x}} \le \boldsymbol{x}\}$ for a vector $\boldsymbol{x}$; note that the argument of probability (P) is a set, not a number).
(h) We use square brackets for expectations, variances and other operators on stochastic variables (e.g. $\mathrm{E}[\underline{x}]$, $\mathrm{var}[\underline{x}]$, $\mathrm{cov}[\underline{x}, \underline{z}]$; note that $\mathrm{E}[\underline{x}]$ is not a function of $\underline{x}$ and thus it should not be denoted as $\mathrm{E}(\underline{x})$.)
(i) Definitions by mathematical equations are denoted using the symbols '≔' and '≕' (e.g. to define c as the sum of a and b we write $c \coloneqq a + b$ or $a + b \eqqcolon c$).

[I] Prepared by D. Koutsoyiannis and H.H.G. Savenije, 2013, doi: 10.13140/RG.2.2.10775.21922

[II] Ninth edition, http://www.bipm.org/en/si/si_brochure/

[III] http://www.unicode.org/reports/tr25

[IV] We avoid 'a' for year, because in SI 'a' is the prefix atto, meaning 10^{-18}; also it is the symbol of an 'are', a non-SI unit whose multiple hectare is accepted in SI (1 a = 100 m^2; 1 ha = 100 a = 10^4 m^2 = 1 hm^2).

[V] Hemelrijk, J., 1966. Underlining random variables. *Statistica Neerlandica*, 20(1), pp.1-7.

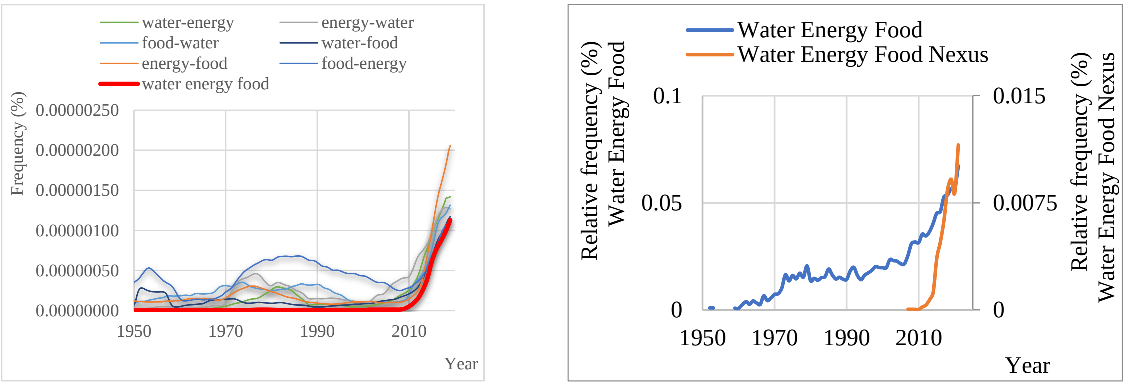
Εκτεταμένη Περίληψη

Γενικές αρχές

Οι ζωντανοί οργανισμοί κάνουν ένα πέρασμα από την ζωή αναζητώντας ευημερία στον υλικό κόσμο.

Υπάρχουν διαφορετικές αντιλήψεις για το τι σημαίνει ευημερία. Κάποιοι θεωρούν ότι σημαίνει χρήμα, άλλοι απολαύσεις, ενώ άλλοι αξιολογούν ως περισσότερο σημαντική την πνευματική ευημερία.

Προϋπόθεση για την κάθε μορφής ευημερία είναι η πρόσβαση των ανθρώπων στο πλέγμα νερού-ενέργειας-τροφίμων το οποίο είναι απαραίτητο για την επιβίωσή τους. Μολονότι το νερό, η ενέργεια και τα τρόφιμα μελετώνται ξεχωριστά σε βάθος χρόνου, ως πλέγμα μελετώνται μόλις τα τελευταία δέκα χρόνια.



(a) (b)

Εικόνα: (a) Συχνότητα εμφάνισης του πλέγματος νερού-ενέργειας και τροφίμων στο Googlebooks (b) Συχνότητα εμφάνισης του πλέγματος νερού-ενέργειας και τροφίμων στο Scopus.

Ενδιαφέρον έχει ότι τα τρία αυτά στοιχεία του πλέγματος, είναι εξαρτόμενα και αλληλοεπιδρούν μεταξύ τους. Αξιολογώντας τα δεδομένα παρατηρούμε ότι η αφθονία καθενός στοιχείου του πλέγματος, αυξάνει το προσδόκιμο ζωής και είναι απαραίτητή παράμετρος ευημερίας.

Όπως εύστοχα είχε παρατηρήσει ο καθηγητής Δ. Κουτσογιάννης (προσωπική επικοινωνία): τα χρήματα δεν δημιουργούν νερό, ενέργεια και τρόφιμα, τα χρήματα δημιουργούνται από το νερό, την ενέργεια και τα τρόφιμα. Δυστυχώς το σύστημα λήψεως αποφάσεων στον σύγχρονο κόσμο θέτει ως κρίσιμο κριτήριο τις οικονομικές παραμέτρους και την νομισματική πολιτική, φέρνοντας σε δεύτερη μοίρα την καλή λειτουργία του πλέγματος νερού, ενέργειας και τροφίμων.

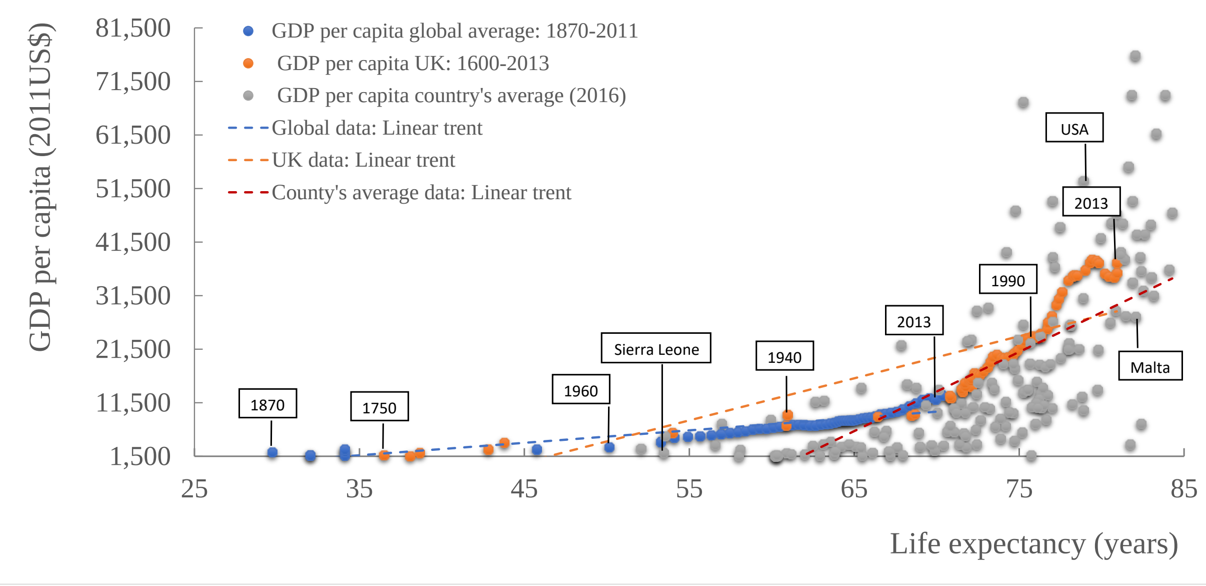
Στην παρούσα εργασία διερευνώνται ορθολογικά και με στοχαστικά εργαλεία, κρίσιμες παράμετροι ευημερίας ξεκινώντας από το πλέγμα νερού, ενέργειας, τροφίμων. Η εργασία επεκτείνεται σε κοινωνικές, οικονομικές, περιβαλλοντικές και πολιτισμικές παραμέτρους της κοινωνικής ζωής, όπως την δυναμική της συσσωμάτωσης/διασποράς την κοινωνική διαστρωμάτωση και την αισθητική ποιότητα του περιβάλλοντος.

Δομή της εργασίας

Κεφάλαιο 2

Στο κεφάλαιο 2 εξετάζονται οι παράμετροι ευημερίας

Ένας τυπικός δείκτης που αξιολογεί την ευημερία είναι το χρήμα το οποίο συνδέεται με την ανάπτυξη, τις υποδομές, την υγειονομική περίθαλψη και φαίνεται ότι όσο περισσότερα χρήματα έχουμε, έχουμε και μεγαλύτερο προσδόκιμο ζωής.

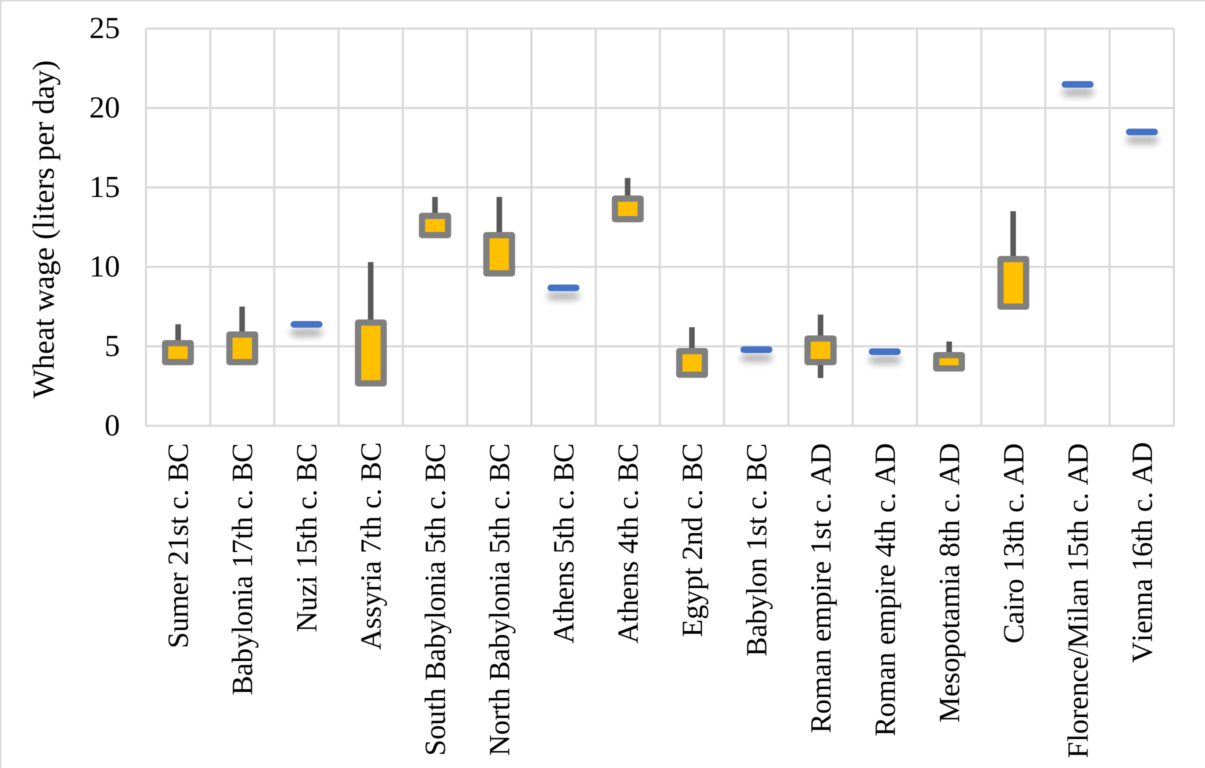


Εικόνα: Το προσδόκιμο ζωής συσχετισμένο με το ΑΕΠ ανά κάτοικο. Παγκόσμιος μέσος όρος (1870-2011). Μέσος όρος 172 χωρών (2016). Δεδομένα Ηνωμένου Βασιλείου (1600-2013).

Όμως εξετάζοντας την αρχετυπική μορφή του χρήματος, το χρυσό και το ασήμι, βλέπουμε ότι η ανταλλακτική τους αξία και ο λόγος συσχετισμού της τιμής τους, είναι εξαιρετικά ευμετάβλητος σε βάθος χρόνου. Ως εκ τούτου, το χρήμα δεν μπορεί να θεωρηθεί ένα ευσταθές μέτρο αποτίμησης πλούτου.

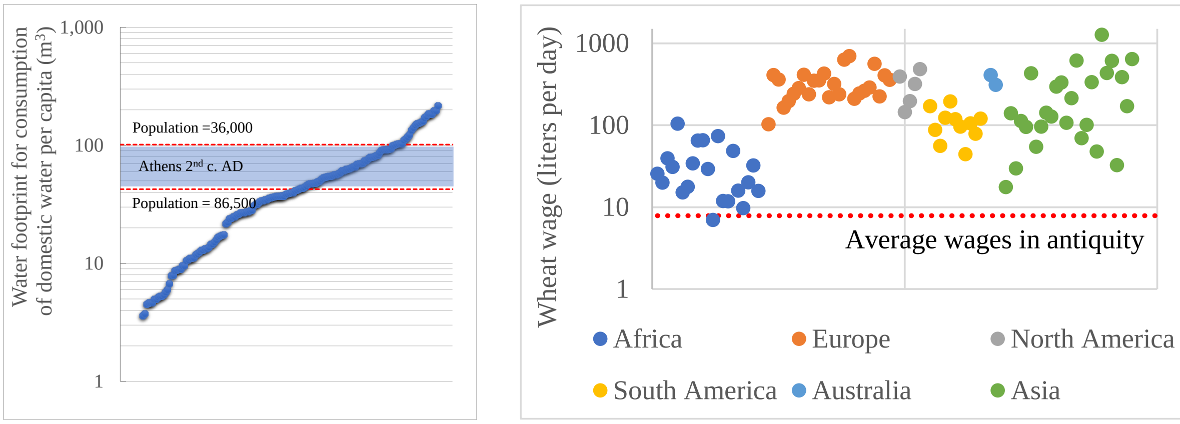
Από την ανάλυση αυτή, φαίνεται ότι μια σταθερή αξία αποτίμησης της ευημερίας είναι η πρόσβαση στο πλέγμα νερού, ενέργειας και τροφίμων που συσχετίζεται με το προσδόκιμο ζωής. Εξ αιτίας αυτής της σταθερής σχέσης, η σύγκριση του επιπέδου ζωής σε διάφορες φάσεις της ιστορίας, γίνεται με μια μέθοδο κατά την οποία ο ημερήσιος μισθός αντιστοιχείται σε λίτρα σιτάρι που είναι η διαχρονική βάση της διατροφής του ανθρώπου.

Επιγραφικά δεδομένα που έχουμε, μας δίνουν την εκτίμηση του πλούτου σε ένα πολύ μεγάλο ιστορικό εύρος των προ-βιομηχανικών κοινωνιών.



Εικόνα: Μέσο ημερήσιο ημερομίσθιο ανειδίκευτων εργατών στις προβιομηχανικές κοινωνίες.

Συσχετίζοντας τις συνθήκες που επικρατούσαν στην προσβασιμότητα των Αθηναίων του 2ουμ.Χ. αιώνα στα τρόφιμα και το νερό με την σημερινή εποχή, διαπιστώνεται ότι η ανθρωπότητα δεν έχει κάνει ουσιαστική πρόοδο αφού περίπου το ¼ της ανθρωπότητας ζει σήμερα με μικρότερη πρόσβαση σε αυτά.



(a) (b)

Εικόνα: (a) Αποτύπωμα της ετήσιας κατανάλωσης του οικιακού νερού κατ' άτομο στην αρχαία Αθήνα και σε διάφορες χώρες του σύγχρονου κόσμου. Τα μέσα ημερομίσθια στον σύγχρονο κόσμο και σε σχέση με το ημερομίσθιο την προβιομηχανική εποχή (λίτρα σιτάρι).

Ο μέσος πλούτος στις προβιομηχανικές κοινωνίες είναι της τάξης των 7.9 L/day που σήμερα αντιστοιχεί στα 2.37 USD/day λίγο μεγαλύτερο από τα 1.9 USD/day που θεωρείται το όριο της ακραίας φτώχειας.

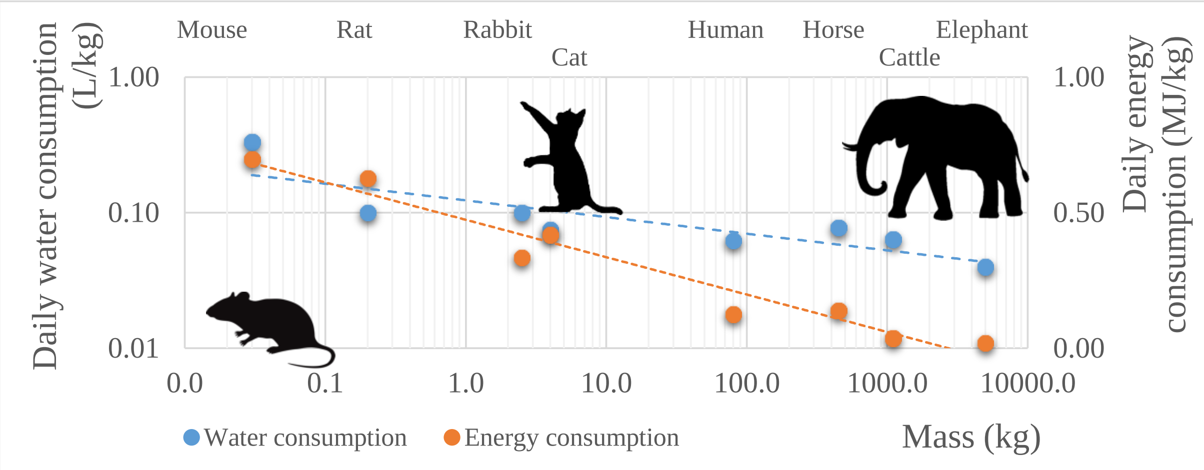
Τέλος, στο κεφάλαιο αυτό αναδεικνύεται ότι η αισθητική είναι και αυτή, παράμετρος ευημερίας. Κατά την διάρκεια της ιστορίας, έχουν προταθεί διάφοροι αισθητικοί κανόνες κυρίως στο θέμα των αναλογιών του ανθρωπίνου σώματος. Στην εργασία ποσοτικοποιείται η αισθητική αξιολόγηση έργων τέχνης αλλά και η αισθητική του τοπίου.

Κεφάλαιο 3

Στο κεφάλαιο 3 αναλύονται δύο βασικές παράμετροι της ευημερίας: η δυναμική της κοινωνικής συσσωμάτωσης/διασποράς και η κατανομή του πλούτου. Αυτά μπορούμε να πούμε ότι διαμορφώνουν την εξωτερική και εσωτερική δομή της κοινωνίας αντίστοιχα.

Αν δούμε την κοινωνία σαν οργανισμό, μπορούμε να θεωρήσουμε ότι η εξωτερική δομή της μορφολογίας περιγράφει την δυναμική της συσσωμάτωσης ενώ η εσωτερική δομή της μορφολογίας μπορεί να θεωρηθεί ότι είναι η διαστρωμάτωση.

Ακόμα και στους ζωντανούς οργανισμούς, τα δεδομένα που παρουσιάζονται δείχνουν ότι η δυναμική της συσσωμάτωσης δημιουργεί, κρίσιμες για την ανάπτυξη και αποτελεσματικές οικονομίες κλίμακας, αφού όσο μεγαλύτερος είναι ένας οργανισμός, τόσο περισσότερο οικονομικά (ως προς την κατανάλωση νερού και ενέργειας) συντηρεί την μάζα του.



Εικόνα: Κατανάλωση νερού και ενέργειας σε διάφορα είδη ζωντανών οργανισμών ανά μέτρο μάζας.

Ενώ φαίνεται πως η συσσωμάτωση είναι και στην φύση μια διαδικασία που οδηγεί σε οικονομίες κλίμακας, η διασπορά είναι μια μέθοδος προστασίας και σ' αυτήν οφείλεται η επιβίωση των μικρών θηλαστικών την περίοδο της εξαφάνισης των δεινοσαύρων.

Οι δυναμικές που παρατηρούνται στο περιβάλλον, παρατηρούνται και στην κοινωνία ενώ όσον αφορά την εσωτερική δομή της κοινωνίας, αυτή θεωρείται ότι διαμορφώνεται από την κατανομή του πλούτου και την κοινωνική διαστρωμάτωση.

Κεφάλαιο 4

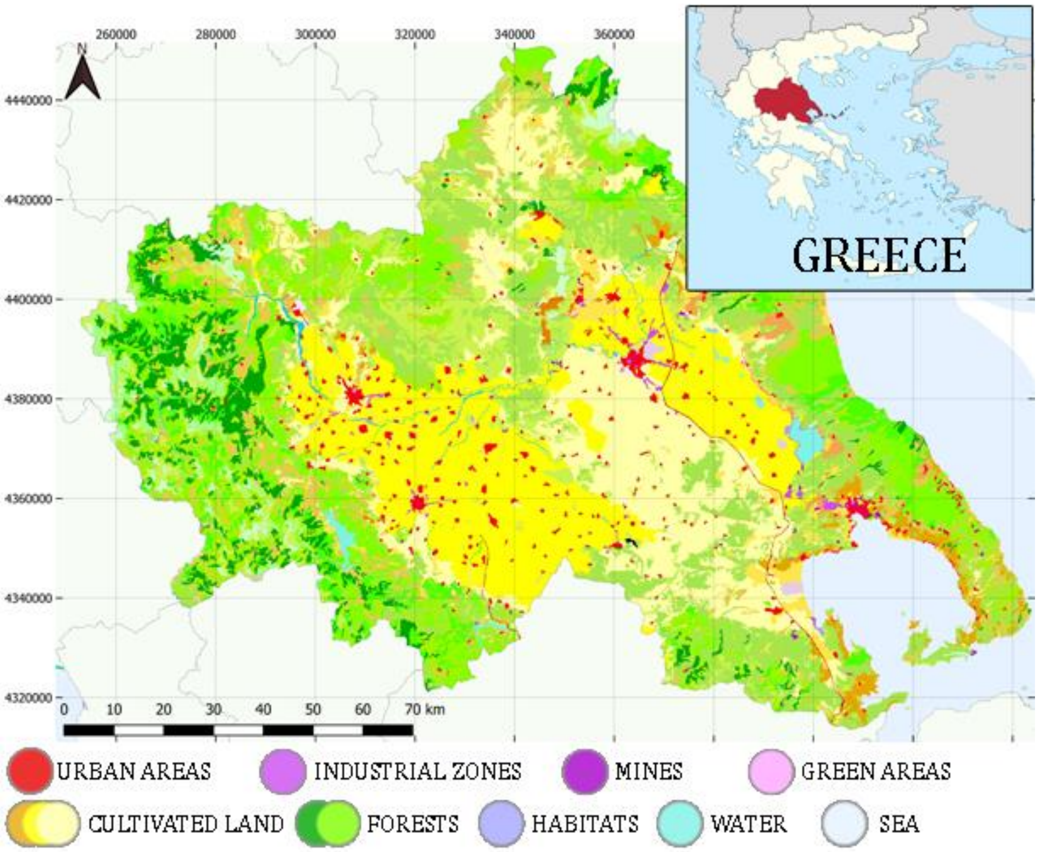
Στο κεφάλαιο 4 διατυπώνονται τα πρωτότυπα στοχαστικά εργαλεία που αναπτύχθηκαν στα πλαίσια της εργασίας. Τα εργαλεία αυτά επιλύουν:

a) Την μελέτη των συσσωματωμάτων στο επίπεδο
b) Την ποσοτικοποίηση της εξέλιξης των συσσωματωμάτων
c) Την κατανομή του πλούτου στην κοινωνία και την δυναμική της ευστάθειάς της καθώς και της εσωτερικής δομής της μέσω της εντροπίας της Φ και του εντροπικού δείκτη ανισότητας Φ_μ.

Με τα στοχαστικά εργαλεία που παρουσιάζονται στο κεφάλαιο 4, εξετάζονται οι μελέτες περίπτωσης στα κεφάλαια 5 έως 8.

Κεφάλαιο 5

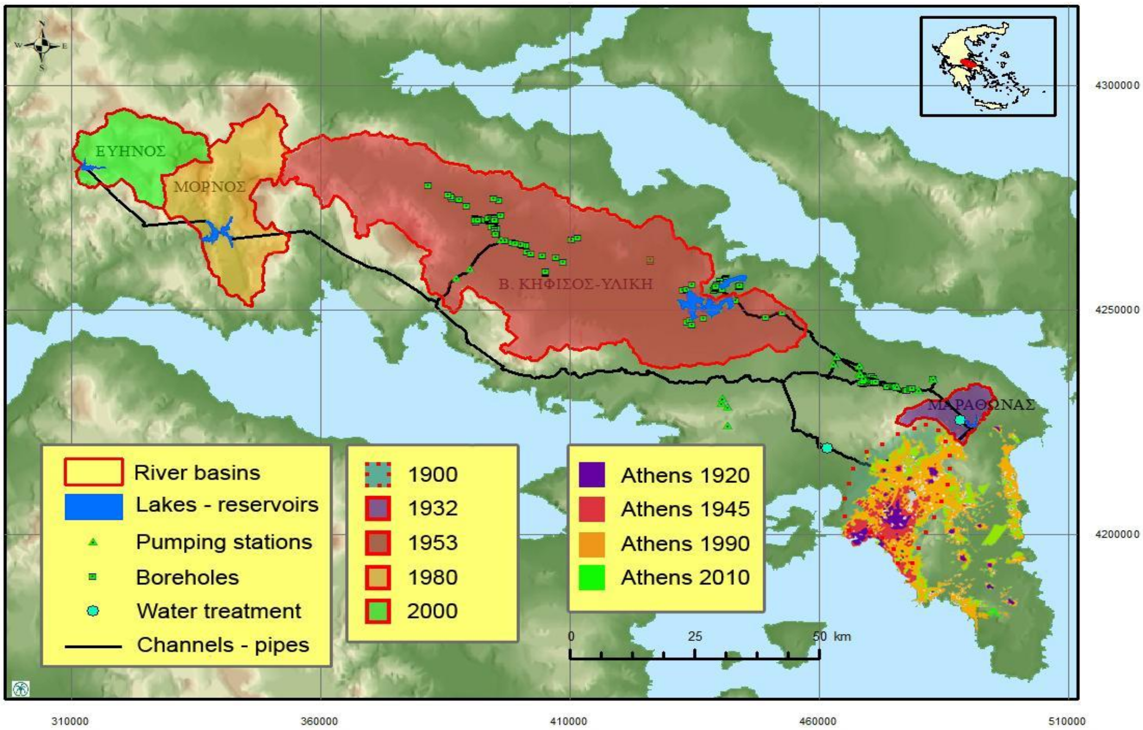
Στο κεφάλαιο 5 περιγράφονται οι σχέσεις αλληλεξάρτησης στο πλέγμα νερού, ενέργειας και τροφίμων αναδεικνύοντας την δυναμική τους μέσω του συσχετισμού παραμέτρων του πλέγματος στην περίπτωση του κάμπου της Θεσσαλίας. Μελετάται η εξαιρετικά αποδοτική οικονομικά, καλλιέργεια των ακτινίδιων σε σχέση με τους φυσικούς πόρους της περιοχής. Μελετάται παράλληλα η εγκατάσταση φωτοβολταϊκών συστημάτων. Η απόδοσή τους αποτιμάται στο πλέγμα νερού-ενέργειας και τροφίμων, συγκριτικά με την παραδοσιακή καλλιέργεια σιταριού.



Εικόνα: Χρήσεις γης στην Θεσσαλία.

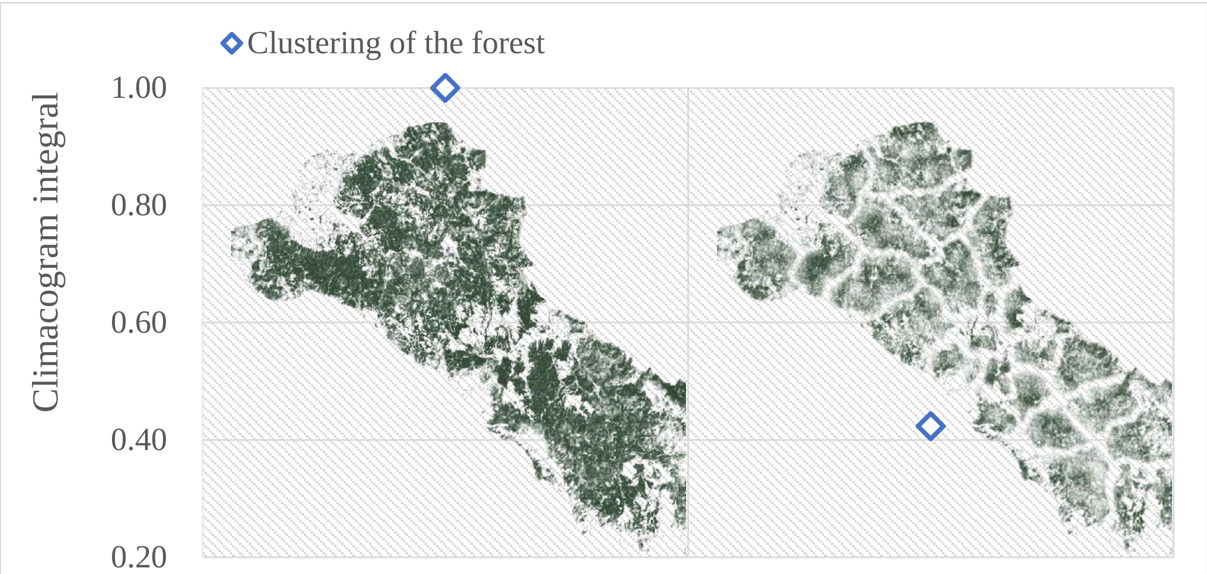
Κεφάλαιο 6

Στο κεφάλαιο 6 μελετάται η δυναμική των συσσωματωμάτων. Περιγράφεται το πως τα συσσωματώματα είναι μια διαδικασία που παρατηρείται στη φύση αλλά και σε ανθρώπινες κοινωνίες όταν υπάρχει αναπτυξιακή προοπτική που εξυπηρετεί οικονομίες κλίμακας. Το σύστημα ύδρευσης της Αθήνας είναι μια χαρακτηριστική περίπτωση. Η Αθήνα έχει ένα από τα μεγαλύτερα υδραγωγεία στον κόσμο. Εξετάζοντας ιστορικά την εξέλιξη των έργων υποδομής, το κόστος τους, το κόστος του νερού και την διαθεσιμότητα του φυσικού πόρου, αναδεικνύεται το πως αυτό το έργο υποδομής μεγάλης κλίμακας είναι η βάση της ευημερίας της πόλης. Παράλληλα, εξετάζεται η εκδοχή του τι θα σήμαινε αν δεν υπήρχε.



Εικόνα: Η εξέλιξη της πόλης των Αθηνών και των υδατικών πόρων τον 20ο αιώνα.

Άλλη χαρακτηριστική περίπτωση εξέτασης στην δυναμική της διασποράς είναι η μελέτη περίπτωσης της μεγάλης πυρκαγιάς στην Εύβοια το καλοκαίρι του 2021 στην οποία αναδεικνύεται το πως περιορίστηκε το φαινόμενο από την διακοπή του δάσους. Διατυπώνεται ότι μια δυναμική προστασίας του δάσους θα ήταν η διασπορά του, με στόχο την ενίσχυση της κοινωνικής δομής των τοπικών κοινωνιών και της ανάπτυξης μέσω της εκμετάλλευσης αυτού του φυσικού πόρου.



Εικόνα: Στα αριστερά η συσσωμάτωση της περιοχής του δάσους πριν τη φωτιά, δεξιά μια προτεινόμενη μορφή της διασποράς του δάσους.

Κεφάλαιο 7

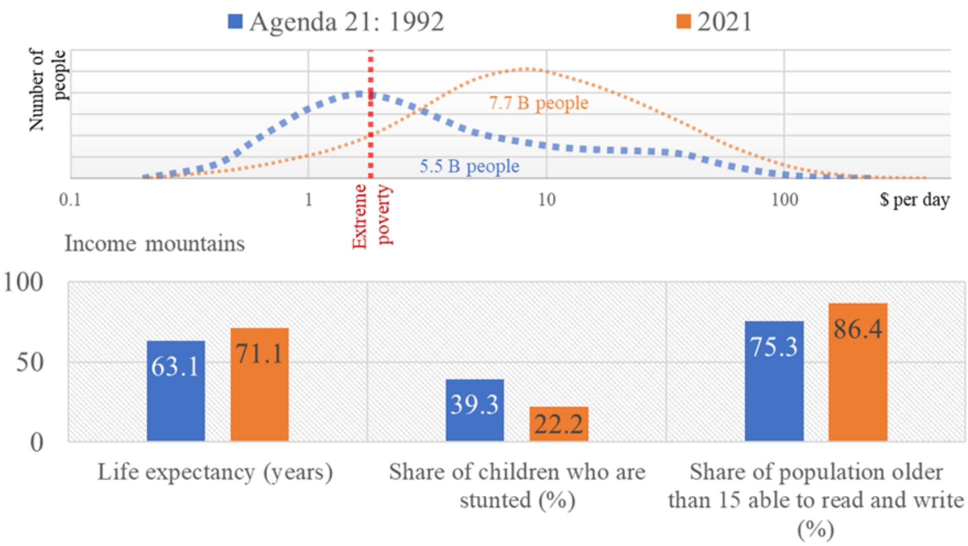
Στο κεφάλαιο 7 εξετάζονται διάφοροι μηχανισμοί ευημερίας και κατάρρευσης των κοινωνιών.

Πολλοί επιστήμονες θεωρούν ότι το φυσικό περιβάλλον καθορίζει τις τροχιές ανάπτυξης ή ύφεσης των κοινωνιών. Η αντίληψη αυτή έχει διαμορφώσει την σχολή που ονομάζεται περιβαλλοντικός ντετερμινισμός.

Αν υποθέσουμε ότι έχουμε την παροχή ενός φυσικού πόρου (π.χ. μιας πηγής) σε ένα νησί που ακολουθεί κανονική κατανομή, σύμφωνα με το αφήγημα του περιβαλλοντικού ντετερμινισμού, το νησί θα έχει μια φέρουσα ικανότητα πληθυσμού η οποία εξαρτάται από την ελάχιστη παροχή. Επειδή όμως έχει αποδειχθεί ότι οι φυσικές μεταβλητές ακολουθούν την δυναμική Hurst-Kolmogorov, αν την προσθέσουμε στην χρονοσειρά, βλέπουμε 4 φάσεις κατάρρευσης.

Θεωρώντας ότι μπορούμε να έχουμε μια μεγαλύτερη εκμετάλλευση της πηγής λόγω τεχνολογίας ή να διαχειριστούμε το νερό αποθηκεύοντάς το, βλέπουμε ότι μπορούμε να αυξήσουμε την φέρουσα ικανότητα του νησιού. Αν θεωρήσουμε ότι η τεχνολογική ικανότητα και η αποθήκευση αυξάνονται, σε συνδυασμό με αειφόρο κατανάλωση, βλέπουμε μια συνεχή αύξηση της φέρουσας ικανότητας. Αντιθέτως ακόμα και αν η τεχνολογική ικανότητα και η αποθήκευση αυξάνονται, η μη αειφόρος κατανάλωση, οδηγεί σε κατάρρευση.

Μολονότι η Δυτική σκέψη, έχει υποδουλωθεί στον περιβαλλοντικό ντετερμινισμό, στο κεφάλαιο αυτό παρουσιάζονται παραδείγματα όπως οι Μίνωες, οι Μάγια, το νησί του Πάσχα και άλλα, στα οποία ο περιβαλλοντικός ντετερμινισμός αποτυγχάνει να ερμηνεύσει την εξέλιξη τους. Το περισσότερο χαρακτηριστικό παράδειγμα αποτυχίας είναι η διακήρυξη στο Ρίο της Βραζιλίας (1992) που διατυπώθηκε από την Agenda21 η οποία ανέφερε ότι λόγω της υποβάθμισης του περιβάλλοντος «Η ανθρωπότητα βρίσκεται αντιμέτωπη με την διαιώνιση των ανισοτήτων, την επιδείνωση της φτώχειας, των ασθενειών και του αναλφαβητισμού». Συγκρίνοντας τα δεδομένα, 30 χρόνια μετά τις προβλέψεις της, βλέπουμε ότι κανένας από τους κινδύνους που είχε εντοπίσει δεν επαληθεύτηκε.



Εικόνα: Σύγκριση των προβλέψεων της Agenda21 με τα σημερινά δεδομένα.

Αντιθέτως, φαίνεται ότι η κοινωνική δυναμική και η μορφολογία της διαστρωμάτωσης των κοινωνιών, είναι το κρίσιμο κριτήριο για την ευστάθεια και την ευημερία τους.

Τα τελευταία χρόνια έχει αναπτυχθεί ως νέο επιστημονικό πεδίο, η οικονομο-φυσική (econophysics, αποτυχημένη παράφραση του economo-physics), το οποίο μελετά την κοινωνικο-οικονομική δυναμική μέσα από τους νόμους της φυσικής και ειδικότερα τον δεύτερο θερμοδυναμικό νόμο και τη θεμελιώδη του έννοια, την εντροπία.

Μολονότι η εντροπία χρησιμοποιείται ευρέως σε αυτόν τον κλάδο με μια λάθος έννοια ως αταξία, ο οικουμενικός χαρακτήρας που έχει η εντροπία όταν αυτή χρησιμοποιείται με τον στοχαστικό ορισμό της ως μέτρο αβεβαιότητας, μαζί με την ικανότητα αξιολόγησης που προκύπτει από την αρχή της μέγιστης εντροπίας, διαμορφώνουν ένα εξαιρετικό εργαλείο περιγραφής της κοινωνικής δυναμικής.

Αν θεωρήσουμε το εισόδημα των ανθρώπων ως δείκτη που αντιπροσωπεύει μια συνεχή στοχαστική μεταβλητή $\underline{x}$ μεταξύ $[0, J]$, στην εξίσωση 1 μπορούμε να ορίσουμε την εντροπία Φ της μεταβλητής ως:

$$\Phi[\underline{x}] := \mathrm{E}\left[-\ln\frac{f(\underline{x})}{\beta(\underline{x})}\right] = -\int_{-\infty}^{\infty} \ln\frac{f(x)}{\beta(x)} f(x)\mathrm{d}x$$

όπου $\beta(x)$ είναι ένα μέτρο βάσης. Ένα συνηθισμένο μέτρο βάσης που χρησιμοποιείται είναι του Lebesgue, $\beta(x) = 1/\lambda$ όπου λ θεωρείται ότι είναι μια νομισματική μονάδα.

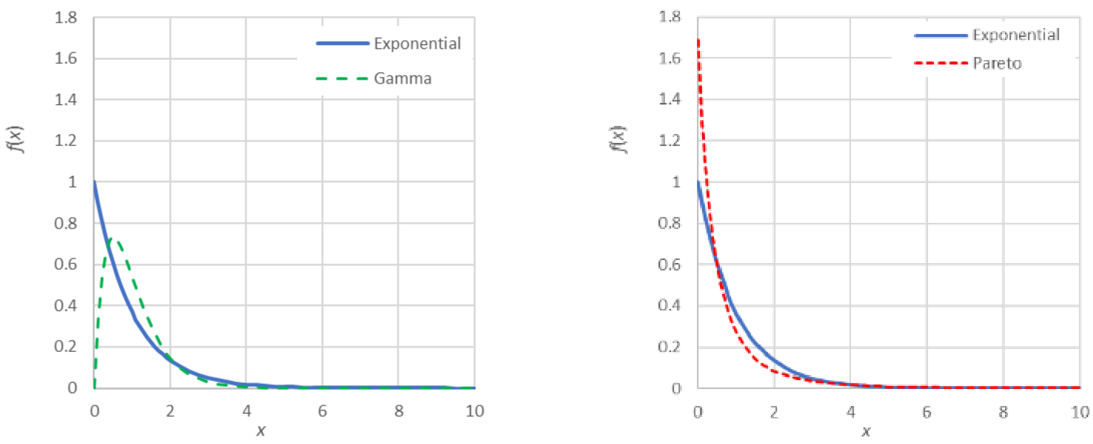
Η εντροπική προσέγγιση δείχνει επίσης έναν άλλο τρόπο αξιολόγησης της ανισότητας. Ενώ για σταθερή πυκνότητα υποβάθρου ίση με το αντίστροφο της νομισματικής μονάδας η εντροπία παρέχει ένα μέτρο του πλούτου της κοινωνίας, αν αλλάξουμε το μέτρο υποβάθρου στην τιμή $1/\mu$, όπου μ είναι το μέσο εισόδημα, η υπολογισμένη με αυτόν τον τρόπο εντροπία είναι ένα μέτρο της ανισότητας. Ονομάζοντας την τελευταία ποσότητα τυποποιημένη εντροπία και συμβολίζοντάς την ως $\Phi_\mu[\underline{x}]$, μετά από αλγεβρικούς υπολογισμούς έχουμε την εξίσωση:

$$\Phi_\mu[\underline{x}] = \Phi[\underline{x}] - \ln\frac{\mu}{\lambda}$$

Υπενθυμίζεται ότι αυθόρμητα, η εντροπία τείνει να αυξάνεται μέχρι να φτάσει στην μέγιστη τιμή που επιτρέπουν οι εκάστοτε περιορισμοί. Εφόσον θεωρηθεί μέτρο βάσης Lebesgue η μεγιστοποίηση της εντροπίας οδηγεί σε εκθετική κατανομή των εισοδημάτων.

Παρατηρούμε δύο μηχανισμούς με διαφορετικές τάσεις, οι οποίοι (και οι δύο) επιδρούν στην μείωση της εντροπίας τροποποιώντας την ευσταθή εκθετική κατανομή.

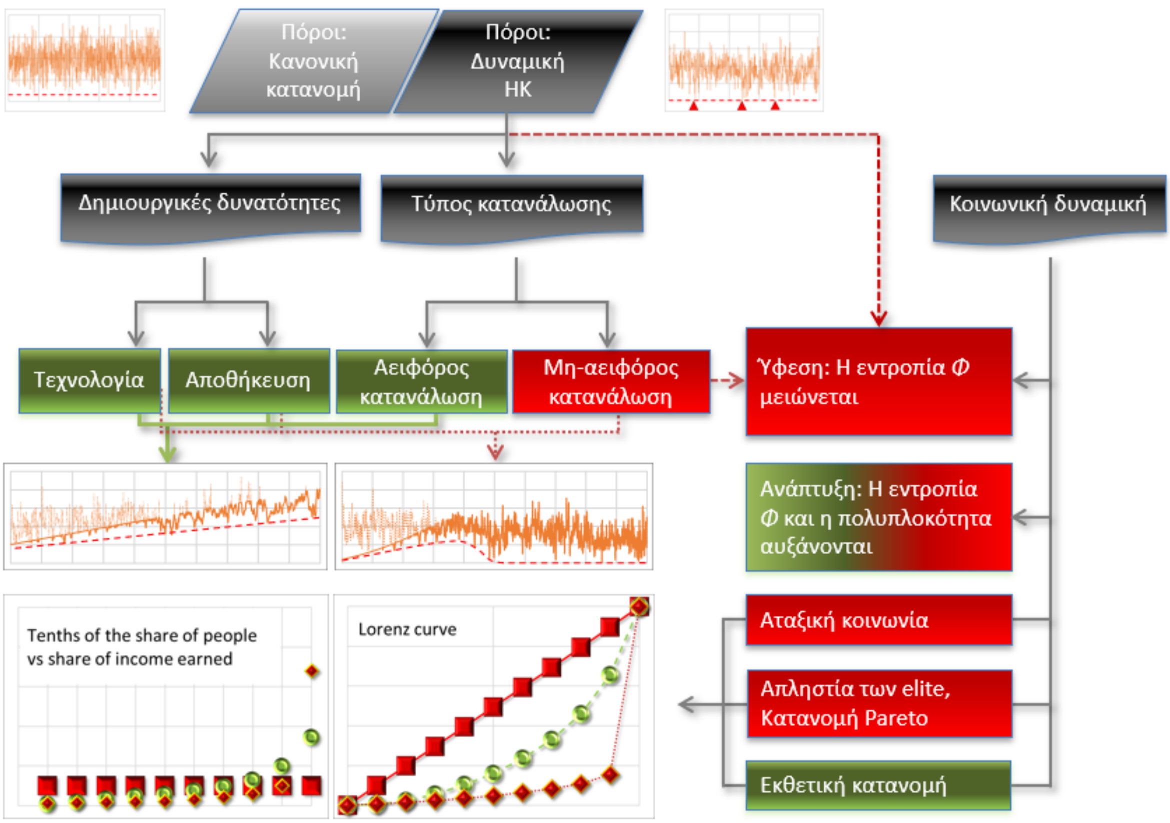
1. Οι οργανωμένες κοινωνίες αναδιανέμουν το εισόδημά τους για να περιορίσουν την φτώχεια και να ενισχύσουν την μεσαία τάξη (κατανομή γάμα)
2. Οι πολιτικο-οικονομικές elite προσπαθούν να απορροφήσουν μεγαλύτερο μερίδιο του πλούτου, που περιορίζει την μεσαία τάξη και αυξάνει την φτώχεια (κατανομή Pareto)



(a) (b)

Εικόνα: (a) Εκθετική κατανομή και κατανομή γάμα (b) Εκθετική κατανομή και κατανομή Pareto.

Άρα το ζητούμενο δεν είναι αν το περιβάλλον σχετίζεται με την κοινωνική αλλαγή, αλλά το πώς μπορούμε να αντιμετωπίσουμε αντικειμενικά τα συζευγμένα προβλήματα που περιέχουν ένα μεγάλο σύνολο ανεξάρτητων μεταβλητών.
Στην παρακάτω εικόνα παρουσιάζεται η περίληψη της μεθοδολογίας.



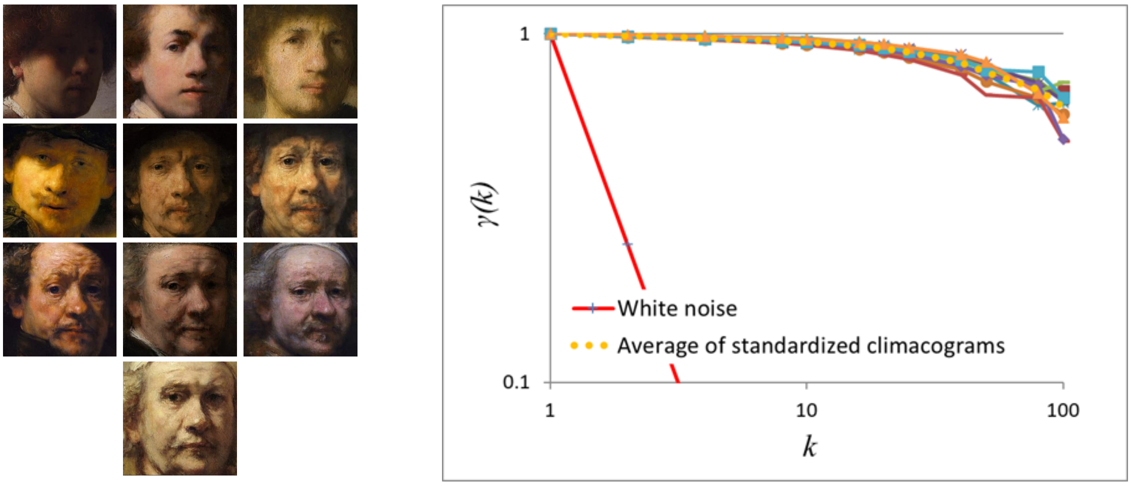
Εικόνα: Περίληψη της μεθοδολογίας. Με πράσινο σημειώνονται οι φάσεις μιας ευημερούσας κοινωνίας και με κόκκινο οι φάσεις με δυναμικές κατάρρευσης.

Στις σημερινές συνθήκες βλέπουμε ότι: η πολυπλοκότητα του κόσμου και η ψηφιακή μετάβαση έχουν φτάσει σε εντυπωσιακά υψηλό επίπεδο, αλλά τα τεχνολογικά βήματα είναι αποκομμένα από τις πραγματικές ανάγκες (π.χ. ο ανταγωνισμός για τα διαστημικά ταξίδια) ενώ παράλληλα το είδος της κατανάλωσης πόρων δεν είναι βιώσιμο· δεν έχουμε λύσει ζητήματα σχετικά με την ικανότητα αποθήκευσης (για παράδειγμα, την αποθήκευση ενέργειας από ανανεώσιμες πηγές ενέργειας).

Κεφάλαιο 8

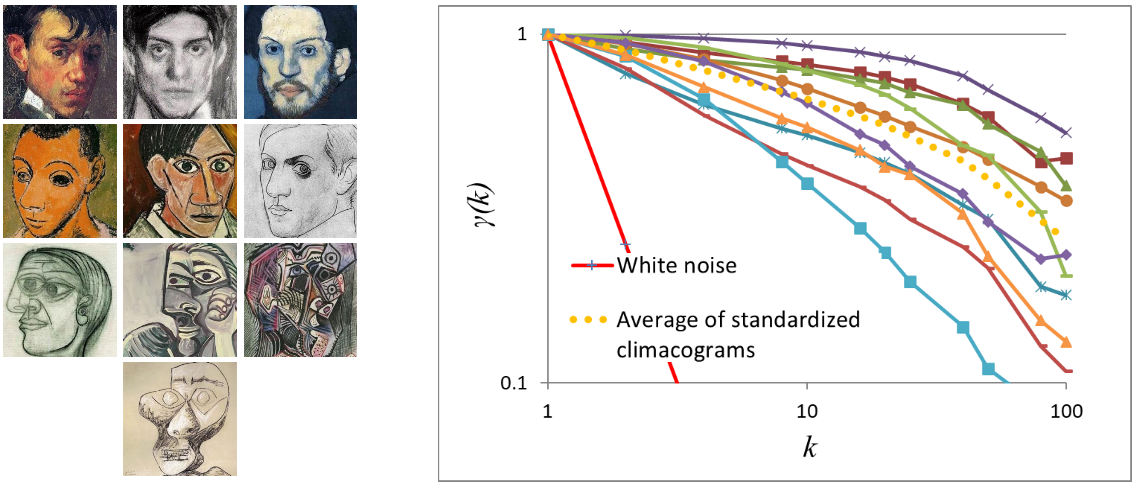
Στο κεφάλαιο 8 εξετάζεται η αισθητική διαφόρων έργων τέχνης και εξάγονται σχετικά συμπεράσματα με την χρήση των στοχαστικών εργαλείων που αναπτύχθηκαν στο κεφάλαιο 4 (ενότητα 4.1). Αναλύοντας την διασπορά της φωτεινότητας σε διάφορες κλίμακες που απεικονίζονται στο κλιμακόγραμμα, αναλύθηκαν ομάδες διαφόρων έργων τέχνης.

Τα στοχαστικά εργαλεία οδήγησαν σε ενδιαφέροντα αισθητικά συμπεράσματα, ορισμένα εκ των οποίων αναφέρονται επιγραμματικά παρακάτω.



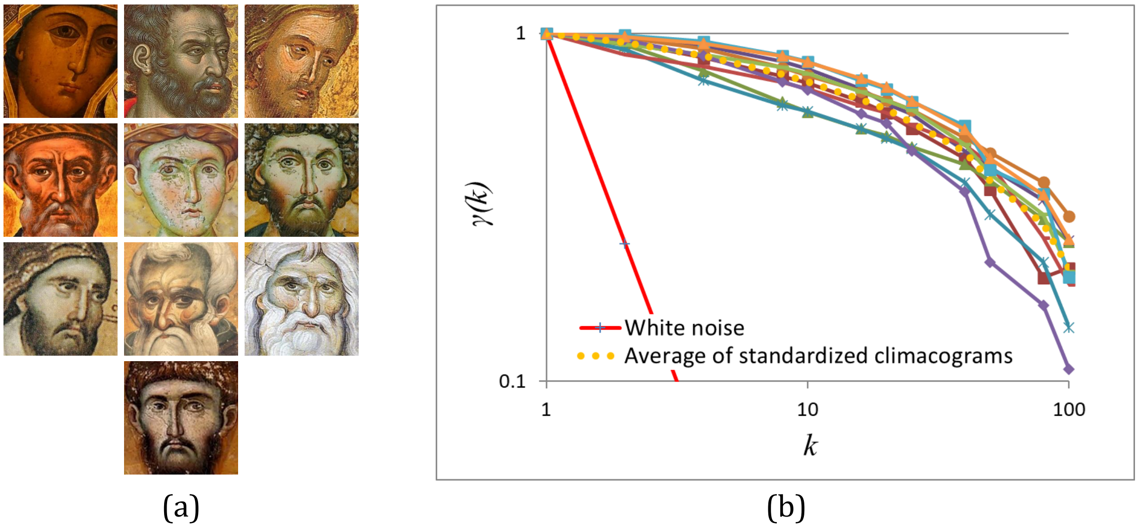
(a) (b)

Εικόνα: Αυτοπροσωπογραφίες του Rembrandt με χρονολογική σειρά και τα αντίστοιχα τυποποιημένα κλιμακογράμματα.



(a) (b)

Εικόνα: Αυτοπροσωπογραφίες του Picasso με χρονολογική σειρά και τα αντίστοιχα τυποποιημένα κλιμακογράμματα.



Εικόνα: Πρόσωπα σε Βυζαντινές εικόνες και τα αντίστοιχα τυποποιημένα κλιμακογράμματα.

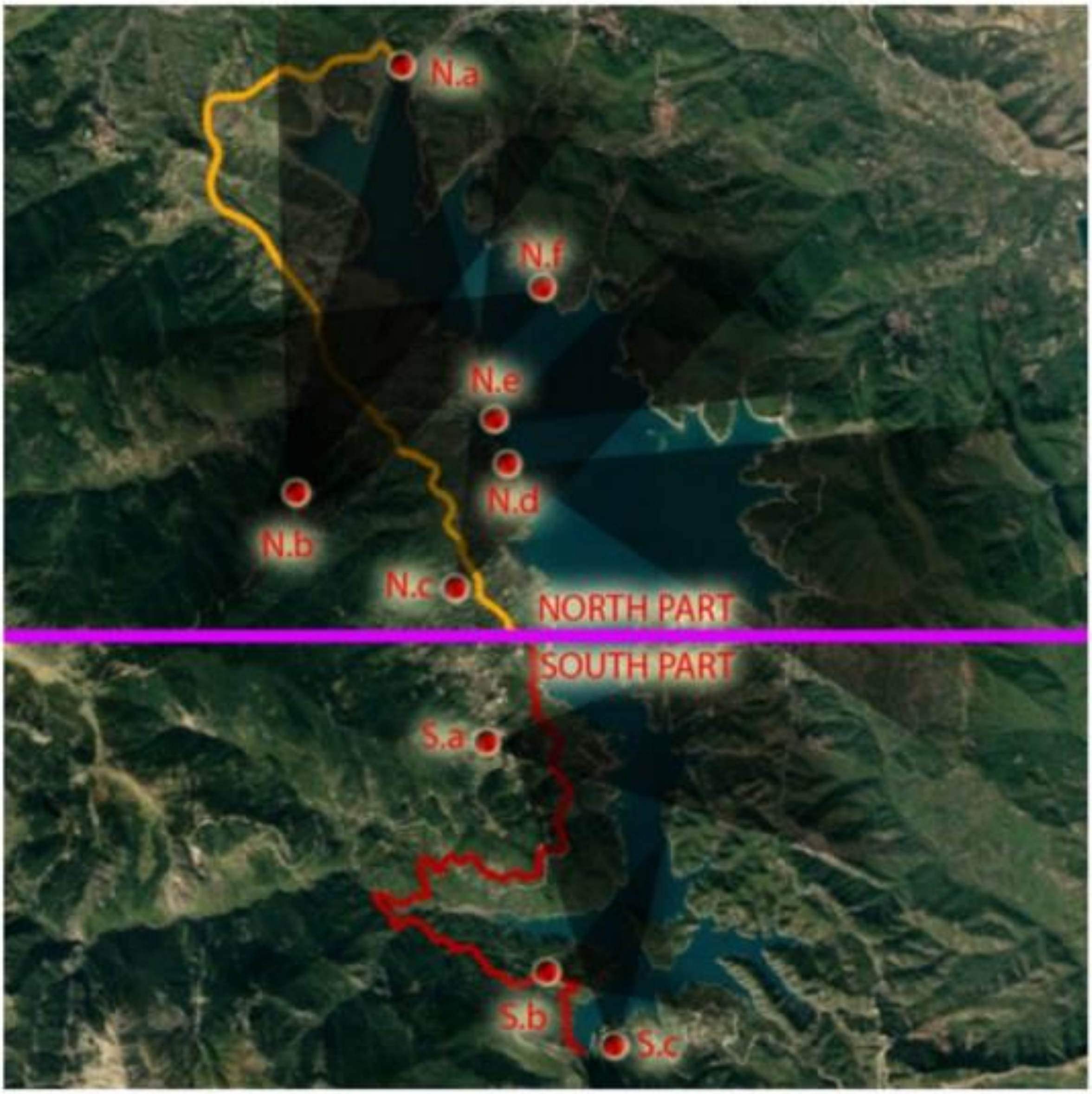
1. Την συνέπεια που εμφάνιζαν τα κλιμακογράματα των αυτοπροσωπογραφιών που έκανε ο Rebrand κατά την διάρκεια της ζωής του.
2. Την ελευθεριότητα που εμφάνισαν τα κλιμακογράμματα των αυτοπροσωπογραφιών που έκανε ο Picaso κατά την διάρκεια της ζωής του.
3. Την τάση των βυζαντινών εικόνων προς τον λευκό θόρυβο που συνάδει με την θεολογική ερμηνεία τους

Με τα συμπεράσματα που προκύπτουν από την ανάλυση των έργων τέχνης, διαπιστώνεται ότι το εργαλείο αυτό είναι αξιόπιστο έτσι ώστε να χρησιμοποιηθεί για την ποσοτικοποίηση της αισθητικής. Επειδή η αισθητική του περιβάλλοντος είναι ένα πολιτισμικό κριτήριο ευημερίας, το στοχαστικό εργαλείο που αναπτύχθηκε στο κεφάλαιο 4 (ενότητα 4.1) σε συνδυασμό με το στοχαστικό εργαλείο που αναπτύχθηκε στο κεφάλαιο 4 (ενότητα 4.2) χρησιμοποιήθηκαν στην αξιολόγηση της μεταβολής του τοπίου λόγω τεχνολογικών υποδομών.

Χαρακτηριστική μελέτη περίπτωσης γίνεται για την περιοχή της λίμνης Πλαστήρα.

Η μελέτη περίπτωσης του τοπίου της Λίμνης Πλαστήρα, στην οποία εφαρμόζεται η στοχαστική μέθοδος για την οπτική αξιολόγηση ομαδοποίησης των Focus Point, επεκτείνει τα αποτελέσματα προηγούμενης εργασίας τόσο σε ποιοτικό όσο και σε ποσοτικό επίπεδο. Μέσω της χρησιμοποιούμενης στοχαστικής μεθόδου, επισημαίνεται μια σημαντική ποσοτική παράμετρος της οπτικής εμπειρίας ενός τοπίου, δηλαδή ο αντίκτυπος της ομαδοποίησης των Focus Pont. Ειδικότερα, συμπεραίνεται ότι η ομαδοποίηση των Focus Point φαίνεται ότι συνέβαλε στη θετική αντίληψη των παρατηρητών στη λίμνη Πλαστήρα, η οποία θεωρείται ως παράδειγμα έργου υποδομής υψηλής βιωσιμότητας και σπουδαίας αισθητικής αξίας.

Στο παράδειγμα της ποσοτικής ερμηνείας της αισθητικής του τοπίου, ερμηνεύτηκε το γιατί παλαιότερες μελέτες, είχαν διατυπώσει ότι το νότιο μέρος της λίμνης είναι περισσότερο όμορφο και ενδιαφέρον από το βόρειο μέρος της λίμνης.



Εικόνα: Μωβ γραμμή: Θεωρητική γραμμή που διαχωρίζει το βόρειο και το νότιο τμήμα του τοπίου. Κίτρινη και κόκκινη γραμμή: κυρίως οδικές αρτηρίες. Κόκκινα σημεία με κώνους: θέσεις των εικόνων μελέτης και περιοχή μελέτης τοπίου.

Συμπεράσματα

Στο κεφάλαιο 9 γίνεται η εξαγωγή των συμπερασμάτων της εργασίας.

Το γενικό συμπέρασμα που μπορούμε να πούμε είναι ότι, μολονότι υπάρχει διάχυτη η συλλογική φαντασίωση που υπακούει στον περιβαλλοντικό ντετερμινισμό, η αλήθεια είναι ότι η πρόσβαση στους φυσικούς πόρους, ιδιαίτερα στο πλέγμα νερού-ενέργειας και τροφίμων, η κοινωνική συνοχή και η κοινωνική σταθερότητα είναι τα βασικά στοιχεία της ευημερίας.

Στο κεφάλαιο 3 διαπιστώνεται ότι:

a) η δυναμική της χωρικής συσσωμάτωσης είναι κρίσιμο στοιχείο ανάπτυξης που οδηγεί σε οικονομίες κλίμακας, ανάπτυξη και ευημερία. Κατ' αντιστοιχία, η δυναμική της χωρικής διασποράς είναι μέθοδος προστασίας.

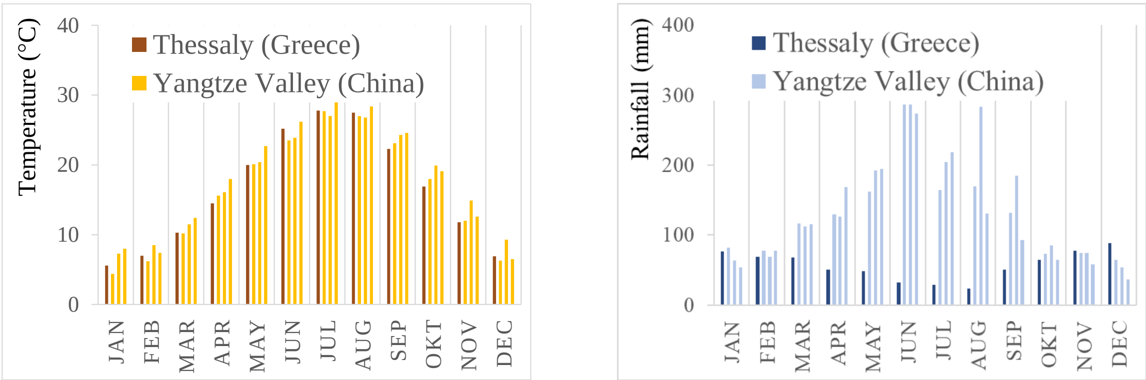
b) κυρίαρχο κριτήριο της ευημερίας είναι η διαμόρφωση της κοινωνικής συνοχής με μια αρμονική κοινωνική διαστρωμάτωση που μπορεί να αξιολογηθεί χρησιμοποιώντας την εντροπία.

Για το πλέγμα νερού-ενέργειας-τροφίμων

Η πρόσβαση στο πλέγμα νερού-ενέργειας και τροφίμων είναι το θεμέλιο της βάσης για μια ευημερούσα κοινωνία. Η επεξεργασία των δεδομένων, δείχνει ότι δυστυχώς περίπου το ¼ του πληθυσμού των ανθρώπων σήμερα ζει με μικρότερη πρόσβαση στο νερό και τα τρόφιμα από τους πολίτες της Αρχαίας Αθήνας (2ος αιώνας μ.Χ.) δείχνοντας ότι η ανθρωπότητα έχει κάνει μικρή πρόοδο τα τελευταία 2000 χρόνια.

Στην ανάλυση της συσχέτισης του πλέγματος νερού-ενέργειας και τροφίμων στο παράδειγμα της Θεσσαλίας, συμπεραίνεται ότι, μολονότι μπορεί κάποιες χρήσεις γης, όπως η καλλιέργεια του ακτινιδίου, να είναι εξαιρετικά αποδοτική οικονομικά, σε μεγάλη κλίμακα θα οδηγήσουν στην κατάρρευση του πλέγματος αφού δεν υπάρχουν διαθέσιμοι φυσικοί πόροι για να τους υποστηρίξουν.

Αυτό φαίνεται από την εξέταση των κλιματικών δεδομένων του χώρου καταγωγής του ακτινιδίου, όπου ενώ οι θερμοκρασίες είναι αντίστοιχες με την Ελλάδα, οι βροχοπτώσεις είναι σαφώς υψηλότερες.



(a) (b)

Εικόνα: Κλιματικά δεδομένα στην Θεσσαλία και στην περιοχή του Yang-tze (Κίνα)[I].

Το πλέγμα νερού, ενέργειας και τροφίμων είναι εξαιρετικά κρίσιμο για την οικονομία και τη βιώσιμη ανάπτυξη, καθώς η προσφορά και η κατανάλωση καθενός από τα τρία στοιχεία είναι προτεραιότητα επιβίωσης και δείκτης ευημερίας.

Καθώς όμως η ζήτηση αυξάνεται, υπάρχει αυξανόμενος ανταγωνισμός μεταξύ του νερού, της ενέργειας και της γεωργίας (τρόφιμα) και άλλων τομέων με απρόβλεπτες επιπτώσεις στα μέσα διαβίωσης των κοινωνιών και στο περιβάλλον.

Η μελέτη του πλέγματος νερού, ενέργειας και τροφίμων μπορεί να οδηγήσει σε ευεργετικές αλλαγές στους τρόπους που παράγουμε και καταναλώνουμε. Ωστόσο, τα θεμελιώδη στοιχεία του πλέγματος συνδέονται σε μεγάλο βαθμό με μια πολύπλοκη και έντονα μη γραμμική σχέση. Ως εκ τούτου, η έρευνα των συνεργειών και των

[I] Climate Data for Cities Worldwide. Available online: https://climate-data.org (accessed on 27 June 2021).

συγκρούσεων τους είναι πολύ σημαντική. Παρουσιάζει ενδιαφέρον ότι η επιστημονική κοινότητα το αντιλήφθηκε αυτό μόλις την τελευταία δεκαετία.

Στην μελέτη περίπτωσης, παρουσιάστηκε μια συγκριτική ανάλυση της ανάπτυξης Φ/Β έναντι της γεωργικής δραστηριότητας στην κύρια αγροτική περιοχή της Ελλάδας, τη Θεσσαλία. Συγκεκριμένα, ποσοτικοποιήθηκαν τρία πιθανά σενάρια: (α) ανάπτυξη ηλιακών υποδομών χωρίς γεωργική χρήση γης, (β) χρήση γης αποκλειστικά για καλλιέργεια σιταριού και (γ) χρήση γης αποκλειστικά για καλλιέργεια ακτινιδίων.

Αν και η παραγωγή ακτινιδίων αποφέρει πολύ υψηλότερο οικονομικό όφελος από την καλλιέργεια σιταριού, παράγοντας σχεδόν ισοδύναμα αποτελέσματα σε θερμίδες με το σιτάρι, οι απαιτήσεις σε νερό είναι πολύ υψηλές, καθιστώντας αυτή την επιλογή μη βιώσιμη. Από την άλλη πλευρά, η εγκατάσταση φωτοβολταϊκών πάνελ, από οικονομική άποψη, είναι πιο συμφέρουσα από τις άλλες δύο επιλογές χρήσης γης.

Αρχικά, η ανάπτυξη των φωτοβολταϊκών πάρκων απαιτεί ένα μεγάλο επενδυτικό κεφάλαιο, σε σύγκριση με τις άλλες δύο επιλογές, αλλά στον κύκλο ζωής του, τα έσοδα από την παραγωγή ενέργειας και η αμελητέα ζήτηση νερού αναδεικνύουν αυτό το σενάριο ως την καλύτερη λύση για τη μελέτη περίπτωσης μας. Ωστόσο, ενώ η ενέργεια είναι απαραίτητη για την ευημερία, δεν είναι βρώσιμη, επομένως αυτό οφείλει να αξιολογηθεί με κριτήριο και την επισιτιστική ασφάλεια.

Επιπλέον, παρατηρήσαμε ότι τα επιτυχημένα παραδείγματα καλλιέργειας (όπως η παραγωγή ακτινιδίων) και οι ιδέες που δεν προσαρμόζονται στα τοπικά χαρακτηριστικά της περιοχής θα μπορούσαν να οδηγήσουν σε κατάρρευση το πλέγμα, αφού καταναλώνουν φυσικούς πόρους που δεν υπάρχουν διαθέσιμοι στην περιοχή.

Το παράδειγμα που αναλύεται, μπορεί να χρησιμεύσει ως πλαίσιο για μελλοντικές μελέτες αειφόρου ανάπτυξης στο πλαίσιο του πλέγματος νερού-ενέργειας-τροφίμων-γης και η έρευνα θα μπορούσε να επεκταθεί και σε άλλες περιοχές, με ποικίλα υδροκλιματικά και κοινωνικοοικονομικά χαρακτηριστικά, έτσι ώστε να ληφθούν υπόψη διάφορα είδη καλλιεργειών.

Με τον τρόπο αυτό εκτιμάται ότι θα μπορέσει να γίνει εξαγωγή γενικότερων συμπερασμάτων σε σχέση με τις συγκρούσεις και τις συνέργειες μεταξύ όλων των στοιχείων του πλέγματος.

Η εξωτερική μορφολογία: συσσωμάτωση και ανάπτυξη, διασπορά και προστασία

Η συσσωμάτωση είναι ανθρώπινη τάση που δημιουργεί την κοινωνία και οδηγεί σε οικονομίες κλίμακας. Καθώς τόσο η κλίμακα των σημερινών κοινωνιών όσο και εκείνη των έργων υποδομής αυξάνονται, είναι σημαντικό να κατανοήσουμε τόσο τη δομή της χωρικής ομαδοποίησης όσο και τη χρονική της εξέλιξη. Για το σκοπό αυτό, αναπτύχθηκε η στοχαστική μέθοδος γενικής εφαρμογής για την ποσοτικοποίηση της χρονικής εξέλιξης της χωρικής συσσωμάτωσης ως εργαλείου για την αξιολόγηση, την παρακολούθηση και πιθανή πρόβλεψη στοιχείων παγκόσμιων αλλαγών.

Με μια προσεκτική επιλογή εικόνων που αντιπροσωπεύουν χωρικές πληροφορίες, μπορούμε να εξαγάγουμε έναν ποσοτικό προσδιορισμό της εξέλιξης των συσσωματομάτων, με την πάροδο του χρόνου, που να είναι χρήσιμος είτε για τον ποσοτικό χαρακτηρισμό γνωστών χωρικών αλλαγών, ή ακόμα και για την αποκάλυψη χωρικών μοτίβων που είναι λιγότερο αναμενόμενα, π.χ., που να σχετίζεται με βρόχους ανατροφοδότησης μεταξύ ανθρωπογενών παρεμβάσεων και φυσικής μεταβλητότητας.

Τα αποτελέσματά μας υποστηρίζουν την ιδέα ότι υπάρχει μια τάση για ομαδοποίηση τόσο στον φυσικό όσο και στον κόσμο που διαμορφώνεται από τον άνθρωπο. Ωστόσο η τάση αυτή εξαρτάται από την κλίμακα καθώς πέρα από μια συγκεκριμένη κλίμακα μπορεί το ίδιο το συσσωμάτωμα που είναι ευεργετικό και οδηγεί σε οικονομίες κλίμακας να εμπεριέχει μια δυναμική κατάρρευσης και να είναι ευάλωτο.

Οι περιπτωσιολογικές μελέτες για τα οικοσυστήματα, τα δάση Βόρνεο, τον Αμαζόνιο και τις λίμνες στην Ελλάδα, δείχνουν ότι η μέθοδος ομαδοποίησης προσφέρει έναν αποτελεσματικό χαρακτηρισμό της εξέλιξης των οικοσυστημάτων, αποκαλύπτοντας μοτίβα ομαδοποίησης και διασποράς ενώ σε πολλές περιπτώσεις, η αλληλεπίδραση της φυσικής και της ανθρώπινης μεταβλητότητας είναι δύσκολο να διακριθεί και αναδεικνύεται ως απρόβλεπτη από την άποψη της εξέλιξης.

Οι περίοδοι διασποράς είναι εμφανείς στη φύση και χαρακτηρίζουν την ύφεση. Διατυπώνονται παραδείγματα, που σχετίζονται με πολέμους, λιμούς και φυσικές καταστροφές όπως οι φωτιές

Συγκεκριμένα, στη παρούσα διατριβή διαπιστώθηκε ότι ο ρυθμός της συσσωμάτωσης αυξήθηκε δραματικά από τη βιομηχανική επανάσταση, και η αστικοποίηση ακολούθησε αυτή τη συνολική θετική τάση μέχρι σήμερα. Αυτό είναι σύμφωνο με την ευρέως διαδεδομένη πεποίθηση ότι οι μεγαλύτερες ανθρώπινες δομές ενισχύουν την αποτελεσματικότητα μέσω των οικονομιών κλίμακας.

Ωστόσο, γίνεται ολοένα και πιο σαφές ότι οι ομαδοποιημένες ανθρώπινες δομές ενέχουν επίσης αυξημένους κινδύνους. Για παράδειγμα, στην οικονομία η αυξανόμενη συσσωμάτωση έρχεται με αύξηση των συστημικών κινδύνων, ενώ η συγκέντρωση υποδομών και πόρων αυξάνει την τρωτότητα του πληθυσμού κατά τη διάρκεια μιας ενδεχόμενης αστοχίας της υποδομής ή ενός πολέμου. Είναι ενδεικτικό ότι την περίοδο 2020-2021, η κοινωνία αναγκάστηκε να επαναξιολογήσει ριζικά τις δομές συσσωμάτωσής της σε διαφορετικές κοινωνικές κλίμακες, προκειμένου να αντιμετωπίσει τον κίνδυνο από την πανδημία COVID-19.

Παρά τα τεράστια οφέλη που προκύπτουν από τις συσσωματωμένες κοινωνικές δομές κατά τους τελευταίους αιώνες, είναι δελεαστικό να εξεταστεί μια εναλλακτική κοινωνική κατανομή στο χώρο, ίσως πιο αραιή και πιο αποκεντρωμένη, λαμβάνοντας παράδειγμα της εξέλιξης των φυσικών δομών που χαρακτηρίζονται από την αβεβαιότητα.

Η περίοδος του COVID-19 παρουσίασε μια ευκαιρία να επανεξετάσουμε τους συμβιβασμούς που προκύπτουν από τη φυσική μας τάση να συγκεντρωνόμαστε και είναι μια ευκαιρία να αναθεωρηθούν τα κριτήρια για την επιλογή της βέλτιστης κλίμακας για την ανάπτυξη, καθώς και το νόημα που φέρουν όροι όπως η βιωσιμότητα.

Σε κάθε περίπτωση, η απάντηση στο ερώτημα της αξιολόγησης της βέλτιστης συσσωμάτωσης, της κλίμακας κοινωνικής οργάνωσης και της ανάπτυξης, είναι ένα συναρπαστικό πρόβλημα που και οι μηχανικοί, μεταξύ άλλων, πρέπει να το λύσουν.

Ο Homo Sapiens επέζησε της φυσικής επιλογής ως (μικρής κλίμακας) θηλαστικό και όχι ως (μεγάλης κλίμακας) δεινόσαυρος. Ωστόσο, οι άνθρωποι ήταν τελικά σε θέση όχι μόνο να προσαρμοστούν στις νέες συνθήκες αλλά να διαμορφώσουν νέες συνθήκες και να τροποποιήσουν το περιβάλλον τους μέσω της επιστήμης και της τεχνολογίας.

Εξετάζοντας την δυναμική της συσσωμάτωσης μέσω των έργων ύδρευσης της Αθήνας, βλέπουμε το βαθμό με τον οποίο αυξάνεται η διαθεσιμότητα των φυσικών πόρων (όπως του νερού) λόγω των έργων υποδομής μεγάλης κλίμακας.

Οι πόλεις μεγαλώνουν ως αποτέλεσμα της συγκέντρωσης και κατανομής της εργασίας καθώς και των οικονομιών κλίμακας που αυτό δημιουργεί. Παρά τις επιπτώσεις της συσσωμάτωσης που σχετίζονται με το μέγεθος, υπάρχει ισχυρή υποψία ότι τα καλύτερα μέρη για τον αναπτυξιακό σχεδιασμό είναι σε μικρότερες και όχι μεγαλύτερες πόλεις, αντανακλώντας ένα αντιστάθμισμα μεταξύ οικονομιών κλίμακας και τρωτότητας, η οποία αυξάνεται όσο μεγαλώνουν οι πόλεις.

Η Αθήνα είναι παράδειγμα μιας πολύ μεγάλης πόλης. Ενδεικτικά, φιλοξενεί το 30% του πληθυσμού της Ελλάδας και παράγει το 47,3% του ΑΕΠ της Ελλάδας. Ωστόσο, η λεκάνη απορροής που συμβάλλει στο σύστημα ύδρευσής της είναι περίπου το 3% της Ελλάδας.

Μελετώντας την αύξηση του πληθυσμού της Αθήνας τον 20ο αιώνα και της ανάγκης του για ύδρευση, το σχετικό ερώτημα είναι: Δικαιολογήθηκε αυτή η μετανάστευση πολιτών; Θα μπορούσε ο κόσμος να είχε επιλέξει μια περιοχή της Ελλάδας με περισσότερους υδάτινους πόρους αντί να ζει στη σχετικά άνυδρη περιοχή της Αθήνας;

Το κόστος κατασκευής της υδάτινης υποδομής για την Αθήνα για να φιλοξενήσει έναν τόσο μεγάλο πληθυσμό ήταν σίγουρα υψηλότερο από ό,τι σε άλλες πόλεις που ήταν πιο κοντά σε πηγές νερού, αλλά μάλλον αυτό δεν ήταν ανησυχία των ανθρώπων. Πιθανότατα, δεν ανησυχούσαν ποτέ γι' αυτό και διεκδίκησαν «το δικαίωμα στην πόλη» χωρίς άγχος για τη διαθεσιμότητα νερού και τις τεχνικές δυσκολίες του συστήματος ύδρευσης, αλλά μόνο ωθούμενοι από τις σύγχρονες κοινωνικές τους συνθήκες, ιδιαίτερα μετά από περιόδους κρίσης.

Σε ένα σενάριο όμως που οι Αθηναίοι θα ήθελαν να μείνουν στην Αθήνα με τον σημερινό τρόπο ζωής αλλά χωρίς αυτές τις ιδιαίτερες υδραυλικές υποδομές μεγάλης κλίμακας, μάλλον θα επέλεγαν να τις ξαναχτίσουν. Με σχετική αναγωγή που αναλύεται στο παράρτημα του παρόντος τεύχους, εκτιμήθηκε ότι το κόστος νερού πριν τα μεγάλα έργα υποδομής (1913) ήταν περίπου 400 €/m^3 για νερό (σχεδόν η τιμή του εμφιαλωμένου νερού σήμερα). Με την τιμή αυτή, οι σύγχρονοι Αθηναίοι, θα είχαν κάνει απόσβεση του κεφαλαίου των σχετικών υποδομών του συστήματος ύδρευσης σε λιγότερο από ένα μήνα.

Έτσι συνολικά, παρόλο που η μεγάλη συγκέντρωση πληθυσμού στην Αθήνα απαίτησε μια πρωτοφανή ένταση κεφαλαίου για τη διαχείριση του νερού, αυτή οδήγησε στη συνέχεια σε προσιτή πρόσβαση στο νερό. Επομένως, φαίνεται ότι οι οικονομίες κλίμακας στα υδραυλικά έργα ήταν απαραίτητες για την ανάπτυξη της πόλης των Αθηνών.

Εάν το σύστημα ύδρευσης της Αθήνας σχεδιαζόταν με μικρότερους ταμιευτήρες, αυτοί θα είχαν και μικρότερες λεκάνες απορροής. Έτσι, μεγάλες εκτάσεις των λεκανών απορροής τροφοδοσίας του τρέχοντος συστήματος θα ήταν ανεκμετάλλευτες και για την εξυπηρέτηση της ζήτησης θα έπρεπε να αυξηθεί η απόσταση των υδάτινων πόρων. Επιπλέον, οι πολυάριθμες μικρές δεξαμενές αυτής της εναλλακτικής θα απαιτούσαν ένα πολύ πιο εκτεταμένο σύστημα υδραγωγείων για τη μεταφορά του νερού στην Αθήνα. Σε αυτή την περίπτωση, το κόστος του νερού ήταν πάλι αυξημένο.

Η Αθήνα μπορεί να λειτουργήσει ως ενθαρρυντικό παράδειγμα. Λόγω του ξηρού κλίματος της, η παροχή νερού στην Αθήνα εξαρτάται από ένα σύστημα τροφοδοσίας υδατικών πόρων μεγάλης κλίμακας. Οι επενδύσεις για την κατασκευή αυτού του συστήματος είχαν πάντα την ύψιστη προτεραιότητα και έλυσαν τεχνικά και κοινωνικά προβλήματα μειώνοντας το οικονομικό κόστος ως αποτέλεσμα των υποδομών μεγάλης κλίμακας. Συνολικά, οι υποδομές για την ύδρευση της Αθήνας προσφέρουν ένα διδακτικό παράδειγμα βιώσιμης διαχείρισης των φυσικών πόρων για την εξυπηρέτηση του πληθυσμού και της πόλης.

Ένα παράδειγμα της δυναμικής της διασποράς, είναι η διασπορά των δασικών συσσωματωμάτων και η κατ' αντιστοιχία τους προστασία από την πυρκαγιά. Στην εργασία περιγράφεται μια διαδικασία που θα ενίσχυε την κοινωνική συνοχή, την ανάπτυξη και την εκμετάλλευση των δασικών συστημάτων.

Στην κατεύθυνση της διαχείρισης των δασών, πραγματοποιήθηκε διερεύνηση μιας λογικής δασοπροστασίας που δίνει προτεραιότητα στον μετριασμό των τοπικών πυρκαγιών σε συνδυασμό με ένα κοινωνικό σύστημα διασποράς των δασικών συσσωματωμάτων.

Η ιδέα πίσω από αυτό είναι ότι τα διασπαρμένα δασικά συστήματα μπορεί να πλεονεκτούν σε σχέση με τα μεγάλα δασικά συσσωματώματα. Επισημαίνεται ότι ενώ η πρόληψη στη διαχείριση των δασών για τον μετριασμό των πυρκαγιών φαίνεται να επικρατεί, η σχετική πολιτική και πρακτική αναπτύσσει μέτρα προστασίας μόνο μετά από μεγάλες καταστροφικές πυρκαγιές.

Εσωτερική κοινωνική δομή: κοινωνική διαστρωμάτωση και κοινωνική δυναμική

Οι ανθρώπινοι πολιτισμοί έχουν επιβιώσει μέσω φυσικών καταστροφών, κλιματικών αλλαγών και σε εχθρικά περιβάλλοντα.

Από διαφορετικά παραδείγματα βλέπουμε ότι όταν υπάρχει προηγμένη κοινωνική οργάνωση, η κοινωνία μπορεί να ξεπεράσει περιβαλλοντικά ζητήματα, όπως έκαναν οι Μίνωες, όπου παρά την έκρηξη ηφαιστείου ή τις κλιματικές αλλαγές που συνέβησαν γύρω στο 1500 π.Χ. ξεπέρασαν τις περιβαλλοντικές κρίσεις και κατέρρευσαν τέσσερεις αιώνες αργότερα, γύρω στο 1100 π.Χ.

Υπάρχει μια γενική τάση και βλέπουμε αρκετές μελέτες, οι οποίες απέτυχαν να προβλέψουν ή να ερμηνεύσουν την κοινωνική εξέλιξη και την κοινωνική δυναμική (ιστορικά ή σήμερα) με βάση μόνο περιβαλλοντικά κριτήρια.

Επιπλέον, είναι αναμφισβήτητο γεγονός ότι, όταν η κοινωνική οργάνωση καταρρέει, οι κοινωνίες δεν μπορούν να επιβιώσουν.

Γενικά, επισημαίνουμε ότι ο περιβαλλοντικός ντετερμινισμός εκπλήσσεται, εντυπωσιάζεται και γοητεύεται από τα φυσικά φαινόμενα και τα συνδέει με τις κοινωνίες χωρίς να εξετάζει την ίδια την δυναμική τους. Ωστόσο, βλέπουμε ότι οι δημιουργικές ικανότητες (τεχνολογία, εμπόριο, αποθήκευση), το είδος της κατανάλωσης (βιώσιμο, μη βιώσιμο, η ανάπτυξη ή ύφεση), η κοινωνική δυναμική και η πολυπλοκότητα ενός πολιτισμού έχουν σημαντικό ρόλο στη βιωσιμότητά του.

Επομένως, είναι σημαντικό να κατανοήσουμε το πώς διαταράχθηκε η εξελικτική τροχιά των πρώιμων πολιτισμών. Σαφώς, οι αναμενόμενες φάσεις ύφεσης, οι οποίες περιγράφονται από τη δυναμική του Hurst-Kolmogorov, υποδηλώνουν ένα στοιχείο επαναληψιμότητας στο οποίο οι αρχαίοι πολιτισμοί ήταν ευάλωτοι, ωστόσο, ακόμη και οι αρχαίοι πολιτισμοί, όπως οι Μάγια και οι Μίνωες, μπόρεσαν να αντέξουν πολλές από αυτές τις φάσεις, πιθανώς με καλή κοινωνική οργάνωση και τη διαχείριση μιας σοφής ελίτ.

Η περίπτωση των Μινώων δείχνει ότι το κλειδί για την ικανότητα ενός πολιτισμού να ευδοκιμεί είναι οι μεγάλης κλίμακας υποδομές και η τεχνολογία, που βελτιώνουν τις συνθήκες διαβίωσης. Αυτό προϋποθέτει αλλά και ενισχύει την οργάνωση της κοινωνίας. Ακολουθώντας αυτόν τον απλό κανόνα, οι κοινωνίες εκμεταλλεύονται τα πλεονεκτήματα των οικονομιών κλίμακας για μπορέσουν να θηρεύσουν το πλέγμα νερού-ενέργειας-τροφίμων που είναι απαραίτητο για την επιβίωση και την ευημερία. Για να γίνει αυτό, είναι απαραίτητη η οργάνωση, ο καταμερισμός της εργασίας (που αναγκαστικά οδηγεί σε κοινωνική διαστρωμάτωση) και η ανάπτυξη (που αναγκαστικά οδηγεί σε πολυπλοκότητα). Υπό το πρίσμα αυτό, θεωρούμε επομένως την κοινωνική δυναμική ως σημαντική, αν όχι την πιο σημαντική, σε σύγκριση με τις εκτιμήσεις του περιβαλλοντικού ντετερμινισμού.

Στην εργασία, εξάγεται το συμπέρασμα ότι η κοινωνική συνοχή μπορεί να αξιολογηθεί από αυτό που ονομάσαμε ως «εσωτερική δομή της κοινωνίας» (την διαμόρφωση της κοινωνικής διαστρωμάτωσης) ποσοτικοποιημένη με την μέθοδο της εντροπίας.

Σύμφωνα με την προσέγγιση αυτή, η μακροπρόθεσμη κοινωνική και οικονομική ανάπτυξη δείχνει ότι συνδέεται με την κοινωνική διαστρωμάτωση, όπως προκύπτει και από την αρχή της μέγιστης εντροπίας. Ωστόσο, η κοινωνική διαστρωμάτωση έχει αμφισβητηθεί ως φυσική ανθρώπινη τάση από τους περισσότερους ανθρωπολόγους γιατί σχετίζεται με το αντί-παράδειγμα των Κυνηγών-Συλλεκτών.

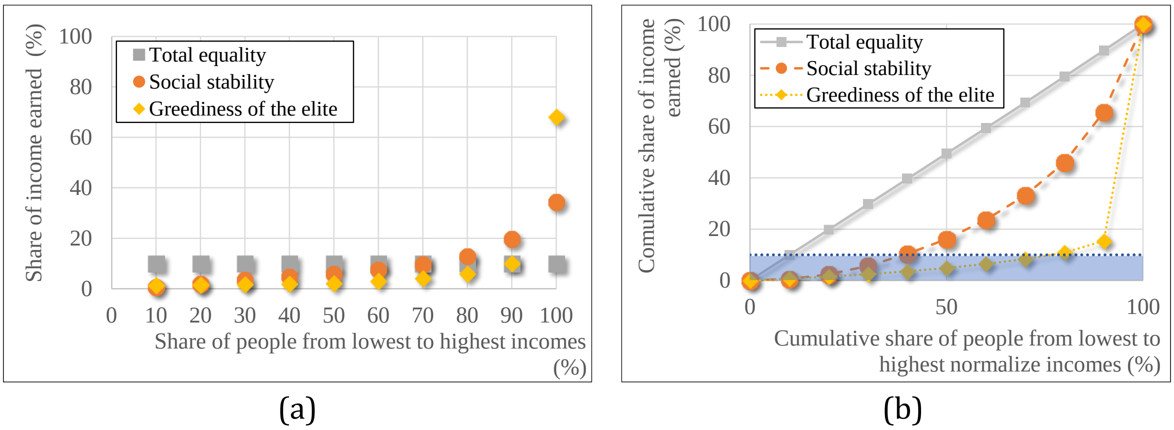
Όμως θα ήταν υπεραπλούστευση αν θεωρούσαμε ότι οι διαθέσιμοι πόροι κατανέμονται εξίσου μεταξύ των μελών της κοινωνίας. Πρόσφατες σχετικές εργασίες δείχνουν ότι η πρόοδος στην τεχνολογία και στη διαθέσιμη ενέργεια (χρήση ζώων) στην αρχαιότητα σχετίζεται με την αύξηση της ανισότητας ενώ τα ίδια συμπεράσματα προκύπτουν από άλλες εργασίες και για τις σύγχρονες οικονομίες.

Το κρίσιμο σημείο της κοινωνικής συνοχής είναι η κοινωνική οργάνωση. Εάν η κοινωνική οργάνωση αποσυντεθεί, ο πολιτισμός θα καταρρεύσει. Πιστεύεται ότι η ηθική παρακμή και η ακραία διαστρωμάτωση είναι μερικές από τις αιτίες που συμβάλλουν στην κατάρρευση του πολιτισμού. Για παράδειγμα, στην βιβλική ιστορία της περιόδου των «παχιών και των ισχνών αγελάδων», εάν στα χρόνια της αφθονίας, ο Φαραώ κρατούσε όλο το πλεόνασμα της αποθήκης για να ικανοποιήσει την ελίτ και να αγοράσει άχρηστα σύμβολα εξουσίας, η κοινωνική κρίση, ο λοιμός και η κατάρρευση θα ήταν μονόδρομος.

Μια φάση ύφεσης σημαίνει και μεταβολή της διαστρωμάτωσης. Μια γενική σκέψη είναι ότι ο πιο ευάλωτος πληθυσμός σε αυτή τη φάση είναι η ελίτ, καθώς η ύπαρξή τους βασίζεται στο πλεόνασμα, το οποίο θα περιοριστεί. Ωστόσο, είναι ακριβώς αυτό το πλεόνασμα που δίνει στην ελίτ την ανθεκτικότητα σε φάσεις ύφεσης και τη δυνατότητα να καταπιέσει τα κατώτερα στρώματα ή να αναδιανείμει τον πλούτο με πολλαπλούς μηχανισμούς.

Η επόμενη εικόνα δείχνει το πώς μια φάση ύφεσης θα επηρέαζε τους φτωχούς εάν οι πλούσιοι δεν αναδιανέμουν τον πλούτο. Η μπλε περιοχή δείχνει τα άτομα που επηρεάζονται όταν οι πόροι μειώνονται κατά περίπου 10%.

Στην κατανομή Pareto (για παράδειγμα στην Αρχαία Αίγυπτο όπου ο δείκτης Gini υπολογίζεται κοντά στο 0,7), θα επηρεαστεί περίπου το 80% του πληθυσμού. Στην εκθετική κατανομή, θα επηρεαστεί περίπου το 40%. Σε μια εντελώς ισότιμη κοινωνία, καθώς όλοι οι άνθρωποι είναι ίσοι, θα μπορούσε κανείς να υποθέσει ότι αυτό θα είχε αντίκτυπο στο 100% του πληθυσμού.



Εικόνα: Διάφοροι τύποι κοινωνικής διαστρωμάτωσης. Τα γκρι τετράγωνα δείχνουν μια κοινωνία πλήρους ισότητας, οι πορτοκαλί κύκλοι μια κοινωνία με εκθετική κατανομή πλούτου και οι κίτρινοι ρόμβοι την κατανομή πλούτου τύπου Pareto (a) Μερίδιο πλούτου (b) Καμπύλη Lorenz (η μπλε περιοχή αντιστοιχεί σε ύφεση 10%).

Το παράδειγμα αυτό, δείχνει την δυναμική μιας σοφής ελίτ στην διατήρηση της συγκρότησης της κοινωνικής συνοχής, ακόμα και σε περιόδους ύφεσης. Η ιστορία δείχνει ότι οι διαστρωματωμένες κοινωνίες διήρκεσαν για μεγάλο χρονικό διάστημα όταν έδωσαν προτεραιότητα σε έναν καλύτερο τρόπο ζωής για τα μέλη της κοινωνίας.

Πολιτισμικά στοιχεία ευημερίας

Με την προϋπόθεση ότι τα παραπάνω ζητήματα έχουν με κάποιον τρόπο επιλυθεί, αφού αποτελούν προϋπόθεση για την ίδια την ύπαρξη του ανθρώπου, εξετάζεται η αισθητική του περιβάλλοντος ως ζήτημα ευημερίας.

Τα τελευταία χρόνια, οι διαδικασίες τεχνητής νοημοσύνης και τα μαθηματικά υπολογιστικά εργαλεία έχουν χρησιμοποιηθεί για την ανάπτυξη μεθόδων ταξινόμησης και αξιολόγησης της αισθητικής. Έχουν επίσης χρησιμοποιηθεί μέθοδοι παραλλαγής κλίμακας παρόμοιες με την παρουσιαζόμενη στοχαστική ανάλυση, αλλά συνήθως περιλαμβάνουν πολύ περίπλοκες διαδικασίες και αλγόριθμους που δεν είναι εύκολα κατανοητοί από μη ειδικούς.

Στην εργασία αναδεικνύεται το πως το στοχαστικό εργαλείο που αναπτύχθηκε, ποσοτικοποιεί μέσω κλιμακογραμμάτων, την διασπορά της φωτεινότητας σε μια εικόνα με αποτέλεσμα να εξάγονται χρήσιμα συμπεράσματα για την αισθητική αξιολόγηση πινάκων ζωγραφικής και φωτογραφιών παρατηρώντας στοχαστικά μοτίβα μεταξύ διαφορετικών ομάδων καλλιτεχνών ή καλλιτεχνικών τάσεων.

Στην επεξεργασία καλλιτεχνικών έργων που παρουσιάζεται στην παρούσα εργασία, επικεντρωθήκαμε σε πίνακες και φωτογραφίες που απεικονίζουν το ανθρώπινο πρόσωπο. Εντοπίσαμε δομές εξάρτησης παρόμοιες με αυτές των φυσικών διεργασιών, με μέσο όρο $H \approx 0,9$, σε φωτογραφίες προσώπων, καθώς και σε πορτρέτα που ανήκουν στην περίοδο της Αναγέννησης/Μπαρόκ και στις αυτοπροσωπογραφίες του Ρέμπραντ. Τα πορτρέτα μοντέρνας τέχνης και τα πορτρέτα του Πικάσο έχουν επίσης ένα μέσο $H\approx 0,9$ που υποδηλώνουν ισχυρές δομές εξάρτησης, αλλά δείχνουν ένα ευρύτερο φάσμα διακυμάνσεων ενδεικτικό της επιδίωξης μιας πιο ελεύθερης καλλιτεχνικής έκφρασης.

Αντίθετα, οι πιο αυστηρές βυζαντινές μορφές που εμπνέονται από το Ορθόδοξο Δόγμα παρουσιάζουν μια γενικά ασθενέστερη δομή εξάρτησης (μέσος όρος $H \approx 0,8$) και τον μικρότερο συντελεστή διακύμανσης (0,379) μεταξύ των άλλων συνόλων.

Αυτά τα ευρήματα υποδηλώνουν ότι η παρουσιαζόμενη μεθοδολογία μπορεί να συλλάβει τη σχέση μεταξύ της στοχαστικής έκφρασης των έργων τέχνης και των φιλοσοφικών ζητημάτων που θέλουν να περιγράψουν (desideratum).

Δεδομένου ότι η μεθοδολογία αυτή, έδειξε ότι είναι αξιόπιστη μέσω της αισθητικής αξιολόγησης έργων τέχνης, χρησιμοποιήθηκε στην αξιολόγηση της μεταβολής του τοπίου λόγω των τεχνολογικών υποδομών, αφού η αισθητική του τοπίου είναι προϋπόθεση για ευημερούσες κοινωνίες.

Τα έργα τεχνολογικής και αστικής υποδομής υποστηρίζουν τις ανάγκες της ανθρώπινης κοινωνίας, αλλά δημιουργούν έντονους μετασχηματισμούς σε αστικά και φυσικά τοπία σε πολλαπλές κλίμακες. Οι μετασχηματισμοί αυτοί, γίνονται ακόμα περισσότερο αντιληπτοί όταν αλλάζουν, αστικά ή φυσικά, ιστορικής και πολιτιστικής σημασίας τοπία. Τα τοπία (κάστρα, παραδοσιακοί οικισμοί, ιεροί τόποι κ.λπ.) φέρουν το πνεύμα του τόπου (Λατινικά: genius loci) και ο μετασχηματισμός τους με σύγχρονες υποδομές μπορεί να επηρεάσει τόσο την αισθητηριακή εμπειρία των επισκεπτών όσο και τη γνωστική τους αντίληψη του τόπου. Οι επιπτώσεις των υποδομών στο τοπίο μπορούν να συσχετιστούν με τη βιωσιμότητα των υποδομών, τόσο ως προς τις αντιδράσεις των πολιτών στα έργα υποδομών στο στάδιο της ανάπτυξης, όσο και ως προς τις επιπτώσεις στην ποιότητα ζωής των πολιτών, μετά την ολοκλήρωση των έργων.

Μέσω διάφορων συνδυαστικών παραδειγμάτων, συμπεραίνεται ότι η μεθοδολογία που παρουσιάζεται, μπορεί να βρει ευρεία εφαρμογή σε μελέτες τοπίου και να ποσοτικοποιήσει την μεταβολή του.

Πρέπει ωστόσο να σημειωθεί ότι ένας περιορισμός αυτής της μεθόδου έγκειται στην υποκειμενικότητα που σχετίζεται με το ποιοι τύποι αστικών υποδομών θεωρούνται ότι έχουν αρνητικό αντίκτυπο στο τοπίο και ποιοι θεωρούνται θετικοί. Ωστόσο, ο περιορισμός αυτός μπορεί να περιορίσει τη σχετική υποκειμενικότητά του, μέσω της ανάλυσης των αντιλήψεων του κοινού.

Συγκεντρωτικά συμπεράσματα

Η εργασία αυτή περιγράφει ως θεμελιώδεις τις παρακάτω παραμέτρους κοινωνικής ευημερίας.

a) Η βάση της ευημερίας είναι το πλέγμα νερού, ενέργειας και τροφίμων.
b) Η εξωτερική μορφολογία της κοινωνίας περιγράφεται από:

- Την αναπτυξιακή δυναμική των συσσωματωμάτων που οδηγεί σε οικονομίες κλίμακας.
- Την προστατευτική δυναμική της διασποράς.

c) Η εσωτερική δομή της κοινωνίας περιγράφεται από την κοινωνική διαστρωμάτωση (κατανομή του πλούτου), η μορφή της οποίας είναι ουσιώδες κριτήριο της κοινωνικής ευημερίας και ποσοτικοποιείται μέσω της εντροπίας.

d) Πολιτισμικές παράμετροι όπως η αισθητική του τοπίου, είναι πλέον δυνατόν να ποσοτικοποιηθούν σε μια ολιστική προσέγγιση με τα στοχαστικά εργαλεία που αναπτύχθηκαν.

Η ποσοτικοποίηση με στοχαστικές μεθόδους που αναπτύχθηκαν των παραπάνω παραμέτρων που αποτελούν τη βάση για την κοινωνική ευημερία, αποτελούν την πρωτοτυπία της εργασίας.

Η επεξεργασία των δεδομένων οδηγεί στο γενικό συμπέρασμα ότι: Υπάρχουν ποικίλες συλλογικές φαντασιώσεις (με επιστημονικό περίβλημα) που επικρατούν, οι οποίες δεν υπακούν στον ορθολογισμό, με αποτέλεσμα η ευημερία να διακυβεύεται.

Ως εκ τούτου, ο ορθολογισμός είναι προϋπόθεση της ευημερίας.

Chapter 1. Introduction

1.1 Motivation and general setting

Living organisms pass through life seeking prosperity in a materialistic world.

There are different meanings of prosperity. Some people think that it is measured in money, others relate it to pleasure and life satisfaction, while others link it to spirituality. However, it could be argued that the basic human needs related to the Water, Energy and Food (WEF) compose a nexus not only necessary for the survival of humans, but able to explain their prosperity as well.

Unfortunately, decision-making in modern world is largely driven by economic aspects and monetarist policies. Koutsoyiannis (personal communication) notes that water, energy and food are not derived by money; rather money and economic growth derives from the availability and the access to water, energy and food.

In this thesis, we study critical issues of prosperity rationally, using publicly available data, historical evidences and stochastic tools. The studied issues are based on the WEF nexus but extend to various other societal, environmental and cultural aspects of human life in societies, ranging from social stratification and urban clustering, to the aesthetic quality of surrounding environment.

1.2 Outline of the thesis

In Chapter 2, we see that the archetypical measures of wealth with economical value (gold and silver), do not have a standardized value. However, we show that access to WEF nexus is positively associated to higher life expectancy which is the true wealth in our materialistic world. In addition, we examine the conflicts between the nexus and the contribution of each different part of the nexus to life expectancy. Analysing the access to nexus from antiquity to the present day, we note that humanity have not done great progress in the last 2000 years, as about 2 billion people (about 1/4 of the population) live with less access to food and water than in antiquity.

In Chapter 3, we introduce and analyse two elements that are found critical for prosperity: the clustering of society and the distribution of wealth. First, we argue that the external dynamics of societal clustering and partitioning can be seen as natural processes, as clustering is associated to growth and partitioning is a way of protection in nature. Human societies and related economic structures (e.g. economies of scale) are shown to behave in a similar way. However, a critical element for the social cohesion and prosperity is the distribution of wealth which formulates the interior structure of the society.

In Chapter 4, we introduce the stochastic tools that are developed in the frame of this thesis. These tools help to:

a) Study the clustering in 2D space which helps to perform quantitative analysis and form related conclusions about the aesthetic elements of an image.
b) Quantify the evolution of clustering in 2D space which helps to understand and characterize the evolution of clustering in nature and social structures.

c) Analyse the entropic aspects of the distribution of society's wealth and study the inequality of societies by an entropic index of inequality which help to gain insights into the stability and the dynamics of social structures.

Using the tools presented in Chapter 4, in Chapters 5-8 we examine the following case studies:

a) Agricultural land or photovoltaic park in Thessaly plain: Studding the WEF nexus in Thessaly plain, we see that, the cultivation of kiwifruit has great potential economic benefits, similar to photovoltaic parks. However, kiwifruit is native to the Yangtze Valley of northern China, an area with abundance of water. We note that, as the water resources are limited in Thessaly plain, kiwifruit is not a sustainable cultivation in big scale, as it requires water which is not available.
b) Clustering: Clustering is a driving force of growth. We analyse the evolution of clustering in structures of nature starting from cosmological simulations, living organisms and ecosystems. We also see that clustering is increased in social structures with dynamics of growth. The Athens water supply system is a typical example of clustering. Athens has one of the biggest aqueducts in the world. Analysing the cost and the effectiveness of infrastructures, the evolution of the cost of the water in 20th century and the evolution of the city's population we see how large-scale infrastructures are cost effective and are the key to growth and quality of life.
c) Partitioning: Partitioning is a de-growth progress but it is also a way of protection. As a case study we analyse the evolution of the fire in Euboea in August 2021 using satellite and meteorological data. We see that, clustered structures (as the forests in North Euboea) are more susceptible to threats (as wildfires), as one incident can destroy the whole structure. Therefore, we present a forest conservation approach based on the partitioning of the forest could as a way of protection.
d) Mechanisms of social prosperity and collapse: In order to analyse present or past civilizations, we will note that Western thought is driven by environmental determinism. However, we present examples of past and present case studies as Minoans, Mayans, Easter Island, and Agenda 21 in which environmental determinism fails to explain and to predict the dynamic of society. In addition, we will see that social dynamics and stratification are critical elements for the prosperity of societies.
e) Cultural elements: In this part we see the analysis of art painting images and their stochastic evaluation showing that the developed stochastic tool is reliable for aesthetic evaluation. Furthermore, as the aesthetic quality of our environment is also a determinant for prosperity, we develop a method which evaluates the degree of transformation of the landscape by civil infrastructures.

1.3 Main original points

The main original points of this thesis are:

a) The saliency of WEF nexus and the quantification of growth and prosperity using publicly available data with stochastic tools.
b) The introduction of a stochastic method for the quantification of the evolution of clustering and its' correlation with the dynamics of nature and society.

c) The finding that entropy Φ can describe social dynamics and the introduction of the entropic index of inequality Φ_μ.
d) The subversion of "Small is beautiful" as we highlight that, economies of scale and large-scale infrastructures are key elements for prosperity.
e) The subversion of environmental determinism as we show with examples that it fails to explain past and present dynamics of societies.
f) The quantification of aesthetical aspects with stochastic tools and the evaluation of the transformation of natural landscapes by civil infrastructures.

Chapter 2. The basic needs for prosperity

2.1 Money

«καὶ ἤκουσα ὡς φωνὴν ἐν μέσῳ τῶν τεσσάρων ζῴων λέγουσαν· χοῖνιξ σίτου δηναρίου, καὶ τρεῖς χοίνικες κριθῆς δηναρίου· καὶ τὸ ἔλαιον καὶ τὸν οἶνον μὴ ἀδικήσῃς»
(Καινή Διαθήκη, Αποκάλυψη 6:6)

"and I heard a voice in the midst of the four beasts say: A measure of wheat for a denarius, and three measures of barley for a denarius; and see thou hurt not the oil and the wine."
(New Testament, Revelation 6.6)

There is a general criticism about the pursuit of humans to wealth which is attributed to their greediness. However, if we look in analytical data, we see that economic status is the quantified prosperity which increases the life expectancy of people, e.g., as seen for Gross Domestic Product (GDP) of 172 countries (**Figure 2.1**) UK (1600-2011) and global average between 1870-2011. In this regard, Confucius famously said that "the first wealth is health" (Bao, 2003; Guo, 1995).

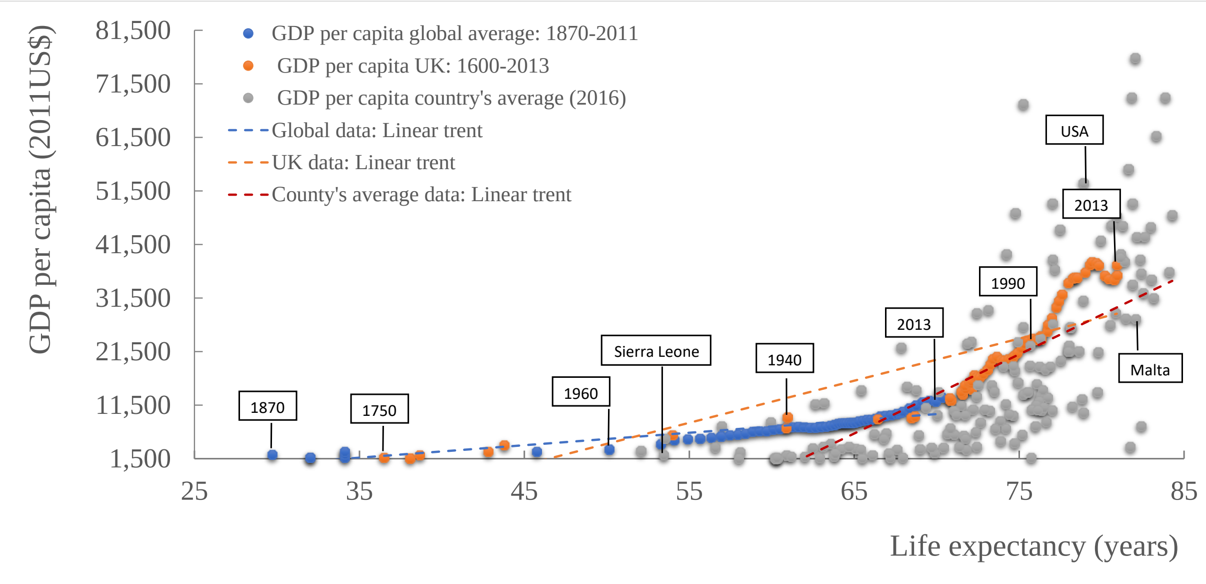


Figure 2.1 Life expectancy related to GDP per capita per year[I]; global average (1870-2011) and 172 countries' average data (2016) [II]UK data (1600-2013)[III].

2.2 Can we standardize the economical symbols of wealth?

Since prehistory humans devoted much of their energy for making works of art, jewellery and other inoperable objects, which eventually became the testimony of his civilization.

[I] Data retrieved on 2022-02-17 by https://ourworldindata.org/life-expectancy

[II] Data retrieved on 2022-02-17 by Maddison Project Database 2018. Available online: https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2018.

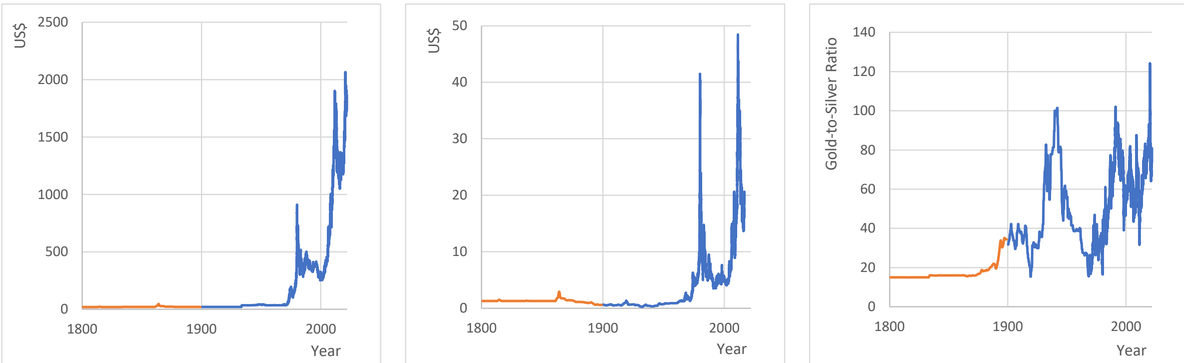
[III] Data retrieved on 2022-01-25 by the Bank of England, Home Statistics Research datasets, available online: https://www.bankofengland.co.uk/statistics/research-datasets

The redundant activities that do not aim to meet survival needs are aimed at two very volatile values: the beauty, which mutates in every cultural phase, and the rarity.

In order to find a stable measure to exchange values, humans needed something precious and rare enough. Professor Andrea Sella, in a very interesting article for BBC[I] explained why mankind's consider gold and silver are precious. Especially for gold, he notes that as other metals are white or red (coper) and most of them can be oxidated, the secret of gold's success as a currency is that with his unique yellow colour, it is unbelievably beautiful. However, as the demand for gold and silver can vary wildly with a fixed supply, that can lead to equally wild swings in its price. Therefore, he concludes that: “gold [and silver] makes the worst possible currency”.

Koutsoyiannis and Mamassis (2021) note that mythology have been very influential in triggering social behaviors. Ancient Greek Mythology describe the subjectivity of gold and how Midas was trapped and starved by his divine charisma transforming everything to gold which is not eatable (Roller, 1983). However, this myth seams that was a footnote to social perceptions, as gold and silver have a timeless value.

Since the beginning of money’s history, precious metals were used as symbols of exchange value because, unlike energy, they have a material substance. In Roman Empire the ratio Gold-to-Silver was about 11-12:1 (Steinlauf, 1945). In modern times, the U.S. government fixed the ratio at 15:1 with the Mint Act of 1792 (Nussbaum 1937). Since late 19th century historical data (orange line in **Figure 2.2** a, b) shows that values had a small variance and the ratio (**Figure 2.2**c) could be considered as consistent to the Mint Act. However, the ratio starts to fluctuate in a wide rage at the end of 19th century.



(a) (b) (c)

Figure 2.2 (a) Values of gold[II]; (b) Values of silver[III]; (c) gold-to-silver ratio.

[I] Rowlatt, J. Why do we value gold? 8 December 2013. Available online: https://www.bbc.com/news/magazine-25255957 (accessed 25 January 2022).

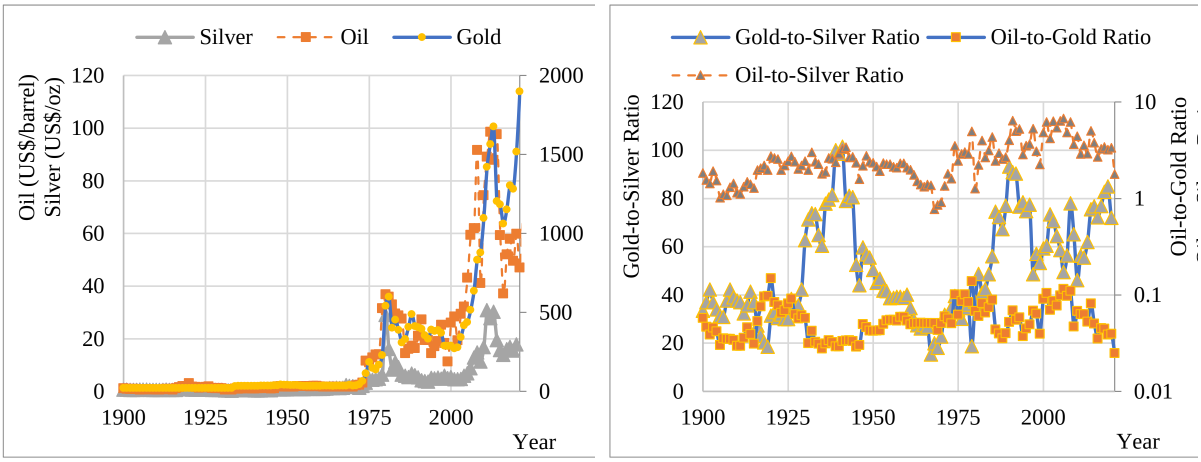
[II] Data retrieved on 2022-02-17 by Gold Prices (Monthly in USD) Available online: https://datahub.io/AcckiyGerman/gold-prices

[III] Data retrieved on 2022-02-17 by 66. Historical data: Silver (ozt) / U.S. Dollar 1:1 (XAGUSD) Available online: https://stooq.com/q/d/?s=xagusd

The last attempt to consolidate the relation of money to precious metals was made in July 1944, at the Mount Washington Hotel near Bretton Woods, which gave rise to what is widely known as the Bretton Woods Agreement[I].

There, the absolute dominance of the dollar in the markets; the strict adherence to trade agreements even between struggling and powerful economies and the linking of the dollar to gold at $35 per ounce were established. But as US had devalued dollars currency, with a unilateral proclamation on an August Sunday in 1970, Richard Nixon[II] suspended the convertibility of the dollar into gold (Irwin, 2013).

Although many analysts at the time predicted the end of the dollar, in an ingenious move that can be said is looking back to the archetypal association of capital with energy, two years later the Americans, through the mediation of Henry Kissinger, came to an agreement with the Saudis and in exchange for guarantees of their security, persuaded them to make all oil transactions in dollars[III], releasing the values of gold, silver and oil in a wide range of fluctuation (**Figure 2.3**a). However, we have to note that even before the petrodollars, their ratio was fluctuated (**Figure 2.3**b).



(a) (b)

Figure 2.3 (a) Values of gold, silver and oil[IV]; (b) ratios of gold, silver and oil.

2.3 The true wealth. Water-Energy-Food (WEF) nexus

«ούκ έπ' ἄρτῳ μόνῳ ζήσεται ἄνθρωπος» (Καινή Διαθήκη, Κατά Ματθαίον 4:4)

"Man shall not live on bread alone" (New Testament, Matthew 4:4)

[I] Ghizoni S. K.: Creation of the Bretton Woods System Available online: https://www.federalreservehistory.org/essays/bretton-woods-created (accessed 25 January 2022)

[II] Nixon and the End of the Bretton Woods System, 1971–1973. Available online: https://history.state.gov/milestones/1969-1976/nixon-shock (accessed 25 January 2022)

[III] 70. The U.S.-Saudi Arabian Joint Commission on Economic Cooperation. Available online: https://www.gao.gov/products/id-79-7 (accessed 25 January 2022).

[IV] Data retrieved on 2022-02-17 by US Energy Information Administration (EIA). PETROLEUM & OTHER LIQUIDS. Spot Prices. Available online: https://www.eia.gov/dnav/pet/pet_pri_spt_s1_m.htm (accessed 25 January 2022).

Humans need a constant supply of water, food and energy to live. These resources are connected to life expectancy, prosperity and wealth (Sargentis, 2021a), and are necessary in sufficient quantity and in quality. Survival limits of humans are 7 days at most without water, and about 45 days without food (Pimentel, 2003), which also represents the energy source for the human body. Thus, food and water require constant replenishment. As energy is essential for prosperity, the whole structure of society has been diachronically shaped and has evolved through systematic expansion of its energy consumption.

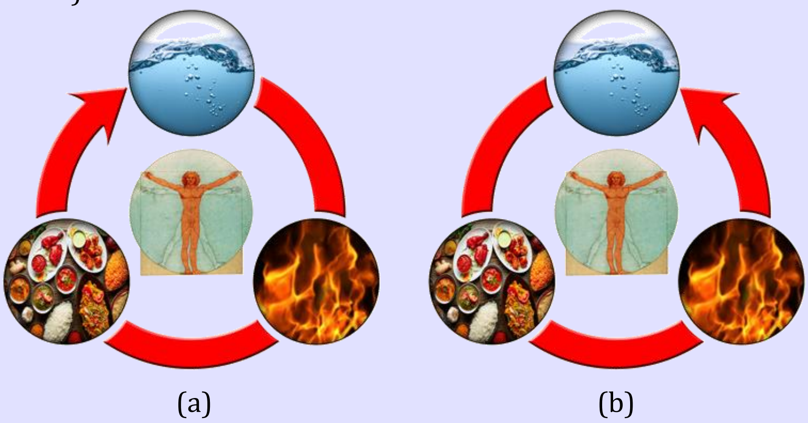
Digression 2.A: From sun to humans

Sun and Earth are the sources of Water-Energy-Food (WEF) nexus which are precious goods. Koutsoyiannis (Koutsoyiannis, 2020) notes that: "*...the total energy involved in the hydrological cycle is 1.290 × 1024 J yr^{-1} or 1290 ZJ yr^{-1}. ... This is about half the global solar energy absorbed by the Earth (161 W m^{-2}, according to Trenberth et al., 2009 (Trenberth, 2009). Compared to the human energy production, which in the past decade was about 170 000 TWh yr^{-1} or 0.612 ZJ yr^{-1} corresponding to the year 2014; (Mamassis et al., 2021), the total energy involved in the water cycle is 2100 times higher. Put differently, the total human energy production in 1 year equals the energy consumed (or released) by the hydrological cycle in about 4 h.*"

Summarizing, we conclude that half of the energy provided by the sun is being consumed in the water cycle, and its consumption is a necessary condition for human life (Frank et al., 2011). A small part of the other half is being used to convert inorganic to organic matter (Lewis, 1945). Humans consume a small part of the organic matter as food (animals, plants) and another part as energy (wood, oil (Kvenvolden, 2006) etc.) which is essential for prosperity (**Figure 2.4**).

Figure 2.4 Solar energy moves the water circle and transforms inorganic matter, to useful organic. Water, food, energy supplies are essential for human survival and prosperity.

An important issue also, is to understand the interactions between the WEF nexus (**Figure 2.5** (Sargentis et al., 2021b).



(a) (b)

Figure 2.5 The interaction between water-food-energy nexus.

The multiple and complex interconnections between water, energy and food, either expressed as complementarities or conflicts, raised the need for an integrated viewpoint, to ensure a fair and sustainable sharing of the three vital resources across all scales of interest (international, national, local). In this vein, the concept of Water-Energy-Food (WEF) nexus is recognized as the running paradigm for their combined planning and management (Gulati et al., 2013; Simpson et al., 2019; Yu et al., 2020; Del Borghi et al., 2020; FAO 2014).

In addition to these three critical elements, land is also a precious resource (Rulli et al., 2016; Magliocca, 2020; Berndes et al., 2017). Land is needed for food production, or for cultivating biofuels, both raising water needs for irrigation (FAO, 2008; Popp et al., 2014; Stenzel et al., 2021; Marta et al., 2011). Recently, it is also used for the installation of all kinds of infrastructures that are associated with energy and water production (Teter et al., 2018). In this vein, a major conflict arises within the WEF nexus, given that land is their common interface (OECD, 2017; Hoff, 2011[I]; Spang, 2014).

2.4 Overview of WEF nexus and conflicts

Even there are many related books and studies of water-food, food-water, water-energy, energy-food, references of "water, energy, food" in papers and articles can be found starting in 1960s (**Figure 2.6**, **Figure 2.7**). In 2009 Koutsoyiannis et al. (Koutsoyiannis et al., 2009) connected the competition of these issues and the necessity to study them together under the prism of uncertainty. Nexus's potential has become clear among the scientific community after 2011, (Simpson 2019) and recent years the WEF nexus has been of particular interest to the scientific community[II] (WEF, 2011; Yang et al., 2013). Furthermore, there are many attempts for the transition from the theoretical aspects of WEF nexus to the practical ones (Albrecht, 2018).

In prehistory, humans relied on energy and water to transition from hunter-gatherers, to farmers, and this gave them the ability to cluster in smaller spaces like cities. The increase of clustering gives rise to civilization (Sargentis et al., 2020b). Nowadays, humanity is facing a major challenge: the rapidly growing demand for WEF. Population growth, the different ways of life of each society, and the urgent need to improve WEF security for the poorest are putting increasing pressure on resources (Chanzimpiros et al., 2007). Unless there are significant changes in production and consumption patterns, agricultural production should increase by about 60% until 2050 and global electricity production is projected to increase by about 60% over the next ten years[III]. Thus, we note that a careful management of the nexus is required.

[I] Hoff, H. Managing the Water-Land-Energy Nexus for Sustainable Development. United Nations Chronicle. Available online: https://www.un.org/en/chronicle/article/managing-water-land-energy-nexus-sustainable-development (accessed on 29 June 2021).

[II] 34. The water, Energy & Food Security Resource Platform. Available online https://www.water-energy-food.org/ (accessed 27 June 2021).

[III] WEF Background. Available online: www.water-energy-food.org/mission (accessed 27 June 2021).

IRENA, Global energy transformation: a roadmap to 2050, 2019. Available online: https://www.irena.org/publications/2019/Apr/Global-energy-transformation-A-roadmap-to-2050-2019Edition (accessed 27 June 2021).

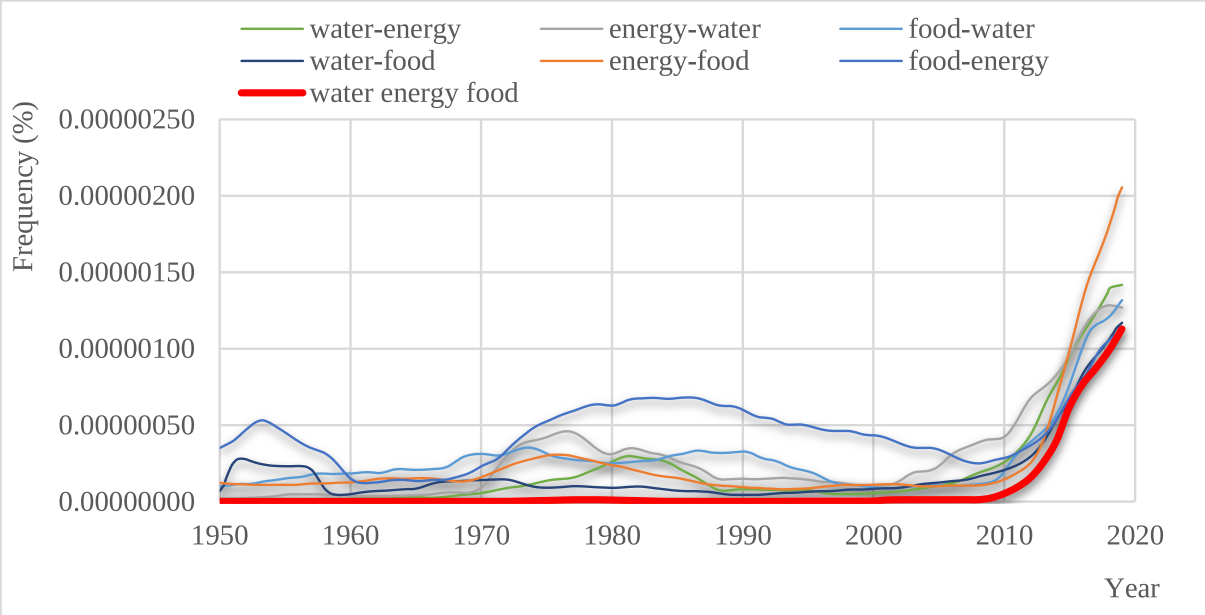


Figure 2.6 Frequency of appearances of the indicated phrase in Google Books up to year 2020 (Michel et al., 2011). Data adapted graphically by Google ngrams[I].

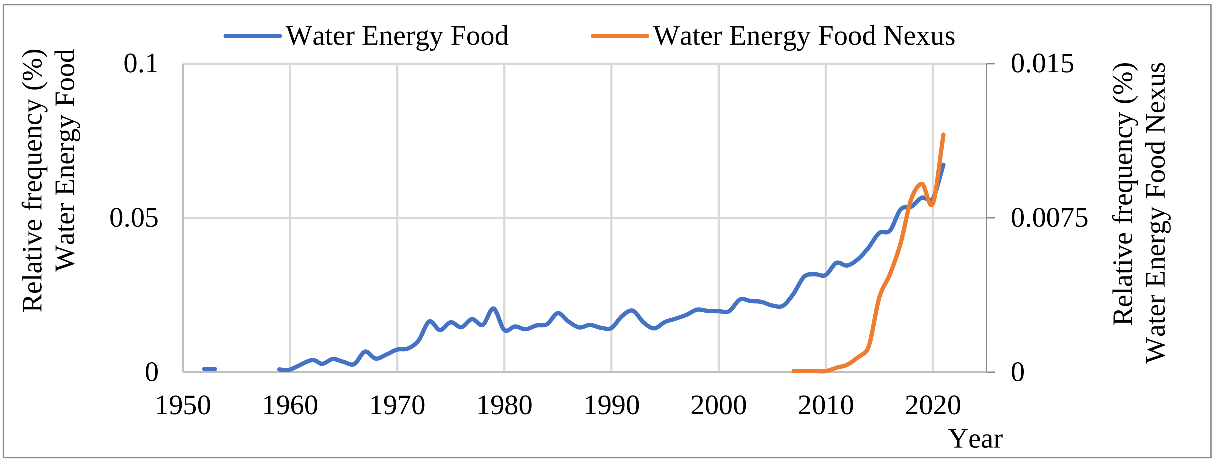


Figure 2.7 Relative frequency of appearances of the indicated key phrases in the article titles, abstracts and keywords of about 70 million articles written in English, which are contained in the Scopus database up to 2021[II].

Digression 2.B: WEF optimization

Notably, the optimization of WEF nexus management is already part of the evolution process of homo sapiens. Related papers have overviewed the relationship, through the evolution process, of homo sapiens with items such as:

- water and food consumption (Sargentis et al., 2020)
- walking on two feet which was an energy-saving step (Michael et al., 2007)
- the function of the brain which is more energy efficient than animals (Boyer and Harrington, 2018).

As WEF nexus is so critical for human survival, and the abundance of resources is connected to life expectancy (**Figure 2.8-Figure 2.10**) we have to assume that an optimization of WEF nexus

[I] Data retrieved on 2022-02-17 by https://books.google.com/ngrams /

[II] Data retrieved on 2022-02-17 by https://www.scopus.com/

management is required and it is very important to minimize the resources for production. In this aspect the target should be to isolate the parts of the nexus and minimize e.g. water for food, water for energy, energy for water, energy for food, fertilizers for food, etc.

In these circumstances, an important issue is to ensure secure access to WEF nexus for all people, reducing inequalities.

2.5 The role of water, energy and food for humans

Life expectancy is depended on the availability of water-food-energy nexus which is necessary for survival (**Figure 2.8**, **Figure 2.9**, **Figure 2.10**). The optimum caloric supply for humans is between 2000-2500 calories[I]. However, data from 172 countries', UK (1600-2013) and global average, shows that even more consumption of caloric supply are corelated to life expectancy and is an indicator for prosperity (**Figure 2.8**).

Since Homeric times the size of ox's or cattle's herd signified the wealth of a person. The symbol of wealth measurement in Roman Empire was the head of an animal (Latin: *capis*), which bequeathed to us the term capital. In 1909 Wilhelm Ostwald first noted that energy consumption is corelated with life expectancy (Ostwald 1909). Data in **Figure 2.9** shows 172 countries' average and global average (1870-2011) which confirm his hypothesis.

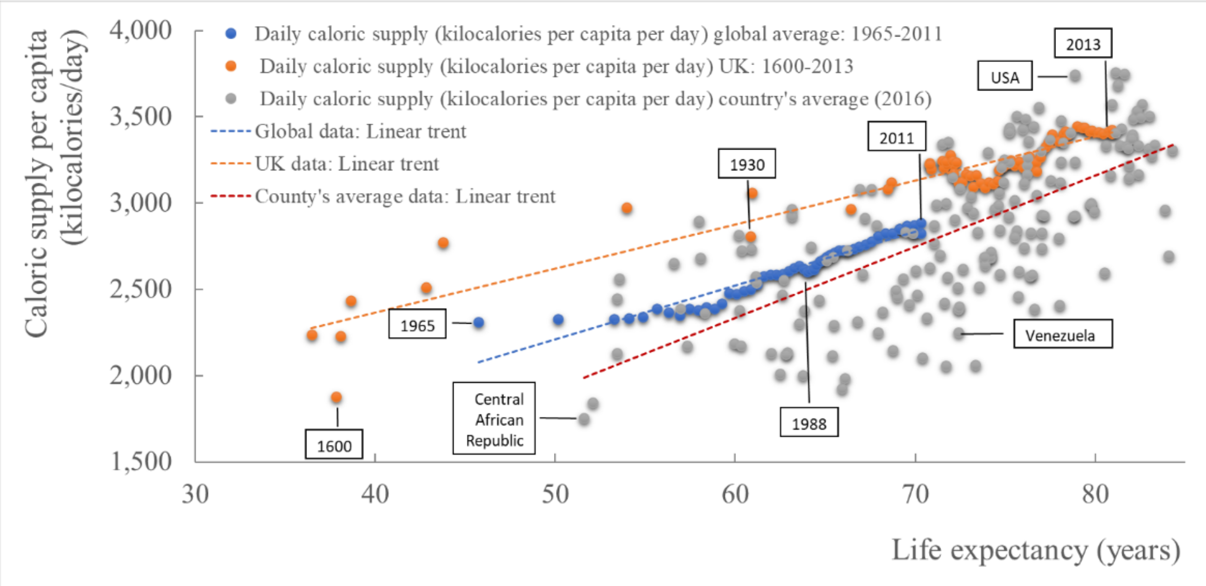


Figure 2.8 Life expectancy[II] related to daily caloric supply; global average (1965-2011) and 172 countries' average data (2016)[III] UK data (1600-2013)[IV].

[I] Report of a Joint FAO/WHO/UNU Expert Consultation, Food and nutrition Technical reports series, 2001. Available online: https://www.fao.org/3/y5686e/y5686e.pdf (accessed 25 January 2022).

[II] Data retrieved on 2022-02-17 by https://ourworldindata.org/life-expectancy

[III] Data retrieved on 2022-01-25 by FAOSTAT, United Nations Food and Agricultural Organization (FAO). Available online: http://www.fao.org/faostat/en/#data/FBS.

[IV] Data retrieved on 2022-01-25 by the Bank of England, Home Statistics Research datasets, available online: https://www.bankofengland.co.uk/statistics/research-datasets

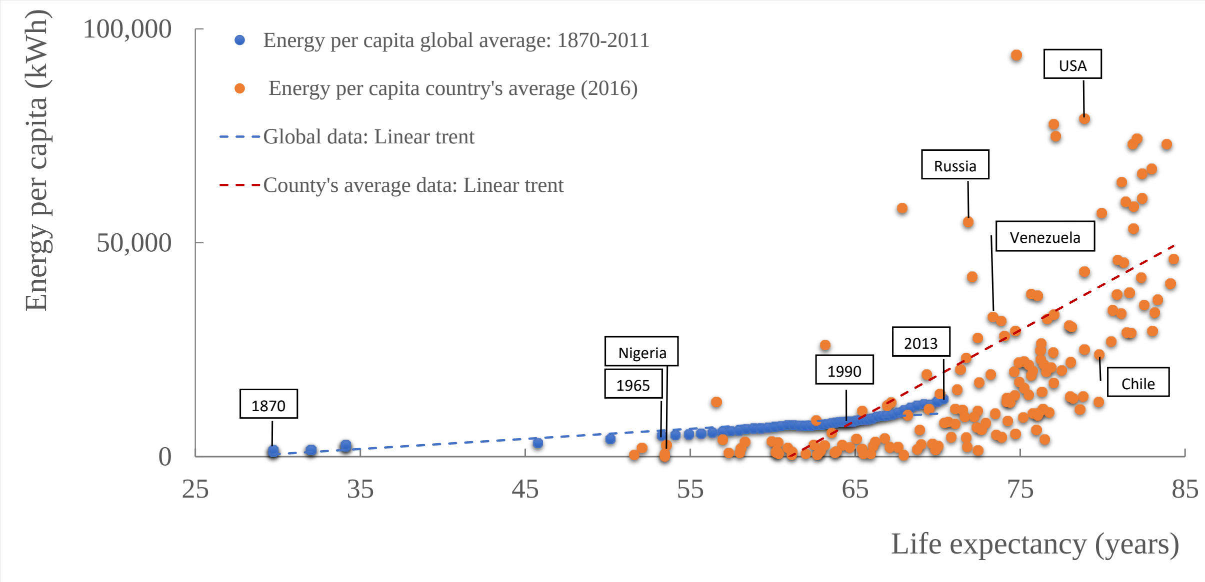


Figure 2.9 Life expectancy[I] related to annual energy consumption per capita; global average (1965-2011), 172 counties' average data (2016)[II].

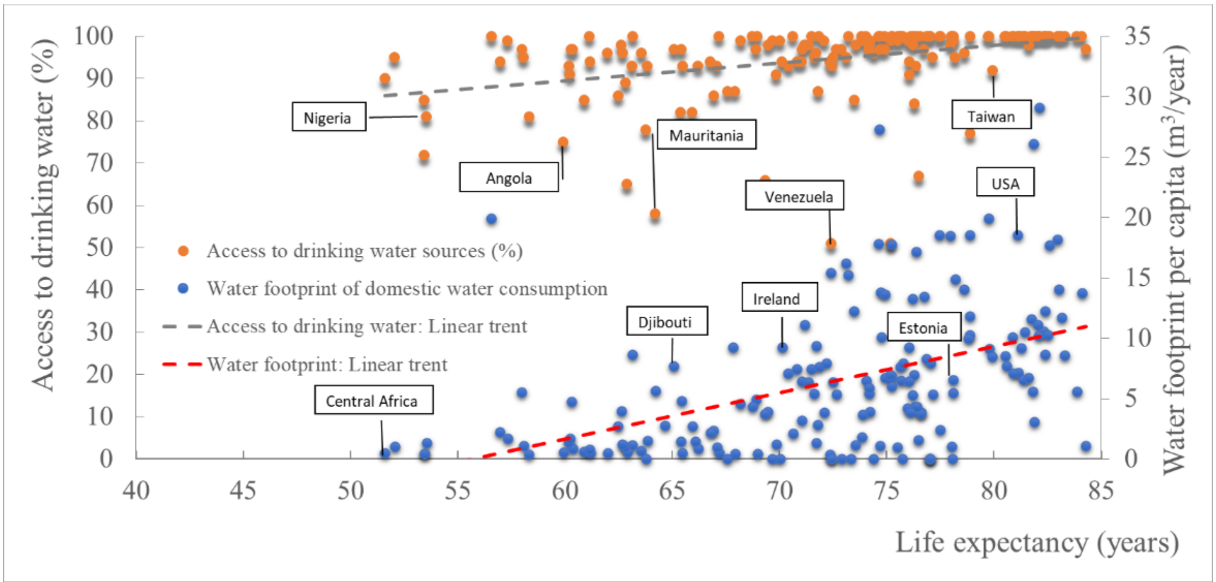


Figure 2.10 Life expectancy[III] related to access to drinking water[IV] and the annual water footprint of consumption of domestic blue water per capita (1996—2005)[V] (Hoekstra and Mekonnen, 2012).

However, energy sources (e.g. animals) could not be easily validated as are mostly used multiplying the wealth (e.g. agriculture) formulating the stratification of the society.

[I] Data retrieved on 2022-02-17 by https://ourworldindata.org/life-expectancy

[II] Data retrieved on 2022-02-17 by BP. Statistical Review of World Energy Available online: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

[III] Data retrieved on 2022-02-17 by https://ourworldindata.org/life-expectancy

[IV] Data retrieved on 2022-02-17 by WHO/UNICEF (2015) Progress on Sanitation and Drinking Water: 2015 Update. Available online: https://data.world/adamhelsinger/unicef-drinking-water-database

[V] Data retrieved on 2022-02-17 by Water footprint network. National water footprint statistics. Available online: https://waterfootprint.org/en/resources/waterstat/national-water-footprint-statistics/

A related paper by Kohler et al., shows that the increasing of technology and available energy (use of animals) in ancient times is related to the stratification of the societies (Kohler et al., 2017). Recent studies (Koutsoyiannis and Sargentis, 2021; Sargentis et al., 2021) deliver also the same conclusions, presenting the dynamics of stratification in societies with an entropic approach (Koutsoyiannis, 2020). Same conclusions are delivered by Atkinson for modern economies (Atkinson, 2015).

The access to clean water is also indicator of societies' prosperity and humans' life expectancy. Data in **Figure 2.10** shows 172 countries' average (2015) in the access of drinking water and countries' average footprint for domestic water which corresponds to the hygienic standards of the society (Mekonnen and Hoekstra, 2011).

2.6 Access to water: from antiquity to present

Controlling water availability is a key factor. Advanced hydraulic works served as a multiplier of civilization as an irrigable area can produce multiple amounts of food versus that of a non-irrigable area (Angelakis et al., 2021).

There are various theories about the social dynamics of hydraulics. An interesting theory was developed by Karl August Wittfogel (Wittfogel, 1957). Wittfogel assumes that hydraulic works are the basis for human society, but they need management and according to his theory, this justifies social stratification and despotism as there are needs of special knowledge and a bureaucratic management of resources and infrastructures by an elite.

However, what is also worth noting is the role of hydraulics as a peace maker. Civilizations with large hydraulic works and infrastructure which improved the quality of life such as demonstrated by the Romans (Smith, 1978) and the Chinese (Liu et al., 2017; Li et al., 2020) endured and prevailed for a significant time. On the contrary, civilizations based in state-of-the-art military technology like Alexander the Great (Ferrill, 2018) and the Mongols (Allsen, 2002) did not last quite as long (**Figure 2.11**).

<u>Energy:</u> The agricultural revolution, was a pivotal advancement for the development and survivability of civilization. The adoption of new techniques in agriculture and the use of animals allowed humans to cluster about 100 times more with a cost of about 3 times more energy per person to produce food than when living as hunter-gatherers (Sargentis et al., 2021).

Human society need infrastructure to exploit water resources, not only abundance of water. In South Africa where there is abundance of water, there is lack of water as there are no water infrastructures (**Figure 2.12**). In the 21st century, a person's "reasonable access" to water is considered to be 20 litres per person per day from a source less than 1 km from their home, while depending on the water resources, infrastructure and cultural characteristics of each region (Gleick, 1996).

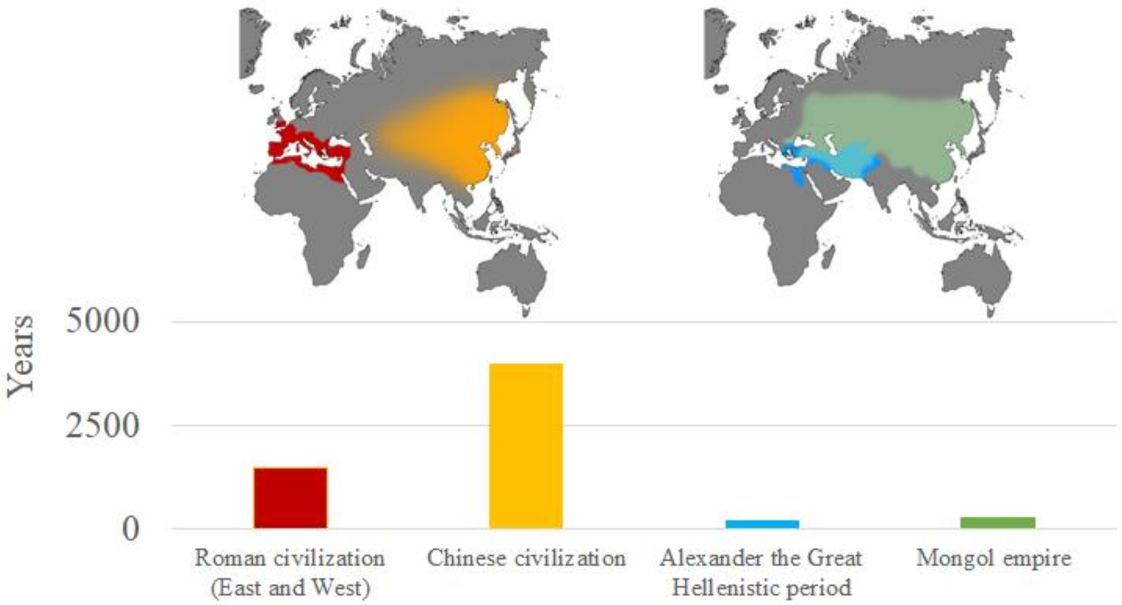


Figure 2.11 Roman, Chinese, Alexander the Great-Hellenistic Period, Mongols. Top: Expansion of civilizations; Bottom: Duration of civilization based in civil infrastructures (Roman Chinese) and duration of civilization based in state-of-the-art military technologies (Alexander the Great-Hellenistic Period, Mongols). Geographical areas are delineated approximately.

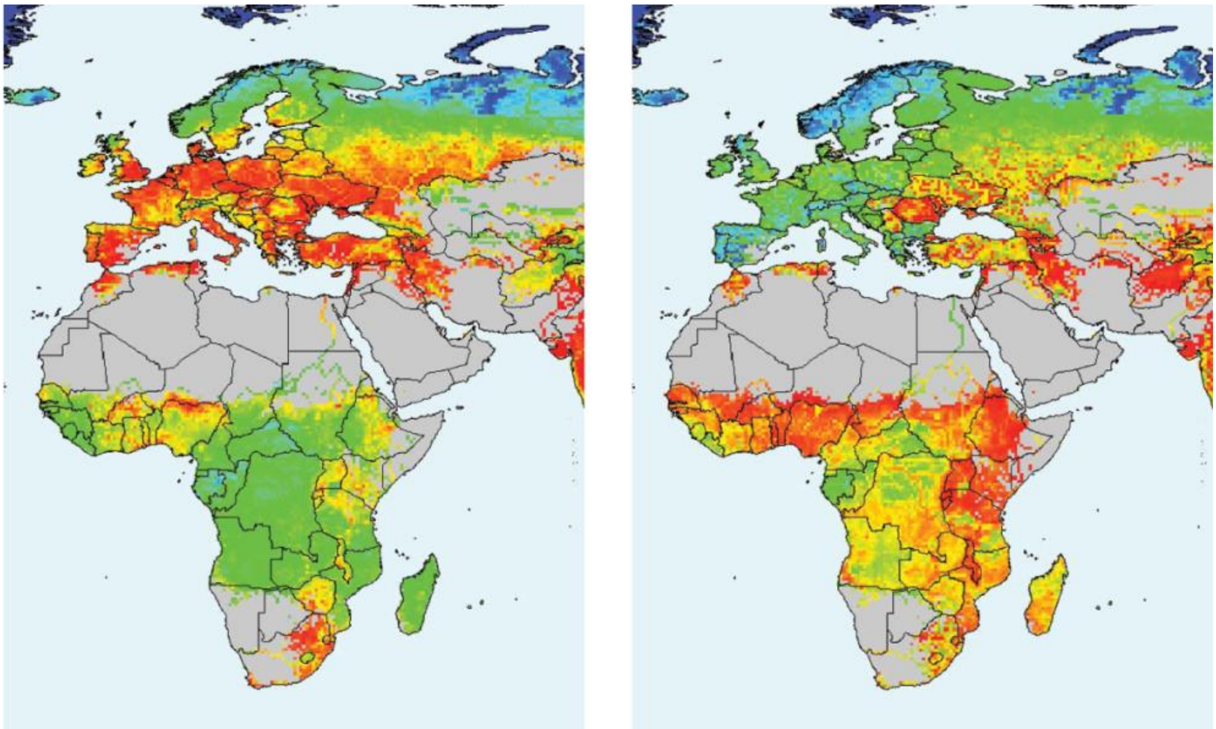


Figure 2.12 World distribution of human water security (HWS) threat: (a) as appears naturally and (b) after accounting for water technology benefits (source: Vörösmarty et al., 2010, as available for download in www.riverthreat.net/data.html).

According to Mays (Mays 2010) the water consumption in ancient communities that had no direct access to water resource was estimated to 10-20 L/cap/d and especially for the city of Jerusalem in 1000 BC was estimated to 20 L/cap/d. A minimum requirement of 40 L/d per household results from the legislation of Solon[I], in the beginning of the 6th century BC (Koutsoyiannis and Mamassis, 2018).

> *Since the area is not sufficiently supplied with water, either from continuous flow rivers, or lakes or rich springs, but most people used artificial wells, Solon made a law, that, where there was a public well within a hippicon, that is, four stadia [710 m], all should use that; but when it was farther off, they should try and procure water of their own; and if they had dug ten fathoms [18.3 m] deep and could find no water, they had liberty to fetch a hydria (pitcher) of six choae [20 L] twice a day from their neighbours; for he thought it prudent to make provision against need, but not to supply laziness.*

In Ancient Rome, total water consumption was estimated to 14,018 quinariae (about 550,000 m^3) per day. Domestic consumption in these lower classes neighbourhoods is estimated to 85 L/day per capita but in addition, lower classes had also access to public water consumption (baths, fountains, battleships) which corresponds to another 200 L/day per capita[II].

Several estimations can be found in the literature, that corelate the area of the city with population in capita per hectare (population density). Indicative are: Ancient Mesopotamia, 300-500 people/ha (Frankfort, 1950); Alexandria, 326 people/ha (estimated by the descriptions of Diodorus Siculus[III]); Pompeii, 160 people/ha (Goubert and Mols, 1959); Russel (Russel, 1958) notes that the population density of most ancient settlements would have been “about 100-120 persons per ha”, although he acknowledged that some settlements might have had up to 200 people per ha. In Medieval Europe he estimates the density to about 100-200 people/ha. According to Hippodameian system in Piraeus a block of 8 residences in Hellenistic period with total 40 dwellers have an area of 0.2 ha. That gives a population density of 200 people/ha (Mamassis et al., 2022). Hanson and Ortman estimate average population densities of 1st AD in about 180 people/ha (Hanson and Ortman 2017) however, estimate the population density of Athens to 429 people/ha.

Morris (Morris, 2013) held that by 150 BCE, Athens had declined to less than 10,000 inhabitants. Others, hold that 10,000 is too low, and suggest that Athens in Roman times may have had up to 20,000 inhabitants (Hin 2016). Russell et al., estimate that the population in Athens in 1 AD was about 25,000 inhabitants (Russell and Russell, 2000).

Archeological evidences, show that the area of the city of Athens in Roman period was 234 ha (about 200 ha if we exclude public places as Acropolis and Agora) (**Figure 2.13**). Piraeus (the city nearby), therefore, considering the population density by Hanson and

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I Plutarch, Solon, 23. Translation by John Dryden. Available online: http://classics.mit.edu/Plutarch/solon.html) after adaptation (accessed 25 January 2022).

II Sextus Iulius Frontinus, De Aquaeductu Urbis Romae, On the water management of the city of Rome. Translated by R. H. Rodgers, The University of Vermont 2003. Available online: http://www.uvm.edu/~rrodgers/Frontinus.html (accessed 25 January 2022).

III Diodorus Siculus (17.52.6). Available online: https://penelope.uchicago.edu/Thayer/E/Roman/Texts/Diodorus_Siculus/17C*.html (accessed 25 January 2022).

Ortman estimations, we assume the possible range of Athens' inhabitants between 36,000—85,800 people.

When it was fully functional Hadrianic aqueduct even in dry periods transferred daily at least 10,000 m^3, (Chiotis, 2018) therefore (excluding Peisistratean and wells) we could consider that the water footprint for consumption of domestic uses of an Athenian was between 42—101 m^3/year per capita.

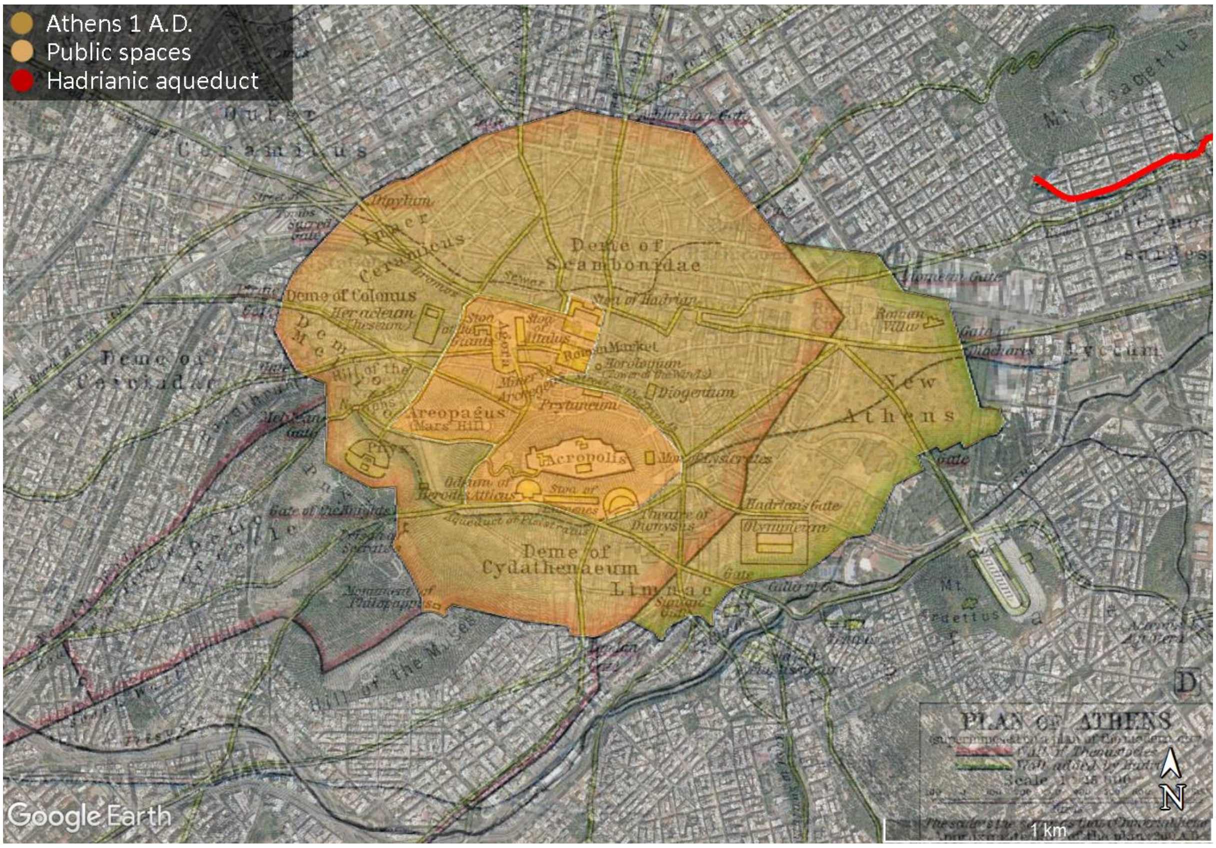


Figure 2.13 Athens in Roman era. Data adapted by Historical Atlas by William Shepherd[I] to Google Earth.

However, in recent history, (about 50 years ago) in the mainland of Greece, drinking water was transported by the springs to the house on foot, in jars, by women (**Figure 2.14**) as the villages had been developed either around a spring that could supply homes (rarely), or upstream from a river. The only available energy, human energy, had to be properly channelled so people could distribute it to rural labour, livestock and water transportation (**Figure 2.15**).

One typical family of this period had (6-8 persons) needed at least 10-20 litters per day of drinking water. This water should come (in average) from about 1 km transferred by the women. Low quality water was coming from open pipes for dishwashing and other functions.

[I] Historical map of Athens, superimposed on a plan of the modern city. Approximate date of the map: 200 A.D. Credits: University of Texas at Austin. Historical Atlas by William Shepherd (1923-26) Available online: http://www.emersonkent.com/map_archive/athens_200_ad.htm (accessed 25 January 2022).

Transfer of water was mainly distributed to women, meaning that they walked loaded 0.5-1h (if they needed to go twice a day) consuming 4 kcal/min[I] i.e., 100-200 kcal per day for this activity when overall consuming 1800-2400 kcal per day (Dufour and Piperata 2008) (~850 kWh per year). So, the energy for drinking water was 50-100 kWh per year which means 5-10% of the total energy consumption of the women. But women carried this water for their families (6-8 people) so the total energy per person is 5-15 kWh per year which reviled to 0.5-1% of total consuming energy for drinking water.

(a) (b) (c)

Figure 2.14 Historical photos (a) Spring in the center of village[II]; (b) Women in the spring[III]; Women with jars[IV].

(a) (b)

Figure 2.15 Historical photos (a) Rural labor[V] ; (b) Livestock[VI].

[I] Sources: A compilation of energy costs of physical activities November 2005 Public Health Nutrition 8(7A):1153-83 DOI: 10.1079/PHN2005802; Energy Consumption by Construction Workers for On-Site Activities, Available online: https://www.researchgate.net/publication/324092004

[II] Source: http://thesprotia-news.blogspot.com/2010/01/frederic-boissonnas-1858-1946.html

[III] Source: http://thesprotia-news.blogspot.com/2010/01/frederic-boissonnas-1858-1946.html

[IV] Source: http://www.aspromavro.net/2015/07/blog-post_26.html

[V] Source: http://thesprotia-news.blogspot.com/2010/01/frederic-boissonnas-1858-1946.html

[VI] Source: https://www.instazu.com/media/2018125859493091946

Modern Greeks consumes about 30.000 kWh per year[I]. The energy cost of 1 m^3 of drinking water in Athens is estimated as 0.1 kWh/m^3 (Sargentis et al., 2019) thus a modern man who needs 62 m^3/year will consume 6.2 kWh per year which reviled to 0.02% of total consuming energy for drinking water.

Interestingly about two billion people have less available water for domestic uses than minimum water level assumed for the Athenians in the early 21nd century (**Figure 2.16**).

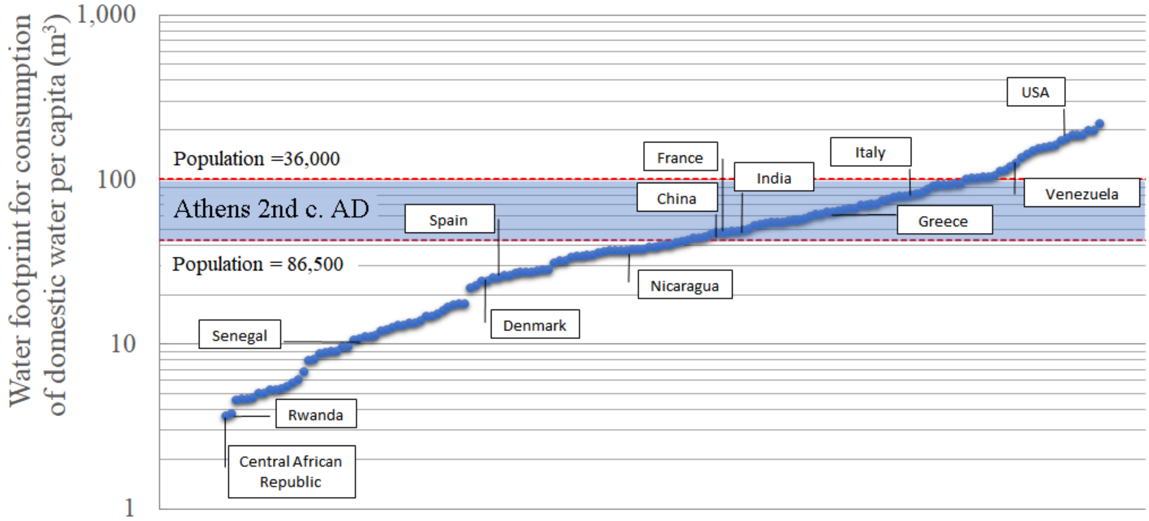


Figure 2.16 Footprint of the annual consumption of domestic water per capita[II] (1996—2005) (Hoekstra and Mekonnen, 2012).

2.7 Access to energy: from antiquity to present

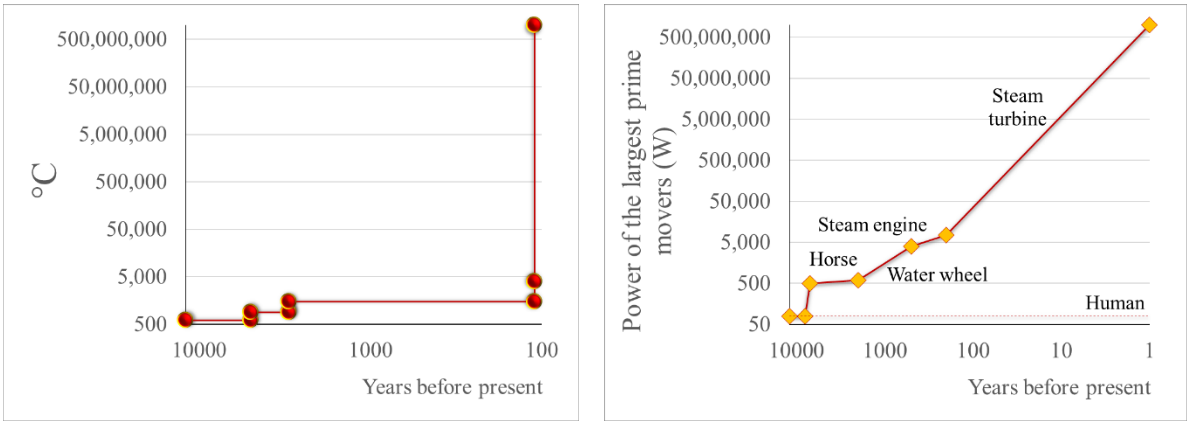
In order to obtain an overview of the role of energy in society's evolution, we also plot the maximum temperatures achieved by humans (**Figure 2.17**a) and the power of the largest prime movers (**Figure 2.17**b) in history and before.

In prehistory, humans lived in tribes (Hunter-Gatherers), having almost the same technological limit consisting of their own power (~120 W) and metabolized their food, ~2500 kcal, producing and using ~3 kWh per day muscular energy. So, energy in Hunter-Gatherers societies was equally distributed. Population was sparse and the natural resources were ample with ~100 ha sufficing to produce food for one human.

Generally, anthropologists assume that Hunter-Gatherers, lived without stratification (Gowdy, 2006; Smith et al., 2010; Orans, 1966) but some approaches show that there was a stratification in prehistory (Angle, 1986). A related paper estimates average Gini coefficient, an overall measure of wealth inequality, assuming multiple parameters in Hunter-Gatherers, equal to 0.25 (Smith et al., 2010) which shows a faint stratification.

[I] BP, Statistical review of world energy, June 2018 https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

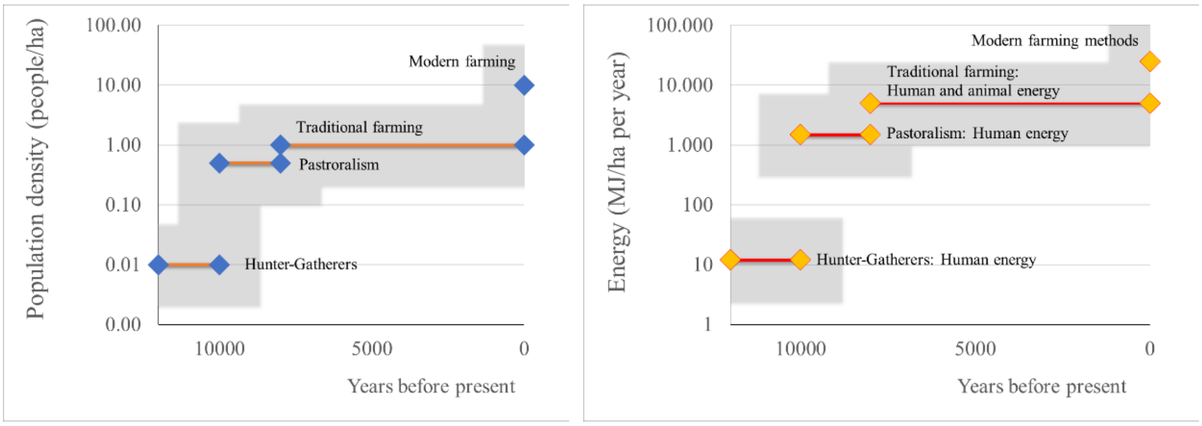
[II] WHO/UNICEF (2015) Progress on Sanitation and Drinking Water: 2015 Update. Available online: https://data.world/adamhelsinger/unicef-drinking-water-database (accessed 25 January 2022).



(a) (b)

Figure 2.17 (a) Temperatures created by human actions in different eras (b) Power of the largest prime movers in different eras [I], (Smil, 2004a; Smil 2004b) (diagrams present data in logarithmic scale as order of magnitude).

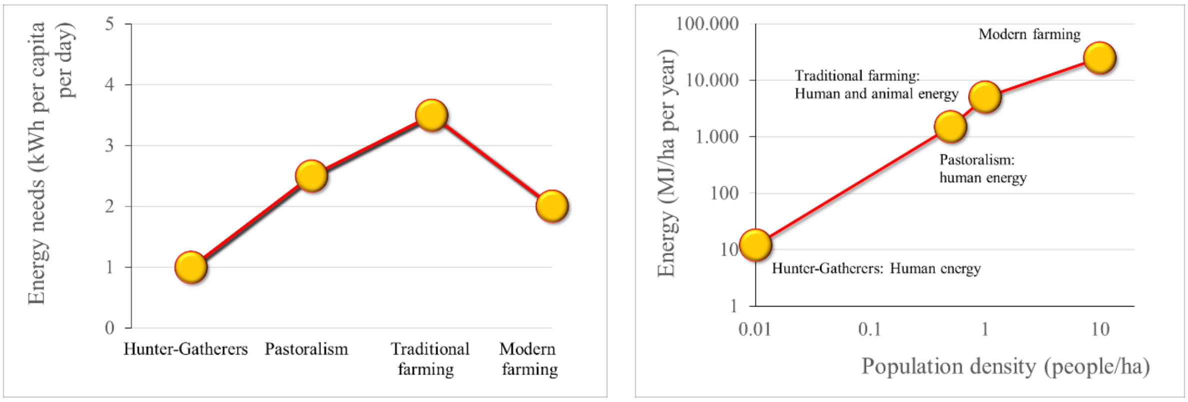
In order to cluster in tribes (Sargentis et al., 2020; Goldewijk et al., 2011), humans had to use smaller areas to collect food. (**Figure 2.18**). In the period of pastoralism, humans were clustered 50 times more than Hunter-Gatherers, and when traditional farming was developed, clustering increased respectively (**Table 2.1**). At the same time, energy required per ha was ~100 and ~200 times more (**Figure 2.19**) (Smith, 2019; Jiang et al., 2019; Davis and Hatfield, 2007; Coughenour et al., 1985; Smil, 2004a; Smil, 2004b; Singh et al., 2002; Canakci et al., 2005; Kander et al., 2009; Kander and Warde, 2011; Schnepf, 2004; Vreni et al., 2015; Sackett, 1996). Sackett found that adults in foraging and horticultural societies work, on average, about 6.5 hours a day, whereas people in agricultural societies work on average 8.8 hours a day (Sackett, 1996).



(a) (b)

Figure 2.18 Typical types of food production in different eras related to (a) population density (b) energy needs (diagrams present data as order of magnitude).

[I] Steam Turbines: How Big Can They Get? Available online: https://www.modernpowersystems.com/features/featuresteam-turbines-how-big-can-they-get/ (accessed on 5 October 2020).



(a) (b)

Figure 2.19 (a) Population density related to energy needs (b) Energy needs per capita per day in different types of societies (diagrams present data as order of magnitude).

Table 2.1 shows that Hunter-Gathers, needed a relatively small amount of their energy to collect food. Survival needs arising from human clustering are energy intensive and more powerful means than humans, as horses and ox (~500 W, ~10 times more) were employed.

Table 2.1 Prehistoric human, different types of living, minimum area and energy needs for food production (present data as order of magnitude)

Type of living	Area (ha)	Energy per capita per day for food (kWh)
Hunter-Gatherers	100	1
Pastorals (pastoralism)	2	2,50
Granger (agriculture)	1	3,50

2.8 Access to food: from antiquity to present

It is almost impossible to estimate the value of wealth based on the exchange rate of the currencies or the value of precious metals in historical eras. But as wheat is the base element of the digestive menu of humans and we have historical information of its cost and the wages, we estimate the wheat wages (i.e., the litters of wheat which can be bought by a daily wage). This allows as to create an important cross-cultural comparison of economic wellbeing (Scheidel, 2010; Milanovic et al., 2007; Jursa, 2010).

In antiquity the average daily wage levels was about 7.9 liters/day. Classical Athens had the highest average daily wage. Loomis (1998) notes:

> *In Eleusis near Athens in the 320s BCE, epigraphic records report that unskilled construction workers received 1.5 drachms per day, compared to 1.25-2.5 drachms for skilled workers. At that time, wheat sold for 5 to 6 drachms per medimnos (c. 52 liters).*

This translates into a daily wheat wage of 13-15.6 liters.

Figure 2.20 visualize the average daily wheat wages of unskilled labourers from 21st c. BC until Renaissance [I] (Milanovic, 2006; Van Zanden, 1999; Boyne, 1865).

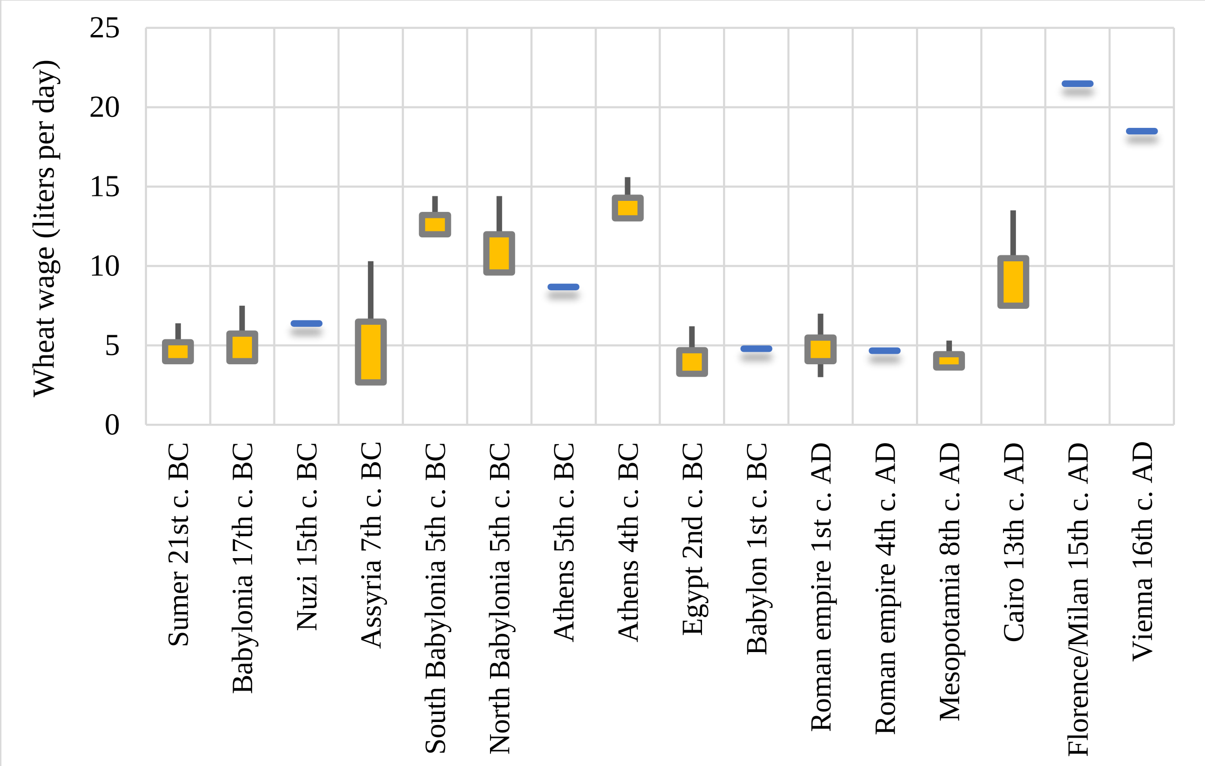


Figure 2.20 Average wheat wages of unskilled labourers in preindustrial societies.

As we want to correlate the wealth with wheat wages, we study the values of gold, silver and oil related to wheat in today values (1990-2019) in **Figure 2.21**.

In this analysis we note the following range of fluctuations e.g., coefficient of variation of: Gold-to-Silver Ratio=2.57; Gold-to-Wheat Ratio=0.95; Oil-to-Wheat Ratio=0.04 and Silver-to-Wheat Ratio=0.01. Interestingly note is that the minimum fluctuation corresponds to the Silver-to-Wheat Ratio.

The prices of wheat in countries' markets are differing than the prices of global markets, however, considering local prices double than global markets (e.g. 0.3 US$/L), we visualize an indicative relation of wheat wages based on the average GDP per capita[II] of 95 different countries in 2016 (**Figure 2.22**).

Figure 2.22 is encouraging, and shows the progress we have done from antiquity. However, it shows the average values of daily wheat wages and not the wages of unskilled laborers. With reverse calculation we find that the average daily wheat wage of an unskilled laborer in antiquity (7.9 L/day) corresponds to about 2.37 US$/day, slightly

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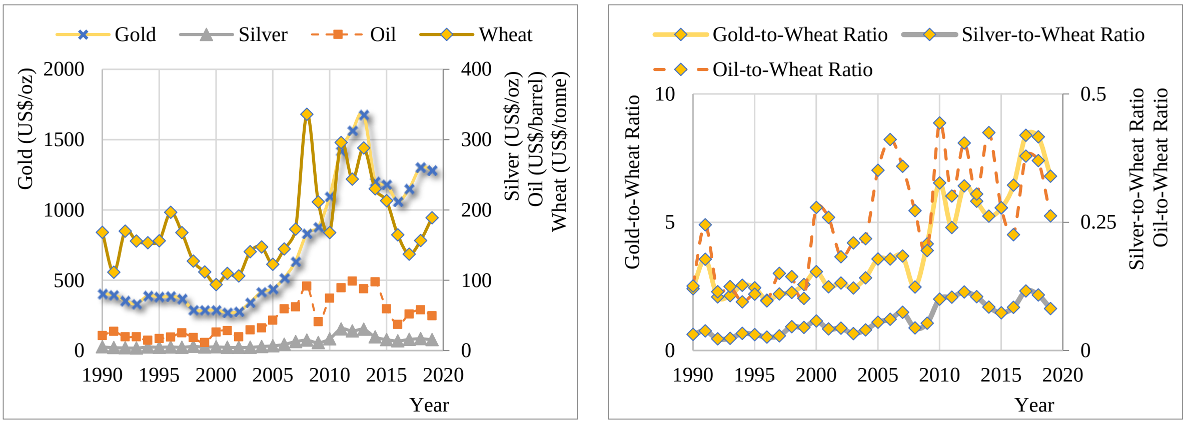
[I] International institute of social history. Value of the Guilder versus Euro . A comparison of the purchasing power of the guilder from the year 1450 to another year. Available online: https://iisg.amsterdam/en/research/projects/hpw/calculate.php#Europe (accessed 25 January 2022).

[II] Data retrieved on 2022-01-25 by Maddison Project Database 2018. Available online: https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2018.

higher than the value of 1.9 US$ which is considered as the limit to extreme poverty[I]. Studding the income mountains in Gapminder (year 2016)[II] we find that about 1.4 billion people (17.5% of population) live today under the average daily wage in antiquity.



(a) (b)

Figure 2.21 (a) values of gold and wheat; (b) gold-to-wheat ratio; (c) values of oil and wheat; (b) oil-to-wheat ratio; (e) values of silver and wheat; (d) silver-to-wheat ratio[III].

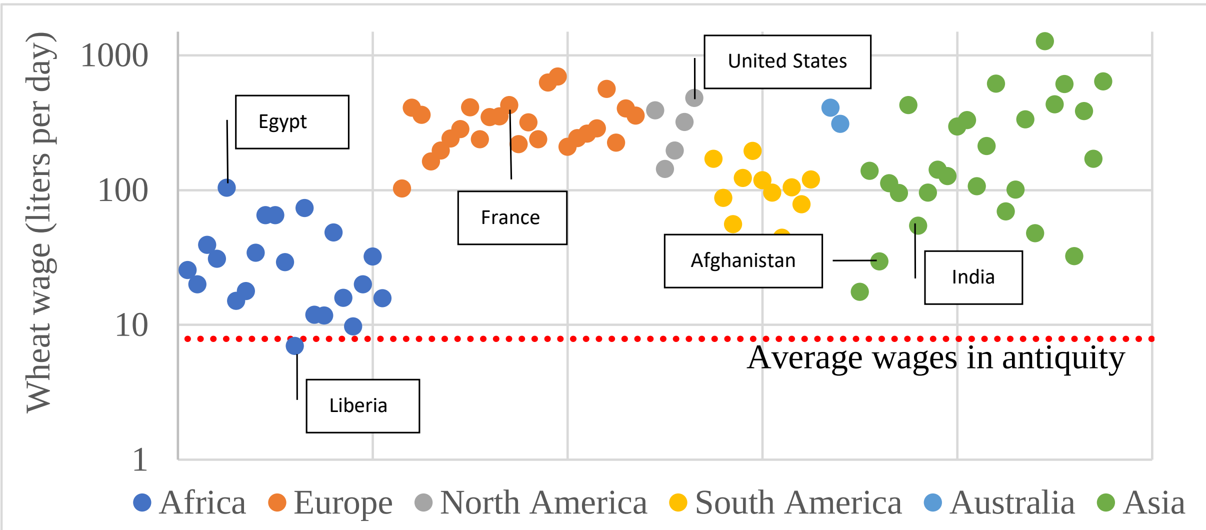


Figure 2.22 Average wheat wages (2016) related to the average wheat wage of an unskilled labourer in antiquity. Data are presented as an order of magnitude.

2.9 Cultural elements of prosperity

Art's functions are vital for our society on multiple levels. A work of art is not only (and perhaps not necessarily) something pleasing to the eye, but also a medium that portrays our emotions. Although each artist's work contains a unique message, the field of art

[I] Global Extreme Poverty. Available online: https://ourworldindata.org/extreme-poverty (accessed 25 January 2022).

[II] Data retrieved on 2022-01-25 by Gapminder. Income Mountains. Available online: https://www.gapminder.org/fw/income-mountains/

[III] Data retrieved on 2022-01-25 by International Monetary Fund. IMF DATA access to macroeconomic and financial data. Available online: https://data.imf.org/

creates a cultural process; aesthetics: a communication channel between the artist and the observer.

Digression 2.C: The correlation of cultural elements and prosperity

Strides of civilization are connected to technological issues which improved the quality of life (Koutsoyiannis and Sargentis, 2021; Sargentis et al., 2021) as; the installation of hydraulic works (Hydraulic Civilization (Wittfogel, 1957)), architectural creations, great technological inventions which change the history (e.g., the evolution of wheels), combination of technological issues which creates a remarkable duration of social stability (e.g., Minoan civilization 3000—1100 BC (Angelakis, 2016) and admirable technological creations as the Mechanism of Antikythera.

Herein a question arises: why do we have to study art issues? Friedrich Nietzsche (1844-1900) notes that: “The ugly truth is: we have art so that we go not to the underlying truth.” (Nietzsche 1888). Maybe what is “true” for an artist is different than truths of a philosopher or a scientist and represents the spirit of the civilization.

It can be argued that human civilization can be studied through the history of forms and their meaning, signifiers and the signified as defined by an observer. Humans create structures and intentional forms on a canvas of natural randomness since the first time a prehistoric man laid two stones one on top of the other to build a home of the other or placed a big rock in the form of a menhir. Cave paintings depicting the activities of hunting or social events already reveal that proportions and colour was, from the earliest known forms of art, essential in expressing the relations between anything that was important to human life and the form through which it was expressed. As urban landscapes started to emerge, architecture and urban forms then begun to reflect the culture and lifestyle of their creators. Thus, both art and the interventions of civilizations in landscapes can be considered as an Ark of historical memory. That contains and, in a sense, protects cultural heritage.

Throughout human history, studying art has mostly been regarded a part of philosophy, social sciences and humanities. However, since as early as the Pythagoreans and up to this day, mathematics have also been used to investigate the nature of artistic expression and its effects on the observer.

Pythagoras and Euclid were the first philosophers known to have searched for the existence of a common rule (canon) in shapes that are perceived as beautiful. Notably, Euclid's Elements (c. 300 BC) includes the first known definition of the golden ratio. The word canon, or set of proportions, comes from Greek (*κανών*) and means a straight rod (measuring line) and metaphorically a rule or standard. Of course, canons, in Euclid's sense, have changed through history, altering artistic expression, taste, and the sense of beauty overall.

Principles and canons (rules) other than the golden ratio have also been used to ʹH used to generate specific aesthetic results. Different proportions of simple shapes have been studied as a way of conveying emotions, in an attempt to approach the very nature of the aesthetic sense and the experience of beauty. An important notion of this type of studies is that these different stances make the observer feel what it would be like to be the observed object, a kind of empathy towards shapes and objects.

These quantifiable properties of aesthetics in an object were introduced from the neo-platonic tradition into medieval thought and have been studied by many thinkers throughout the ages.

It needs to be clarified that the properties in question are not related to the use of the object. As Immanuel Kant points out, the pleasure of beauty is of a very special kind: it is "uninterested" (Beardsley, 1975). This is not to say that the object could or should not have any other use rather than as an object of perception. It is to say that when we discuss the issue of beauty, we refer to any pleasure offered by an object that is independent of practical uses.

2.10 Introductory discussion

We show that wealth as GDP per capita is a prosperity to humanity which increase the life expectancy. However, the true wealth is the availability of water-food-energy which is also related with life expectancy and GDP showing that, the coverage of real needs is what prosperity is. Data analysis confirm our hypothesis.

We also show that the values of commonly used symbols of wealth (gold and silver), change in history by social issues, as the demand for gold and silver can vary wildly with a fixed supply, that can lead to equally wild swings in its price.

Therefore, we estimate the values of wages in antiquity and present, as wages in wheat which is an important cross-cultural comparison of economic wellbeing. Analysing global data, we show that about 1.4 billion people live in present under the average lower wages in antiquity.

Since the creation of science in the 6th century BC (Koutsoyiannis and Mamassis 2021), improvements in the quality of life ensued based on progress of science, technology and medicine (Pickstone, 1993), fostered increasing life expectancies (Alcamo et al., 2003; Aus der Beek et al., 2010).

All of the above (science, technology, medicine) are optimized with division of labor, social organization and economy. Necessary condition of them is the continuity and the function of educational system. Communication-cooperation (interactions), and economies of scale, helped scientific research and technology to create infrastructures and low-cost production which are the base in flourishing societies (Koutsoyiannis, 2011; Sargentis et al., 2019; Sargentis et al., 2018; O'Sullivan, 2003; Koutsoyiannis 1979).

Chapter 3. External and the internal view of societies' structure

Each organism is studied based in its external shape and its internal structure. Therefore, we consider for society: as external shape, the potentialities of clustering or partitioning and as internal structure the distribution of wealth and stratification.

3.1 Clustering and growth

«αἰεὶ τὸν ὁμοῖον ἄγει θεὸς ὡς τὸν ὁμοῖν» (Οδύσσεια, ρ 218)

"All ever, the god is bringing like and like together." (Homer-Odyssey)

Clustering is a natural process which makes the organisms to use more efficient the natural resources[I]. **Figure 3.1** shows that elephants, requires about 10 000 times less energy per mass than a mouse. Larger scales also increase the efficiency for mammals in terms of water consumption for survival.

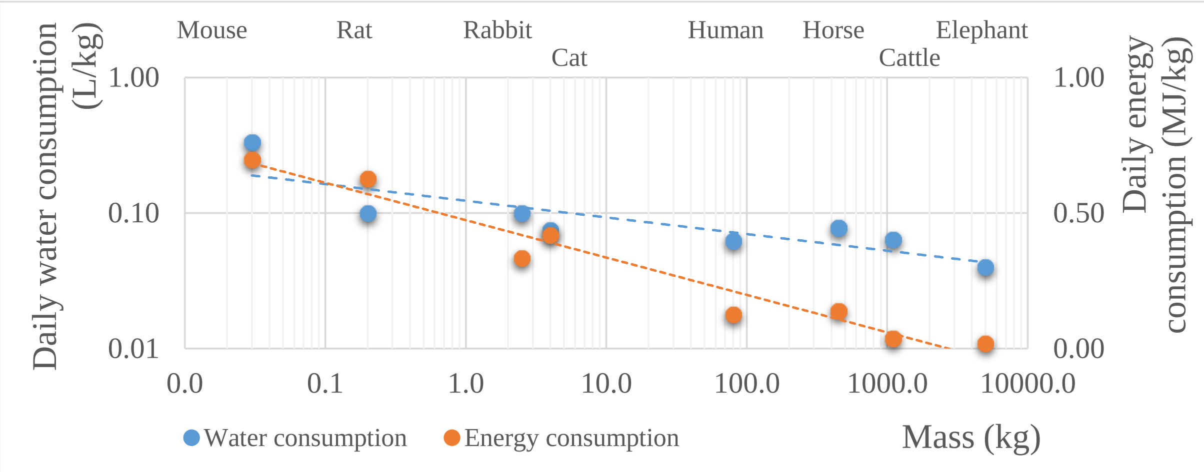


Figure 3.1 Daily energy and water consumption of mammals[II].

3.2 Partitioning and protection

A more holistic inspection of natural evolution reveals however hidden elements of clustering. Dinosaurs were the biggest living creatures in nature but about 66 million

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[I] Johnson, G. Of Mice and Elephants: A Matter of Scale. Science, The New York Times, 12 January 1999. Available online: http://courses.missouristate.edu/chrisbarnhart/bio121/lab/respiration/of_mice_and_elephants.htm (accessed 2 February 2022)

[II] Data adapted by:

Asian elephant nutrition, Energy expenditure, 25 February 2015. Available online: https://asianelephantnutrition.wordpress.com/2015/02/25/big-body-lots-of-energy-maintenance/ (accessed 5 February 2022).

Bermingham, E.; Thomas, D.; Morris, P.; Hawthorne, A. Energy requirements of adult cats. British Journal of Nutrition, 103(8), 1083-1093. 2010. doi:10.1017/S000711450999290X.

National Research Council (US) Subcommittee on Laboratory Animal Nutrition. Nutrient Requirements of Laboratory Animals: Fourth Revised Edition, 1995. Washington (DC): National Academies Press (US); 1995. Available online: https://www.ncbi.nlm.nih.gov/books/NBK231925/ (accessed 5 February 2022) years ago they disappeared. Smaller animals such as mammals survived because of "Being small. If you're small you probably have a large population and thus a wider genetic diversity"[I]. In this sense, even though clustering can be important for economy and is associated with goals of growth, partitioning is a way of protection, by reducing dependencies and risks associated with centralized infrastructure.

Digression 3.A: The vision of Hobbes's Leviathan

The idea of economies of scale as developed by Adam Smith (O'Sullivan, 2003) is that with the increase of growth comes a decrease of the cost per unit. The advantages of economies of scale have theoretical limits, i.e., when reaching the optimal design point where the cost per additional unit begins to increase. Economies of scale are related to scale development of infrastructures where there are also additional limits as induced due to lack of funds, technical difficulties as well as public opposition (Manta, 2020) and resources accessibility. Large scales of infrastructure have risks (Vickerman, 2007) but are also advantageous for local economies (Jadhav and Desai, 2019). Previous works has shown that changing the scale of water infrastructures results to changes in the cost of water in agreement with the so-called "0.6 rule" in macroeconomics (Tribe, 1986; Haldi 1961).

This relationship is also addressed by Wenban-Smith (Wenban-Smith, 2009) who uses the term "density effects" to describe clustering trend towards concentration of population and large scales infrastructures. For instance, in Greece we can see this clustering trend in terms of infrastructure in construction of large-scale dams. Other emblematic examples of large-scale projects, are the controversial "North American Water and Power Alliance" II (not constructed yet), Tehri DamIII (constructed in India) the Three Gorges DamIV (constructed in China).

In order to find the best solution in optimum scale infrastructure problem, multi-criteria optimization is required. Despite the contributions of mathematicians, little progress has been made in engineering problem until the last half of the twentieth century, when high-speed digital computers made it possible to apply optimization techniques to large-scale structures with powerful and popular complex optimization methods. Still, it is often the case that rather than cost-benefit optimization, political and aesthetical reasons (as the desire for creation of civilization signals), are the driving forces for the choice of the scale of historical infrastructures; notable examples are shown in Figure 3.2.

What is common though in these large-scale projects, is the existence of an efficient state structure able to take the relevant decisions about political and administrative mechanisms for decisions clustering, impose them and finance them. Thus, they reflect the presence of a stable social mechanism which, according to the theory of Tomas Hobbes (Hobbes 1968), is represented by Leviathan.

[I] Hone, D. How to survive mass extinction. The Guardian, 20 September 2022. Available online https://www.theguardian.com/science/lost-worlds/2012/sep/20/dinosaurs-fossils (accessed 2 February 2022)

[II] North_American_Water_and_Power_Alliance.
Available online: https://en.wikipedia.org/wiki/North_American_Water_and_Power_Alliance (accessed 2 February 2022)

Nuclear Nawapa XXI gateway to the fusion economy, 21st Century Science & Technology, Special Report, 2013, https://21sci-tech.com/Nuclear_NAWAPA_XXI/Nuclear_NAWAPA_sm.pdf (accessed 2 February 2022)

[III] Tehri Dam. Available online: https://en.wikipedia.org/wiki/Tehri_Dam (accessed 2 February 2022)

[IV] Three_Gorges_Dam. Available online: https://en.wikipedia.org/wiki/Three_Gorges_Dam (accessed 2 February 2022)

(a) (b) (c)

Figure 3.2 (a) The Great Pyramid of Giza 2560 BC[I]; (b) Notre-Dame de Paris, towers on west façade 1220–1250 AD[II]; (c) Eiffel Tower 1887-1889[III].

The latter metaphorically represents a central political entity that seeks to preserve law and peace by imposing a utilitarian egoism driven by the instinct of self-preservation (conatus) and the will to dominate, exercising absolute power only in favor of preserving social peace, i.e., the well-known social contract. Leviathian also undertakes the protection of citizens from external and internal factors, while also protects citizens from the central entity itself. From this idea originates the Constitution as a self-limitation of power. As engineering development is intertwined with social peace and prosperity, we can assume that a form of centralized socio-political structure the likes of Leviathan is required in order to undertake decisions about large-scale development and infrastructure projects.

Digression 3.B: Aristoteles' opinion for large-scale infrastructures

Another view on the creation of large infrastructure projects through centralized social structures is given by Aristotle[IV]: *"…καὶ τὸ πένητας ποιεῖν τοὺς ἀρχομένους τυραννικόν, ὅπως μήτε φυλακὴ τρέφηται καὶ πρὸς τῷ καθ᾽ ἡμέραν ὄντες ἄσχολοι ὦσιν ἐπιβουλεύειν. παράδειγμα δὲ τούτου αἵ τε πυραμίδες αἱ περὶ Αἴγυπτον καὶ τὰ ἀναθήματα τῶν Κυψελιδῶν καὶ τοῦ Ὀλυμπίου ἡ οἰκοδόμησις ὑπὸ τῶν Πεισιστρατιδῶν, καὶ τῶν περὶ Σάμον ἔργα Πολυκράτεια (πάντα γὰρ ταῦτα δύναται ταὐτόν, ἀσχολίαν καὶ πενίαν τῶν ἀρχομένων)"*. English translation[V]: "*And it is a device of tyranny to make the subjects poor, so that a guard may not be kept, and also that the people being busy with their daily affairs may not have leisure to plot against their ruler. Instances of this are the pyramids in Egypt and the votive offerings of the Cypselids, and the building of the temple of Olympian Zeus by the Pisistratidae and of the temples at Samos, works of Polycrates (for all these undertakings produce the same effect, constant occupation and poverty among the subject people*".

This example highlights the mutually dependent relation between central entities and large-scale development: the existence of the one often relies on the other.

While human social clustering increases the chances for social progress and prosperity, it also increases exposure and vulnerability to different kinds of risk. For the first time in human history more people live in cities than in rural areas. This rapid growth in the

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[I] Available online: https://en.wikipedia.org/wiki/Great_Pyramid_of_Giza (accessed 2 February 2022)

[II] Available online: https://en.wikipedia.org/wiki/Notre-Dame_de_Paris (accessed 2 February 2022)

[III] Available online: https://en.wikipedia.org/wiki/Eiffel_Tower (accessed 2 February 2022)

[IV] Aristoteles. Politica; Oxford Clarendon Press: Oxford, UK, 1957; Available online: https://books.google.gr/books/about/Aristotelis_Politica_recognovit_brevique.html?id=--LdnQEACAAJ&redir_esc=y (accessed on 15 September 2020).

[V] Aristotle, Politics, English Translation. Available online: https://www.loebclassics.com/view/aristotle-politics/1932/pb_LCL264.461.xml (accessed on 1 August 2020).

number of people living in cities and urban landscapes is increasing the world's susceptibility to natural disasters[I] and other threats[II]. For instance, in the case of war, large-scale infrastructure projects are important and common targets. **Figure 3.2**a depicts Serbian civilians, forming human shields to protect their country's infrastructure during the NATO bombing of Yugoslavia at the Kosovo War (1999). Large-scale infrastructures are also symbols of civilizations and this is why the World Trade Center was the target during the 9/11/2001 attack (**Figure 3.2**b).

On the other hand, modern large-scale infrastructure projects have a life of no more than 120 years due to aging of their materials and the difficulties in maintaining them[III]. As a simple example, consider the two collapses of large-scale bridges that have occurred in Italy in the past few years, causing fatalities and massive disruption of transportation[IV]. Moreover, it is straightforward to see how a possible failure in large-scale water-supply infrastructures upon which societies are heavily reliant would create a vague gap in social functioning[V].

It is therefore evident that with the increase of the scale of the development along with the planned increase of benefits comes also an increase of risks, as the concentration of goods and services in one place makes the human communities more vulnerable to a destruction thereof. Interestingly, metaphors on the existence of a limit in the scale of human works are present in various literature and theological works since antiquity, perhaps the most famous examples are found in the Bible. In the latter the man is regarded as the crown of God's Creation and by the fall of man in Original Sin, the whole Creation falls. After the fall of humans the environment became hostile and man had to do work to

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[I] India Environment Portal Knowledge for Change, Natural Disasters: Saving Lives Today, Building Resilience for Tomorrow. Available online: http://www.indiaenvironmentportal.org.in/content/383261/natural-disasters-saving-lives-today-building-resilience-for-tomorrow/ (accessed on 20 August 2020).

India Environment Portal Knowledge for Change, Mind the Risk: A Global Ranking of Cities under Threat from Natural Disasters. Available online: http://www.indiaenvironmentportal.org.in/content/389862/mind-the-risk-a-global-ranking-of-cities-under-threat-from-natural-disasters/ (accessed on 20 August 2020).

[II] Hill, D. The City as Destructive System: Wildfires, Dresden and the Case against Urban Sprawl. Available online: https://www.cityofsound.com/blog/2007/10/the-city-as-des.html (accessed on 15 September 2020)

[III] At our Current Pace it'll take 80 years to Repair all the Structurally Deficient Bridges in the US, A Report Finds. Available online: https://edition.cnn.com/2019/04/02/us/deficient-bridge-report-2019-trnd/index.html (accessed on 15 September 2020)

[IV] Crollo del ponte di Albiano Magra, 17 indagati. Available online: https://www.ilsecoloxix.it/la-spezia/2020/04/20/news/ponte-crollato-sul-magra-17-persone-indagate-1.38741043 (accessed on 15 September 2020)

Genova, crollo del ponte Morandi sull'A10: cosa è successo. Available online: https://www.corriere.it/cronache/18_agosto_14/genova-crollo-ponte-morandi-sull-a10-cosa-sappiamo-finora-46d3d094-9fb5-11e8-9437-bcf7bbd7366b.shtml (accessed on 15 September 2020)

[V] Large Dams: Learning from the Past Looking at the Future, Part 166. Available online: https://books.google.gr/books?id=Ug2YrzNl8EUCyhtNvFS78CXu5An_yuovIw&hl=en&sa=X&ved=2ahUKEwilr5PO6KPpAhVynVwKHdc9BGIQ6AEwAHoECAYQAQ#v=onepage&q=icald%20big%20dams&f=false (accessed on 15 September 2020).

survive. In the famous myth of the Babel tower, the Bible explicitly communicates the notion of an upper limit in the scale of human works[I].

(a) (b)

Figure 3.3 (a) Serbians protecting their country's infrastructure from bombing as human shields[II] (b) The north face of Two World Trade Center (south tower) immediately after being struck by United Airlines Flight 175[III].

Recently, due to the ongoing COVID-19 pandemic, we are collectively reminded of how large-scale human social clustering increases the risk of pandemics. In the developed world, the majority of measures to mitigate the spread of a pandemic has been based on forms of social distancing, with lock-down being the ultimate measure. Nearly three billion people were in quarantine in April 2020[IV]. In this respect, the Epicurean philosopher Lucretius says that if there is no immediate risk of death, people are not afraid of death (Smith, 2001), but the fear of death can lead people to make social divisions and suspend their personal growth[V]. Indeed, when people are afraid of dying, it is common to believe that avoidance of social contact will help them avoid danger, illness and death, altogether. This phenomenon is well documented in social fear management studies (Holdbrook et al., 2011) and in this context, it can also be viewed as another implicit communication of the risks of social clustering.

[I] Holy Bible, Old Testament, Genesis 11; Job 38:1-41. Available online: http://www.apostoliki-diakonia.gr/bible/bible.asp?contents=old_testament/contents.asp&main=OldTes (accessed on 15 September 2020).

Holy Bible, New Testament, 8:20-22. Available online: http://www.apostoliki-diakonia.gr/bible/bible.asp?contents=new_testament/contents.asp&main= (accessed on 15 September 2020).

[II] 21 Godina od NATO Agresije- „Nemilosrdnog anđela "nema Zaborava. Available online: https://pvportal.me/2020/03/15-godina-od-nato-agresije-nemilosrdnog-andela-nema-zaborava/ (accessed on 15 September 2020).

[III] September_11_Attacks. Available online: https://en.wikipedia.org/wiki/September_11_attacks (accessed on 15 September 2020).

[IV] Nearly 3 Billion People around the Globe under COVID-19 Lockdowns-Today's Coronavirus Updates. Available online: https://www.weforum.org/agenda/2020/03/todays-coronavirus-updates/ (accessed on 15 September 2020).

[V] Why a Roman Philosopher's Views on the Fear of Death Matter as Coronavirus Spreads. Available online: https://theconversation.com/why-a-roman-philosophers-views-on-the-fear-of-death-matter-as-coronavirus-spreads-132951 (accessed on 15 September 2020).

Digression 3.C: The origins of social stratification

It would be oversimplification if we considered that the available resources are distributed equally between the members of the society[I]. An interesting related paper by Kohler et al., shows that the increasing of technology and available energy (use of animals) in ancient times is related to the increasing of inequality (Kohler et al., 2017). Same conclusions are delivered by Atkinson for modern economies (Atkinson, 2015). Recent studies (Koutsoyiannis and Sargentis 2021; Sargentis et al., 2021) draw similar conclusions, presenting the dynamics of stratification in societies with an entropic approach. Roser and Ortiz-Ospina[II], based on the publication of Milanovic et al. (Milanovic et al., 2011), visualize how inequality increases with higher average income.

Social stratification in the history of human societies occurs persistently and organically, as if it obeys a natural law. There is a wide range of types of stratification in societies, i.e., in terms of financial class, political power, level of education, sanctity, military force. In economic, political and social sciences, stratification is one of the most important issues (Milanovic, 2011; Haitovsky 2001).

3.3 Distribution of wealth and theories of social stratification

«τῷ γὰρ ἔχοντι παντὶ δοθήσεται καὶ περισσευθήσεται, ἀπὸ δὲ τοῦ μὴ ἔχοντος καὶ ὃ ἔχει ἀρθήσεται ἀπ αὐτοῦ» (Καινή Διαθήκη, Κατά Ματθαίον 25:29)

“For everyone who has, will be given more, and he will have an abundance. Whoever does not have, even what he has will be taken from him.” (New Testament, Matthew 25:29)

After the Middle Ages, emblematic approaches examining social stratification were formulated, the most widely known are those of Adam Smith (1723-1890), David Ricardo (1772-1823), Thomas Robert Malthus (1766-1834), Social Darwinists (late 1800s) and Karl Marx (1818-1883).

Smith noted that "wherever there is great property, there is great inequality ... for one very rich man, there must be at least five hundred poor". He also pointed out the important role of morality in social functioning and noted that without the welfare of the labouring classes the prosperity of the nation is both morally unacceptable and practically impossible (Smith, 1776; Philipson, 2010).

Unlike Smith, Ricardo supported the iron law of wages (Gray 1946), according to which working-class wages must be fixed at a "natural price" that would only cover the costs of marginal survival, arguing that from prehistoric times, most grangers also lived in misery (Galbrain, 1987). Exceeding Ricardo’s cynicism, Malthus suggested that the most effective solution would be the abandonment and natural extermination of malnourished people claiming that population growth acted as a deterrent to the progress of a society because the population was supposedly much larger than what the earth could sustain (Malthus 1798).

[I] UNU World Income Inequality Database – WIID Available online: https://www.wider.unu.edu/database/wiidhttps://www.wider.unu.edu/database/wiid (accessed 27 June 2021).

[II] Roser, M.; Ortiz-Ospina, E. How unequal were pre-industrial societies? Available online: https://ourworldindata.org/income-inequality#how-unequal-were-pre-industrial-societies (accessed 9 January 2022).

Herbert Spencer (1820-1903) and Francis Galton (1822-1911) inspired by Charles Darwin's propositions which are described in "Origin of Species" (1859) (Darwin, 1859), advocated the concept of survival of the fittest in the social world, an approach called Social Darwinism. (n.b., Galton was also the father of eugenics). According to this, the state should not interfere in the spontaneous processes of society, leaving the 'strongest' people to survive and the 'weak' to perish, which would presumably lead to ever higher levels of society's development (Rogers, 1972; Hawkins 1997).

Subverting the prevailing theories, Marx argued that social classes were formed unnaturally during the historical period of humankind as a result of extreme material inequalities created by the over-exploitation of the working-class labour by the owners of the means of production (Marx, 1867). Thus, he formulated the rule "From each according to his ability, to each according to his needs"[I] (Sitton, 2010). Another influential economic approach of the last century was presented by John Keynes (1883-1946) in "The General Theory of Employment, Interest and Money" (Keynes, 1936). Arguably, the prevailing theory of modern times is neoliberalism, a policy model that emphasizes the value of free market competition. The theory was supported by the Chicago School and notably expressed by the works of Milton Friedman (1912-2006) (Friedman, 1960) and Friedrich Hayek (1899-1992) (Hayek 1960). Critiques on neoliberalism have been expressed pertaining to its relation with inequality, e.g. as described by Zoya Hasan in "Democracy and the crisis of inequality" (Hasan, 2014) and Walter Rodney (1942-1980) in "How Europe Underdeveloped Africa" (Rodney 1972). Recently new ideas were put forward, one by Tim Jackson who introduced "prosperity without growth" (Jackson, 2009) and the other by Serge Latouche who introduced "Degrowth" (Latouche, 2018; Latouche 2004).

3.4 Common quantitative measures of social stratification

To frame the results within the context of a typical economic analysis of the income distribution, we employ two well-known measures of socio-economic inequality, the Lorenz curve (Lorenz, 1905; Bellù 2005; Tresch, 2015; Ross, 2021) and the Gini coefficient[II].

As usual with economic data, we follow the convention of expressing the income distribution in tenths of the share x (%) of people from the lowest to highest income vs share y (%) of income earned. In **Figure 3.4**a the rectangles show the case of all people having the same income and the diamonds show the case of extended inequality i.e., if the last tenth of share (%) has the most part of the wealth (Pareto distribution).

Figure 3.4b shows the Lorenz curve, which is the plot of the cumulative share of income vs the corresponding cumulative share of the population. In the case of a perfect

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[I] Marx, K. Critique of the Gotha Programme, Available online: https://www.marxists.org/archive/marx/works/1875/gotha/ch01.htm (accessed 21 January 2021)

[II] Income inequality. Available online: https://ourworldindata.org/income-inequality (accessed 25 August 2021).

Gini Index. Available online: https://www.investopedia.com/terms/g/gini-index.asp (accessed 25 August 2021).

socio-economic equality, the curve is a straight line (plotted in rectangles) and the diamonds show the case of extended inequality. From the Lorenz curve we can calculate the Gini coefficient, which is a measure of socio-economic inequality estimated as: $G = A/(A + B)$, where A is the area that lies between the line of equality and the Lorenz curve, and B is the area between the Lorenz curve and the horizontal axes. Values of G tending to 0 indicate equality, whereas values closer to 1 indicate inequality.

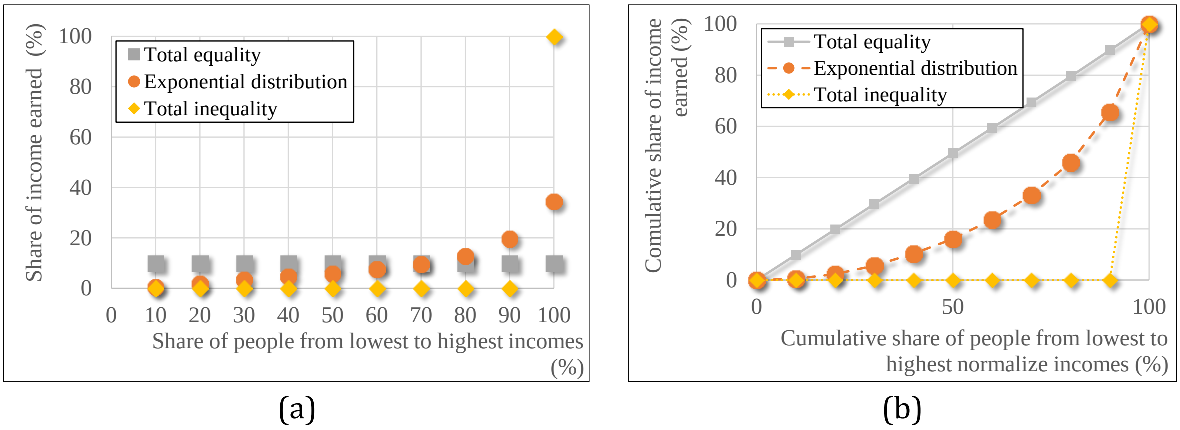


Figure 3.4 Different types of distribution of wealth. Grey rectangles show total equality with Gini coefficient equal to 0; orange circles show exponential distribution with Gini coefficient equal to 0.5; yellow diamonds show power-type Pareto distribution (greediness of elite) with Gini coefficient equal to 0.7 (a) Share of wealth (b) Lorenz curve.

Chapter 4. Stochastic tools

In this thesis many stochastic tools to analyse data have been used. However, as there were not available tools to approach our issues, new tools have been developed. In this Chapter, we will see a presentation and benchmarks of these tools.

4.1 Study of clustering in 2D space (2D-C)

Image processing typically involves filtering or enhancing an image using various types of functions in addition to other techniques to extract information from the images (Zhang, 2004). Image segmentation is one of the basic problems in image analysis. The importance and utility of image segmentation has resulted in extensive research and numerous proposed approaches based on intensity, color, texture, etc, and both automatic and interactive (Martin et al., 2001). A variety of techniques have been proposed for the quantitative evaluation of segmentation methods (Kohonen, 1997; Abdou and Pratt 1979; William et al., 1977; Sahoo et al., 1988; Otsu, 1979; Martin, 1985; Weszka and Rosenfeld, 1978).

Stochastic calculus helps in developing a unified perception of natural phenomena and expel dichotomies like random vs. deterministic. It seems that rather both randomness and predictability coexist and are intrinsic to natural systems which can be deterministic and random at the same time, depending on the prediction horizon and the time scale (Koutsoyiannis, 2010; Dimitriadis et al., 2016).

A variety of processes exhibit Long-Term Persistence (LTP) behaviour such as temperature, humidity, surface wind, precipitation, atmospheric pressure, river discharges etc (Dimitriadis, 2017). Particularly, all these processes are characterized by high unpredictability due to the clustering of events. The behavior of some processes to exhibit high unpredictability due to the clustering of events was first identified in nature by H.E. Hurst in 1951 while working at the River Nile, although its mathematical description is attributed to A. N. Kolmogorov who developed it while studying turbulence in 1940 (Hurst, 1951). Koutsoyiannis (Koutsoyiannis 2010) named this behavior as Hurst-Kolmogorov dynamics (HK), to give credit to both contributing scientists.

This analysis for image processing is based on a stochastic tool called climacogram. The term climacogram (variability vs. scale) (Koutsoyiannis, 2013a; Koutsoyiannis, 2013b) which comes from the Greek word "*κλίμαξ*" pronounced: climax (meaning scale). It is defined as the (plot of) variance of the averaged process (assuming stationary) versus averaging scale k and is denoted as $\gamma(k)$. The climacogram is useful for detecting both the short- and the long-term change (or else dependence, persistence, clustering) of a process, with the latter emerging particularly in complex systems as opposed to white-noise (absence of dependence) or Markov (i.e., short-range dependence) behavior (Dimitriadis and Koutsoyiannis 2015).

In order to obtain a quantitative characterization of the artwork, its image is digitized in 2D and each pixel is assigned a grayscale color intensity (white = 1, black = 0). Assuming that our sample is an area $n\Delta \times n\Delta$, where n is the number of intervals (e.g., pixels) along each spatial direction and Δ is the discretization unit determined by the image resolution, (e.g., pixel length), the empirical classical estimator of the climacogram for a 2D process can be expressed as:

$$\underline{\hat{\gamma}}(\kappa) = \frac{1}{n^2/\kappa^2 - 1} \sum_{i=1}^{n/\kappa} \sum_{j=1}^{n/\kappa} \left(\underline{x}_{i,j}^{(\kappa)} - \overline{\underline{x}} \right)^2 \tag{4.1}$$

where the '^' over γ denotes estimation, κ is the the dimensionless spatial scale, $\underline{x}_{i,j}^{(\kappa)} = \frac{1}{\kappa^2} \sum_{\psi=\kappa(j-1)+1}^{\kappa j} \sum_{\xi=\kappa(i-1)+1}^{\kappa i} \underline{x}_{\xi,\psi}$ represents a local average of the space-averaged process at scale κ, at grid cell (i, j), and, $\overline{\underline{x}} \equiv x_{1,1}^{(n)}$ is the global average of the process of interest. Note that the maximum available scale for this estimator is $n/2$. The difference between the value in each element and the field mean is raised to the power of 2, since we are mostly interested in the magnitude of the difference rather than its sign. Thus, the climacogram expresses in each scale the diversity in the greyscale intensity among the different elements. In this manner, we may quantify the uncertainty of the brightness intensities at each scale by measuring their spatial variability.

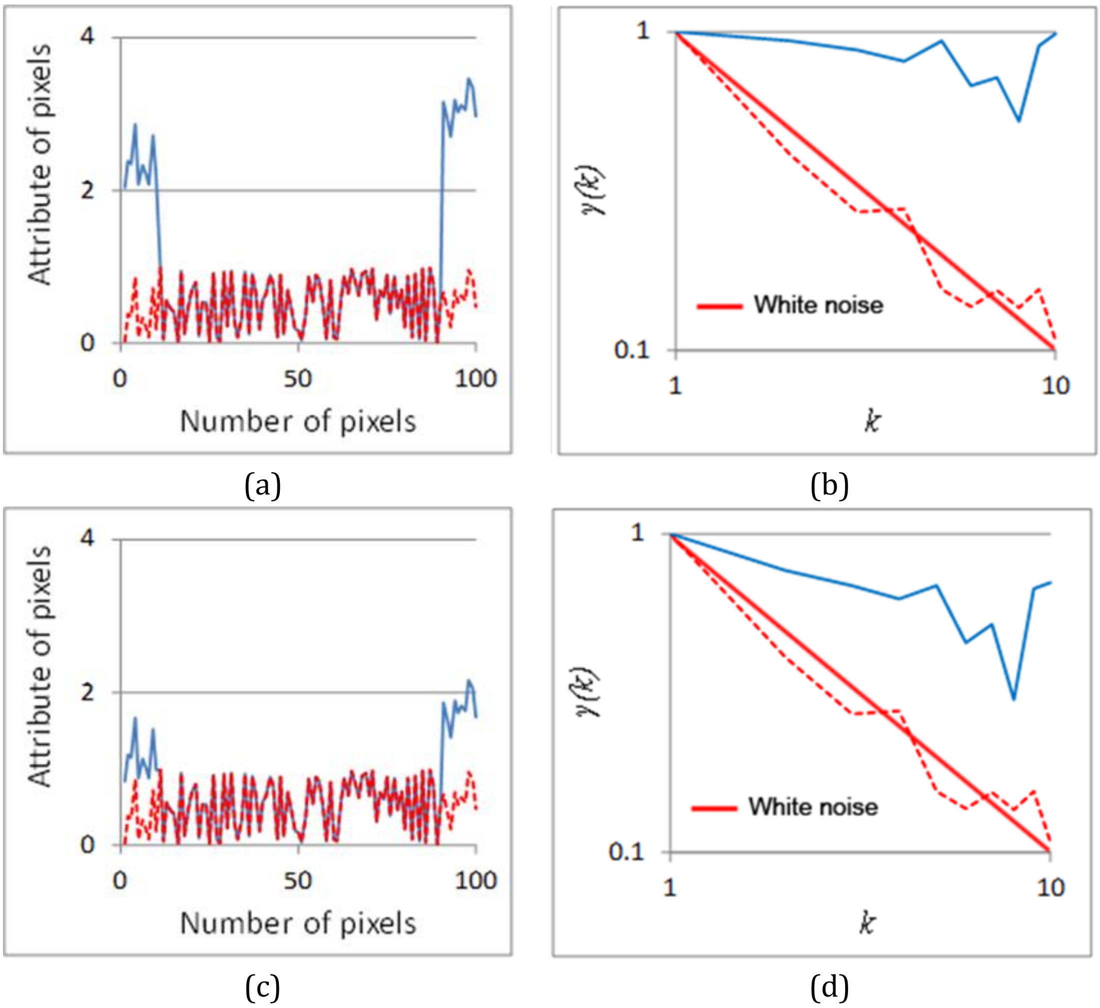
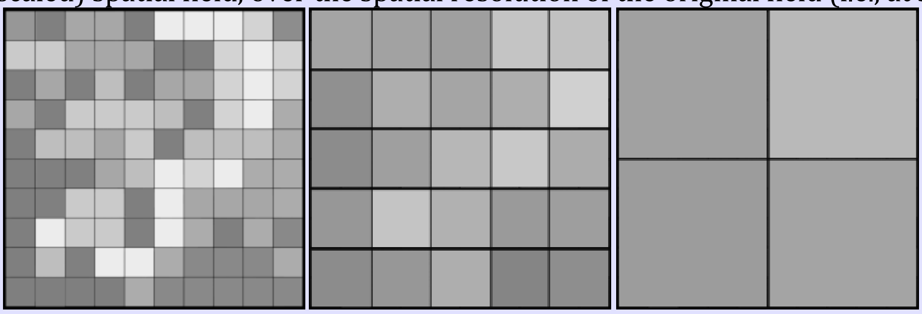


Figure 4.1 (a, c) Examples of data series with different statistical characteristics in one dimension; Colum (b, d) Standardize climacograms of data series of (a, c).

An example of climacograms generated by data sets with different statistical characteristics is presented in **Figure 4.1**a and **Figure 4.1**c. Typical examples of the results related to data are presented in **Figure 4.1**b and **Figure 4.1**d. **Figure 4.1**a and **Figure 4.1**c show a random time series in red and time series partly shifted in blue showing clustering behavior which mimic LTP. The presence of clustering in the blue series is demonstrated by the climacogram behavior which shows a marked difference for the random series (in red). Specifically, the variance of the standardized series is notably higher than that of the random series at all scales, indicating a greater degree of variability of the process (**Figure 4.1**b, **Figure 4.1**d in blue). Likewise, between the two shifted series (**Figure 4.1**a, **Figure 4.1**c in blue) the one with the more pronounced clustering behavior (**Figure 4.1**, in blue) is also characterized by a greater degree of variability (**Figure 4.1**b, d in blue).

Digression 4.A: Benchmark application

A stochastic computational tool abbreviated 2D-C (Sargentis, 2019; Sargentis 2020) is used to study the clustering in 2D space, using images from various sources. 2D-C measures the degree of variability (change in variability vs. scale) in images using stochastic analysis. Here, we refer to spatial scale, defined as the ratio of the area of k × k adjacent cells (i.e., scale k) that are averaged to form the (scaled) spatial field, over the spatial resolution of the original field (i.e., at scale 1).



(a) (b) (c)

Figure 4.2 Example of pixels in 2d picture, (b) grouped pixels at scale k=2 (c) grouped pixels at scale k=5 used to calculate the climacogram. The pixels analyzed are actually represented by numbers based on their grayscale color intensity. Figure present the steps of analysis. (a) shows an example of pixels in 2d picture; (b) shows grouped pixels at scale k=2; (c) shows grouped pixels at scale k=5 used to calculate the climacogram.

An important property of stochastic processes which characterizes the variability over scales is the Hurst–Kolmogorov (HK) behavior (persistence), which can be represented by the Hurst parameter (O'Connell et al., 2016). This parameter is estimated by minimizing the fitting error between the empirical (observed) and the modelled climacogram, both derived from the large-scale values, i.e., the last 50 scales are used in the presented applications). The isotropic HK process with an arbitrary marginal distribution, i.e., the power-law decay of variance as a function of scale, is defined for a 1D or 2D process as:

$$\gamma(k) = \frac{\lambda}{(k/\Delta)^{2d(1-H)}} \tag{4.2}$$

where λ is the variance at scale $k = \Delta$, Δ is the time or space unit, d is the dimensionality of the process/field (i.e., for a 1D process d = 1, for a 2D field d = 2, etc.), and H is the Hurst parameter ($0 < H < 1$). For $0 < H < 0.5$ the HK process exhibits an anti-persistent behavior, H = 0.5 corresponds to the white noise process, and for $0.5 < H < 1$ the process exhibits persistence (i.e., clustering). In the case of clustering behavior due to heterogeneity of the brightness of the image, the high variability in brightness persists even in large scales.

The most common stochastic attribute in natural processes is the long-term persistence behaviour or HK-behaviour, which is identified in global-scale analyses including billions of records, and in over-centennial timeseries of the most important hydrometeorological processes (i.e., temperature, humidity, wind, solar radiation, river discharge, atmospheric pressure, and precipitation), and expressed through the climacogram for large scales. Remarkably, the shape of the dependence structure, as visualized through the climacogram, exhibits similarities among natural processes (**Figure 4.3**), having a Markov-type behaviour at small scales and a long-term persistence behaviour (i.e., a power-law function of scale) at large scales. The latter behaviour can be quantified by the Hurst parameter, which is defined as the semi log-log slope plus one, i.e. $H = s/2+1$, where s is the slope in logarithmic axes of the climacogram at large scales.

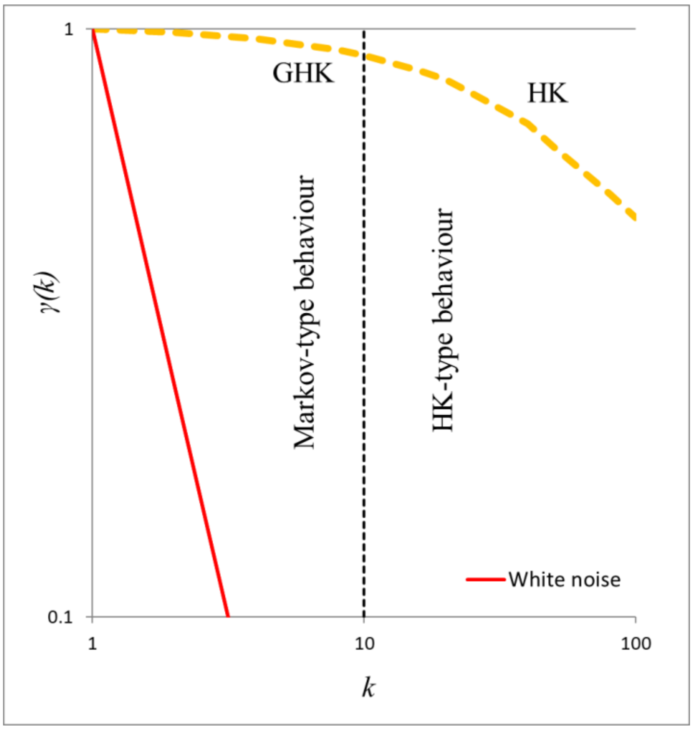


Figure 4.3 Illustration of the Hurst-Kolmogorov dynamics model visualized through the climacogram, γ, vs. scale, k, and expanding from micro (GHK behaviour) to macro (HK behaviour) scales.

This clustering effect may substantially increase the diversity between the brightness in each pixel of the image, a phenomenon also observed in hydrometeorological processes (such as temperature, precipitation, wind etc., natural landscapes and music (Sargentis, 2018).

The algorithm that generates the climacogram in 2D was developed in MATLAB by Panayiotis Dimitriadis for rectangular images (Dimitriadis et al., 2019). In particular, for the current analysis, the images are cropped to 400 × 400 pixels, 14.11 cm × 14.11 cm, in 72 dpi (dots per inch).

Digression 4.B: Aesthetical issues and stochastic analysis

A Benchmark is presented in **Figure 4.4, Figure 4.5.** The results of the analysis are depicted in Figure 4.6.

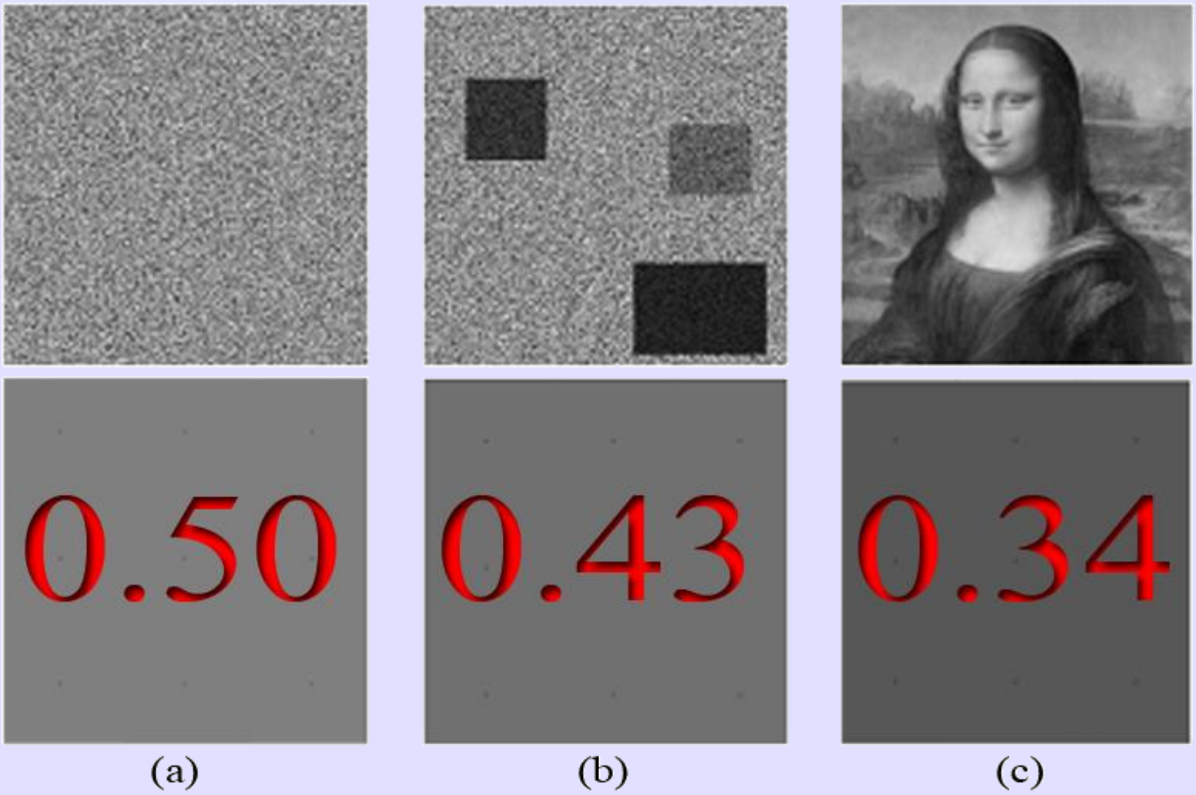


Figure 4.4 Benchmark of image analysis: (a) White noise; (b) Image with clustering; (c) Art painting. The lower row depicts the average brightness in the upper one.

The presence of clustering is reflected in the climacogram, which shows a marked difference compared to independent pixels as in white noise processes (Figure 4.6). Specifically, the variance of the clustered images is notably higher than that of white noise at all scales, indicating a greater degree of variability and uncertainty of the process. Likewise, comparing the clustered image and the art painting, the latter has the most pronounced clustering behavior and a higher degree of variability.

Italian Catholic priest and philosopher of the 13th century Thomas Aquinas, whose writings influence Western thought to this day suggested that the beautiful object is the object that offers pleasure when one sees it ("id quod visum placet"). This "definition" is strikingly laconic, and seems to approach beauty as something subjective - if an object pleases someone, then it is beautiful for him (Chiotinis, 2018).

Aquinas, however, lists four specific and objective components of beauty. These are (1) the right proportions (debita proportio or consonantia); (2) integrity (integritas or perfectio), that is the completeness, presence of all essential parts that characterize the examined object; (3) brightness (claritas), something that is interpreted as its natural glow, the light that the object emits (or reflects) and (4) actuality, which expresses the primal perfection of a thing, and is found in its existence[I].

[I] Medieval Theories of Aesthetics, Internet Encyclopedia of Philosophy. Available online: https://www.iep.utm.edu/m-aesthe/#SH3c (accessed 21 January 2022)

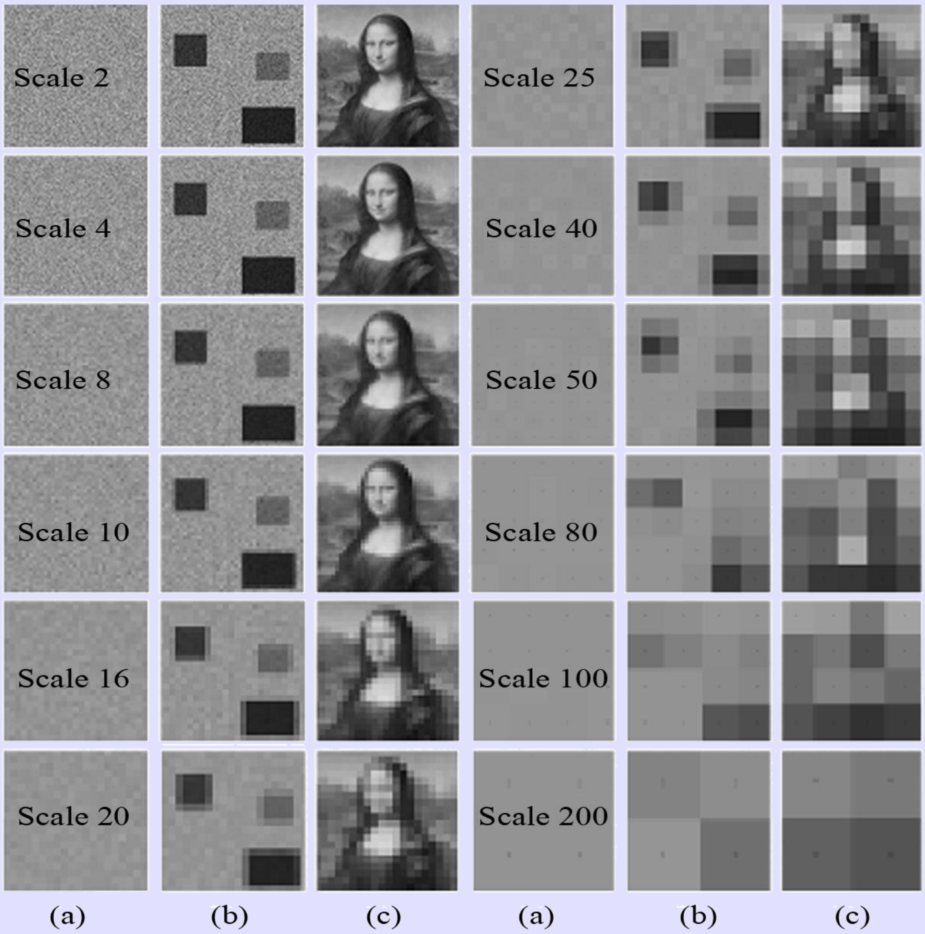


Figure 4.5 Example of stochastic analysis of 2D picture, in escalating spatial scales. Grouped pixels at different scales are used to calculate the climacogram: (a) White noise; (b) Image with clustering; (c) Art painting.

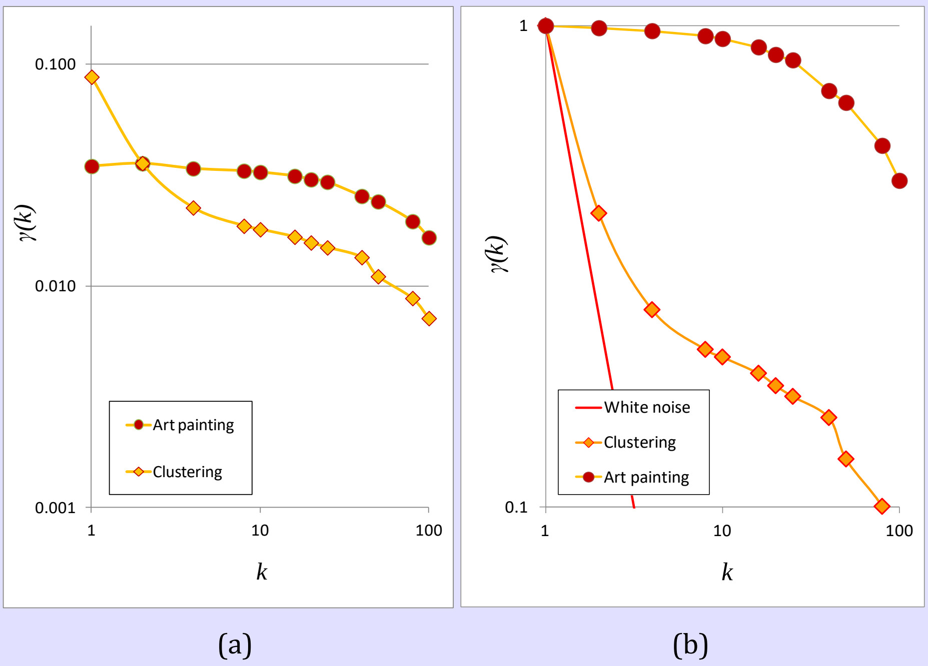


Figure 4.6 (a) Climacograms of the benchmark images; (b) Standardized climacograms of the benchmark images.

Since in the stochastic analysis that is used in this study the brightness of images is used in image processing, we note the importance of this criterion in Aquinas's theory of beauty: "Radiance [(claritas)] belongs to being considered precisely as beautiful: it is, in being, that which catches the eye, or the ear, or the mind, and makes us want to perceive it again" (Gilson, 2000). Brightness is considered the most subjective criterion of beauty: the brightness coming from a beautiful object initially captures the viewer's attention, a feature that is closely related to medieval concepts of light.

More importantly, Aquinas also made a valuable note on the importance of spatial correlations which are the basic function of the stochastic analysis that is utilized: "a predicate may express a mode of being that is common to every being in general… and can be understood in two ways: (1) absolutely – referring to a being as it relates to itself; (2) relatively – referring to a being as it relates to other beings."

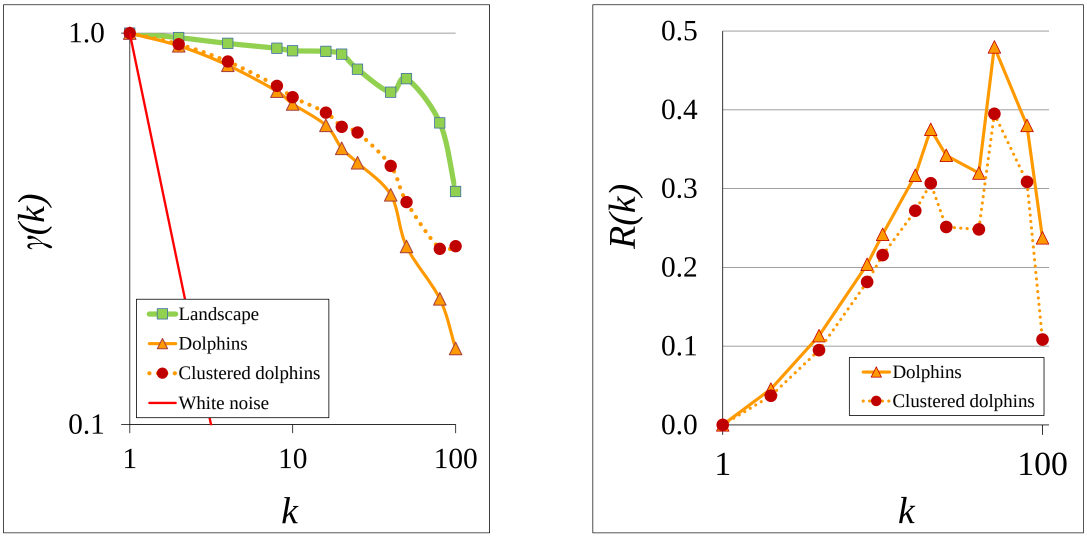
(a) (b) (c)

Figure 4.7 (a) Herd of dolphins (b) clustered herd of dolphins (c) scene without dolphins.

For the quantification of the difference between climacograms, we subtracted their values for each scale:

$$R(k) = \gamma(\kappa)_{\text{original image}} - \gamma(\kappa)_{\text{transformed image}} \quad (4.3)$$

where γ_l and γ_t are the climacogram estimations of the original image and the transformed image, respectively.



(a) (b)

Figure 4.8 (a) Standardized climacograms of images in **Figure 4.7** and (b) evaluation climacograms of original vs. transformed scenery.

Using this tool, we can evaluate the also the transformation of an original image. For example, in a theoretical scenario of a sudden appearance of a herd of dolphins, different clustering arrangements of the herd are examined (**Figure 4.7**a,b) aiming to quantify the visual transformation to the examined scenery, using the original image that does not have any transformation as a baseline (**Figure 4.7**c).

The results (Figure 3) indicate that the minimum alternation to the structure of the original image was caused when the herd of the dolphins is clustered.

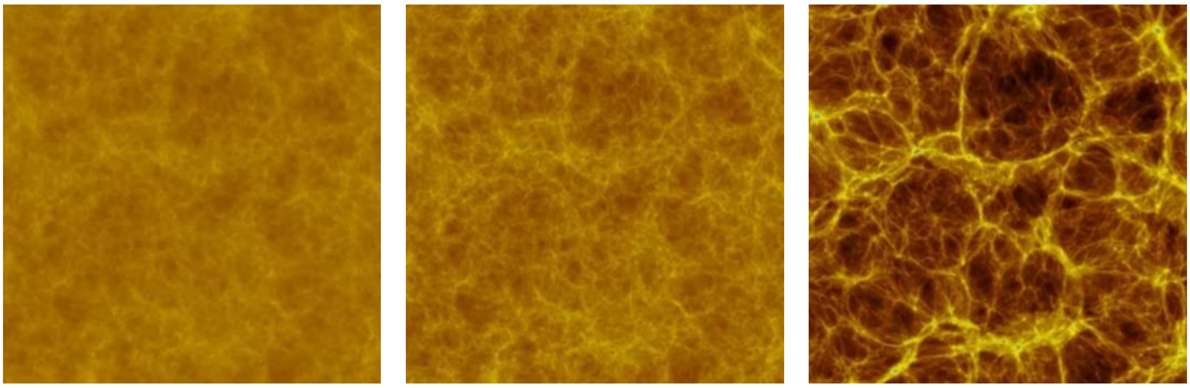
4.2 Quantification of clustering

For the integration of all information contained in the 2D climacogram of each timeframe, we evaluate the cumulative areas underneath each one for all scales (Figure 4a), i.e. the climacogram integral $\int_{\Delta}^{k} \gamma(x)/x \, \mathrm{d}x$, where Δ and k are the minimum and maximum scale and we have divided by x in order for the integral to converge for arbitrarily high k ($k \to \infty$). In the discrete case this can be approximated as:

$$\mathrm{CI}(k) = \sum_{i=1}^{n(k)-1} \left(\gamma(x_{i+1}) + \gamma(x_i)\right) \frac{x_{i+1} - x_i}{x_{i+1} + x_i} \quad (4.4)$$

where $n(k)$ is the number of integration intervals up to scale k. We evaluate $\mathrm{CI}(k)$ at the maximum available spatial scale, so that it be the best approximation of the limit $\mathrm{CI}(\infty)$.

In **Figure 4.11**b each climacogram is represented by the respective integral, thus we can evaluate the rate of alteration of clustering through time.



(a) (b) (c)

Figure 4.9 Benchmark of image analysis, evolution of the universe[I]: (a) 500 million years after Big Bang image with faint clustering, average brightness 0.45; (b) 1000 million years after Big Bang image with clustering, average brightness 0.44 and (c) 10000 million years after Big Bang image with intense clustering, average brightness 0.33.

[I] Evolution of the Universe. Available online: http://timemachine.cmucreatelab.org/wiki/Early_Universe (accessed on 24 August 2020).

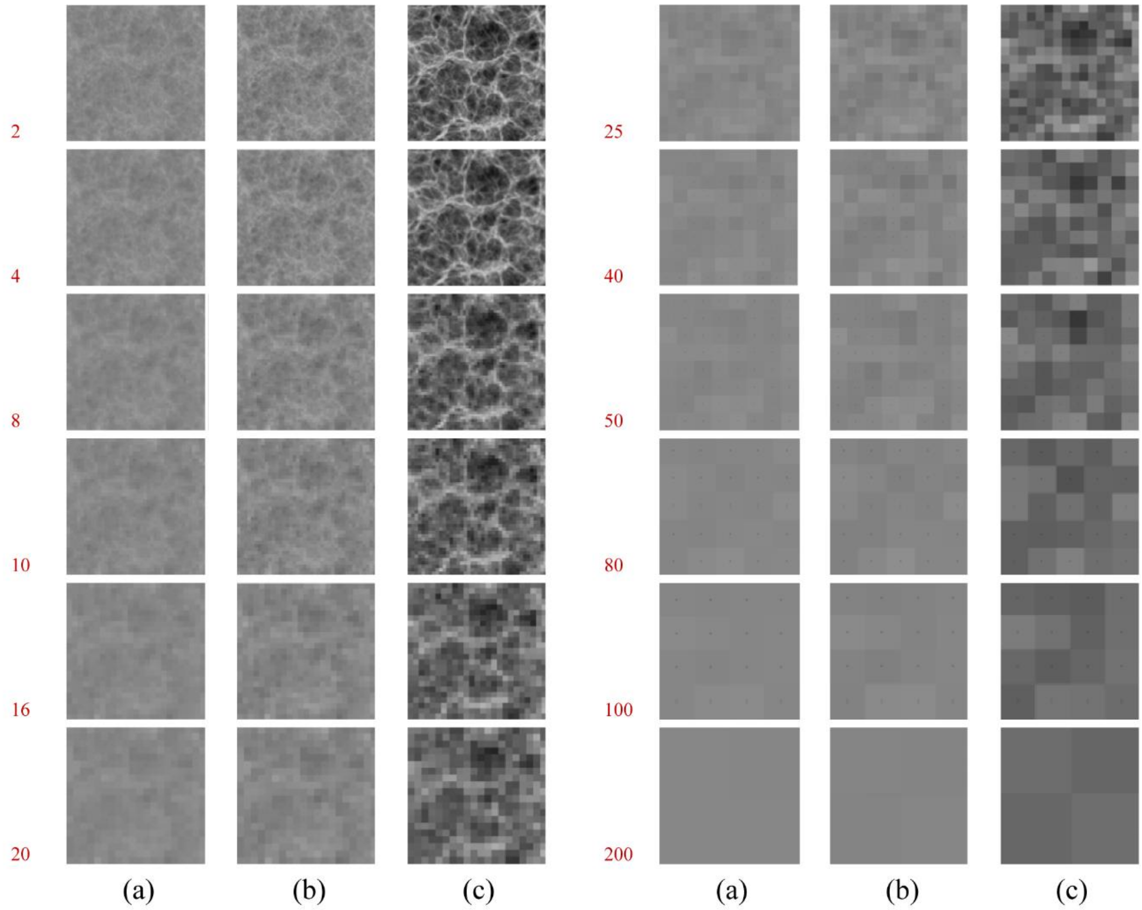


Figure 4.10 Example of stochastic analysis of a 2D picture, in escalating spatial scales, as shown on the left in red colour. Grouped pixels at different scales are used to calculate the climacogram: (a) images (a), (b) and (c) correspond to times as given in **Figure 4.9**.

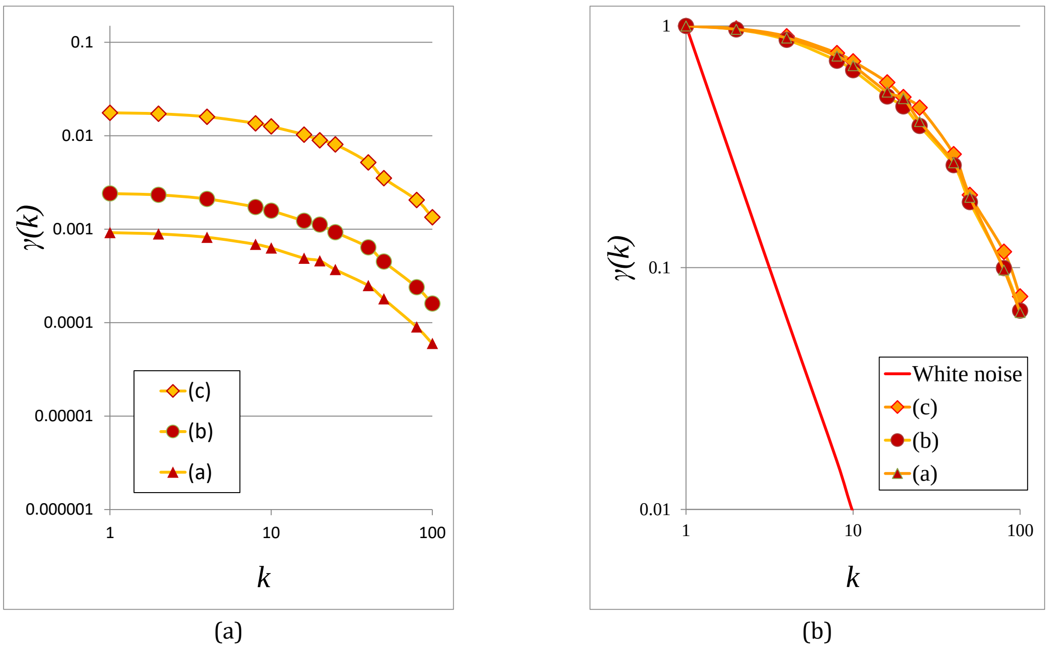
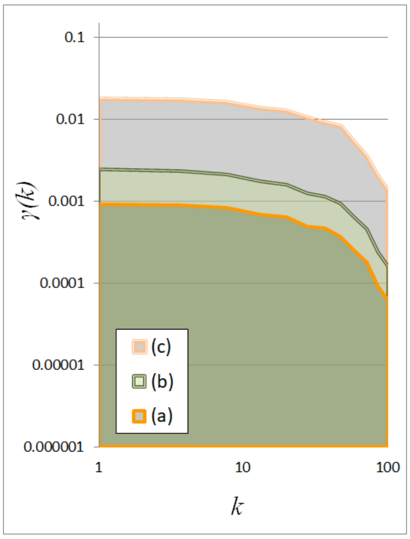
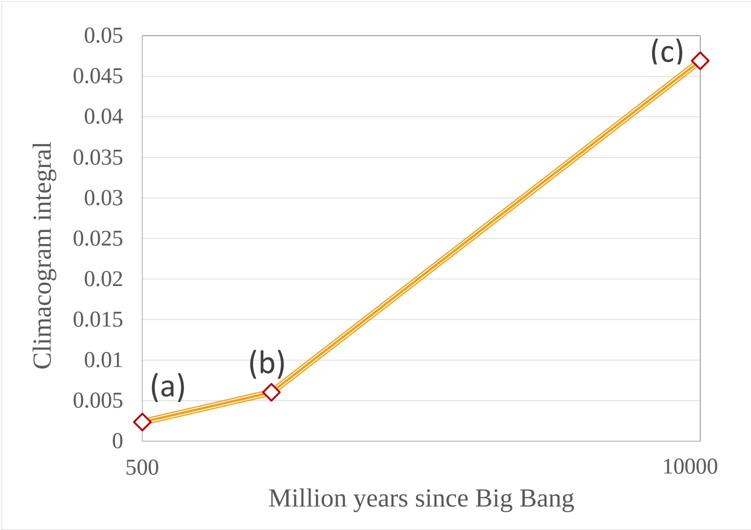


Figure 4.11 (a) Climacograms of the benchmark images; (b) standardized climacograms of the benchmark images. Note that standardized climacogram is not helpful to evaluate the range of clustering thus is not preferred for this application.





(a) (b)

Figure 4.12 (a) Cumulative areas underneath each climacogram for each scale; (b) Rate of alteration of clustering through time.

The pixels analyzed are represented by numbers based on their color intensity in grayscale (white = 1, black = 0). **Figure 4.9** presents images from three timeframe of the evolution of the universe as generated by the cosmological model of evolution[I]: (a) 500 million years after Big Bang, image with faint clustering; (b) 1000 million years after Big Bang, image with clustering and (c) 10 000 million years after Big Bang, image with intense clustering. **Figure 4.10** presents the steps of analysis and shows grouped pixels at scales k = 2, 4, 8, 16, 20, 25, 40, 50, 80, 100 and 200 used to calculate the climacogram. The presence of clustering is reflected in the climacogram, which shows a marked difference as clustering increases (**Figure 4.11**a). Specifically, the variance of the clustered images is notably higher when clusters increase at all scales, indicating a greater degree of variability of the process.

4.3 An entropic analysis of society's structure

Πάντα τὰ ἐμὰ μετ' ἐμοῦ φέρω (All that is mine I carry with me)
Bias of Priene, one of the seven Greek sages; 6th c. BC;
quoted in Latin by Cicero, Paradoxa Stoicorum I, 8, as "Omnia mea mecum porto"

What is entropy

The name "entropy" has been introduced about 150 years ago as a scientific term but later its use became common of everyday language. We can find it in literature in poetry in press, and in web posts, but often its use is irrelevant to its real scientific meaning. The most common use of the word entropy is when a writer wants to describe with an "intellectual" word a kind of disorder.

[I] Early Universe. Available online: http://timemachine.cmucreatelab.org/wiki/Early_Universe (accessed 21 January 2022)

Out of its physical and stochastic context, the term "entropy" is typically used metaphorically and hence its meaning becomes ambiguous or diverse. For example, the term "social entropy", in one of its earliest uses in scholarly publications is equated to "dereliction, pollution and waste", which are created by "economic activity" or by "society as consumers" and has to be minimized. Bailey in his book entitled "Social Entropy Theory" tried to illuminate the fundamental problems of societal analysis with a nonequilibrium approach, a new frame of reference built upon contemporary macrological principles, including general systems theory and information theory (Beiley, 1990).

In economics, Frederick Soddy (1877 –1956) and Nicholas Georgescu-Roegen (1906 – 1994), fascinated by entropy in thermodynamics, sought analogies with economics and development in a Malthusian perspective (Soddy, 1993; Georgescu-Roegen, 1971). Many others have followed their school until today.

The name *ἐντροπία* (Greek for entropy) appears already in ancient Greek (from the verb *ἐντρέπειν*, to turn into, to turn about) but was introduced in the international scientific vocabulary by Rudolf Clausius only in 1865. Clausius recognised that entropy is related to transformation and change, and the contrast between entropy and energy, where the latter is a quantity that is conserved in all changes. This meaning has more clearly been expressed in Clausius' famous aphorism (Clausius 1865):

Die Energie der Welt ist constant. Die Entropie der Welt strebt einem Maximum zu.

(The energy of the world is constant. The entropy of the world strives to a maximum).

Herein, entropy and its ability to increase is the driving force of change.
More than 150 years after the introduction of the entropy concept, its meaning is still debated.

In the public perception entropy has a negative content, and is typically identified with disorganization or disorder, and deterioration. Wiener, the most influential scientist who supported the disorder interpretation. In 1946, he gave a keynote speech at the New York Academy of Sciences in which he declared that (Wiener, 1948):

Information measures order and entropy measures disorder.

There is no doubt that the notion of entropy entails difficulties in understanding but this happens because our education is based on the deterministic paradigm. Indeed, it is difficult to incorporate a clearly stochastic concept, i.e. entropy, in a deterministic mindset. The notion of order looks deterministic-friendly, and its opposite, disorder, has a negative connotation in the deterministic mindset.

But the notions of order and disorder are less appropriate and less rigorous as scientific terms and more appropriate in describing mental states and even more so in describing socio-political states. The latter is manifest in the frequent use of the expression "world order" and "new world order" in political texts included in Google Books (**Figure 4.13**). Other representatives of oligarchic elites prefer the expression "global order" (also included in **Figure 4.13**).

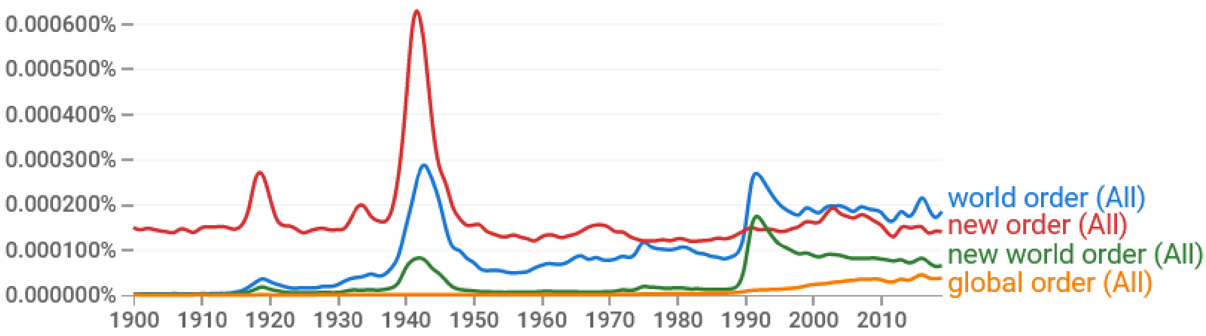


Figure 4.13 Frequency of appearances of the indicated phrases in Google Books. Notice that "new order" was the political order which Nazi Germany wanted to impose and naturally its use peaked in the early 1940s. The other phrases also peaked at the same time but they showed higher peaks after 1990s[I].

Steyer attributes an excessive contribution to the misconception of entropy as disorder to autobiographical book "The Education of Henry Adams". As quoted by Steyer, Adams contests Chaos and Anarchy, and states (Adams, 1918):

> *The kinetic theory of gas is an assertion of ultimate chaos. In plain words, Chaos was the law of nature; Order was the dream of man.*

Undoubtedly, elites that want to control the world have exactly this dream, but this does not necessarily mean that the entire humanity has the same dream with the elites. When speaking about entropy, we should have in mind that the scale is an important element and that entropy per se, being a probabilistic concept, presupposes a macroscopic view of phenomena, rather than a focus on individuals or small subsets.

If we viewed the motion of a particular dice throw, we might say that it was irregular, uncertain, unpredictable, chaotic, random. But macroscopization, by removing the details, may also remove irregularity. For example, the application of the principle of maximum entropy to the outcomes of a die results in equal probabilities (1/6) of each outcome.

This is perfect order. As the accuracy of this law is so high, most people believe that the principle of maximum entropy is a deterministic law. But if entropy is not disorder, what is it?

According to its standard definition, entropy is precisely the expected value of the minus logarithm of probability. If this sounds too difficult to interpret, an easy and accurate interpretation is that entropy is a measure of uncertainty. If "disorder" is regarded as a "bad thing", for many the same is the case with uncertainty. The expressions "uncertainty monster" and "monster of uncertainty" appear in about 250 scholarly articles registered in Google Scholar.

However, if uncertainty is a monster, it is thanks to this monster that life is livable and fascinating. Without uncertainty, life would be a "universal boredom", and concepts such as hope, will (particularly, free will), freedom, expectation, optimism, etc., would hardly make sense. A technocratic system where an elite comprising super-experts who, using

[I] Data retrieved on 2021-08-01 by https://books.google.com/ngrams /

super-models, could predict the future without uncertainty, would also assume full control on the society.

Fortunately, this will never happen because entropy, i.e. uncertainty, is a structural property of nature and life. Hence, in our view, uncertainty is neither disorder nor a "bad thing". How could the most important law of physics (the Second Law) be a "bad thing"? In a deterministic world view, there is no uncertainty and there is no meaning in speaking about entropy. If there is no uncertainty, each outcome is accurately predicted and hence there are no options.

In contrast, in an indeterministic world, there is a plurality of options. This corresponds to the Aristotelian idea of δύναμις (Latin: *potentia*—English: potency or potentiality).

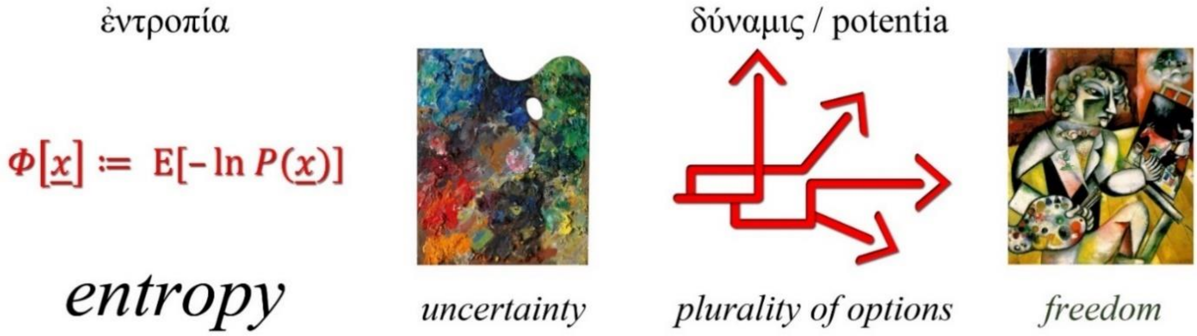


Figure 4.14 An attempt for an artistic representation of the notion of entropy. Uncertainty is depicted by Marc Chagall's Palette and freedom by Marc Chagall's *Self-Portrait with Seven Fingers*; δύναμις (Greek) or *potentia* (Latin) is the Aristotelian idea for potency or potentiality[I].

Guye asked the question: How is it possible to understand life, when the whole world is ruled by such a law as the second principle of thermodynamics, which points toward death and annihilation? (Guye, 1922)

Schrödinger argued that "What an organism feeds upon is negative entropy" (Schrödinger, 1944).

In a rather metaphysical context, assuming a non-statistical definition of negentropy, others see a negentropic principle governing life, biosphere, economy, etc., because these convert things which have less order, into things with more order.

If we see entropy as uncertainty, we also understand that life is fully consistent with entropy maximization. The human-invented steam engines (and other similar machines) increase entropy all the time, being fully compatible with the Second law, yet they produce useful work.

Likewise, the biosphere increases entropy, yet it produces interesting patterns, much more admirable than steam engines. Life generates new options and increases uncertainty. Compare Earth with a lifeless planet: Where is uncertainty greater? In which of the two planets a newspaper would have more events to report every day?

[I] Source: Koutsoyiannis, D.; Sargentis, G.-F. Entropy and Wealth. Entropy 2021, 23, 1356. https://doi.org/10.3390/e23101356

Digression 4.C: Summarize the final theses on entropy

(a) Entropy is a stochastic concept with a simple and general definition. Notably, according to its stochastic definition, entropy is a dimensionless quantity.
(b) As a stochastic concept, entropy can be interpreted as a measure of uncertainty, leaving aside the traditional but obscure and misleading "disorder" interpretation.
(c) The classical definition of thermodynamic entropy is not necessary; it can be abandoned and replaced by the probabilistic definition.
(d) Applied in thermodynamics, the thus defined entropy is the fundamental quantity, which supports the definition of all other derived ones.
(e) The entropy concept is equipped with the principle of maximum entropy, which states that entropy tends to take its maximum value that is allowed, given the available information about the system.
(f) The tendency of entropy to reach a maximum is the driving force of natural change.
(g) Life, biosphere and social processes are all consistent with the principle of maximum entropy as they augment uncertainty. Therefore, no additional "life principle" is necessary to explain them.

Mathematical formulation

In the last century, a new scientific field has developed, econophysics, which combines socio-economic dynamics with the laws of physics.

Although in physics entropy is widely is often used as a measure of disorder, its universal character, stemming from its stochastic definition, features it as a measure of uncertainty. Together with the accompanying principle of maximum entropy, it forms an excellent tool to describe the dynamics of societies.

We consider a stochastic (random) variable $\underline{x}$ (notice that we underline stochastic variables to distinguish them from regular variables) and we denote its distribution function (i.e. probability of non-exceedance) and its tail function (i.e. probability of exceedance), respectively, as:

$$F(x) \coloneqq P\{\underline{x} \leq x\}, \;\; \overline{F}(x) = 1 - F(x) = P\{\underline{x} > x\} \tag{4.5}$$

where P denotes probability. If the variable $\underline{x}$ is discrete, i.e. it can take any of the values $x_j, j = 1, \dots, \Omega$, with probability $P_j \equiv P(x_j) \coloneqq P\{\underline{x} = x_j\}$ then the sequence P_j defines its probability mass function. If the variable is continuous, i.e. it can take any real value (or a value in a subset of the real numbers), then we define the probability density function as the derivative of the distribution function:

$$f(x) \coloneqq \frac{\mathrm{d}F(x)}{\mathrm{d}x} \tag{4.6}$$

From general postulates about uncertainty, a unique (within a multiplicative factor) metric Φ results, serves as the definition of entropy:

$$\Phi[\underline{x}] \coloneqq \mathrm{E}[-\ln P(\underline{x})] = -\sum_{j=1}^{\Omega} P_j \ln P_j \tag{4.7}$$

Social prosperity presupposes social constitution, which in turn presupposes social stratification and development. Social stratification together with the economic aspects of society are the factors that determine entropy.

Koutsoyiannis and Sargentis (2021) note:

According to its standard definition… entropy is precisely the expected value of the minus logarithm of probability. If this sounds too difficult to interpret, an easy and accurate interpretation is that entropy is a measure of uncertainty. Hence, maximum entropy means the maximum uncertainty that is allowed in natural processes, given the constraints implied by natural laws (or human interventions).

Mathematically for a continuous stochastic variable $\underline{x}$ defined in [0, J], the entropy Φ is defined as:

$$\Phi[\underline{x}] \coloneqq E\left[-ln\frac{f(\underline{x})}{\beta(\underline{x})}\right] = -\int_{-\infty}^{\infty} ln\frac{f(x)}{\beta(x)} f(x)\,dx \tag{4.8}$$

where $\beta(x)$ is a background measure and can be any probability density. Typically, it is a Lebesgue density, i.e. constant and it is assumed, $\beta(x) = 1/\lambda$ with λ being a monetary unit (Koutsoyiannis and Sargentis, 2021). If the stochastic variable $\underline{x}$ is the income of people then the entropy reflects the uncertainty in the income distribution. From the principle of maximum entropy, given the constrains that we have about the income, we can determine the probability density $f(x)$, which determines the stratification in the society.

From an entropic view point, we note that when the real average of the people's income increases (growth), the entropy Φ of societies, is increased. Instead of that, if the real average decreases (recession) entropy Φ is decreased. As entropy decreases instead of its natural tendency, in recession phase, societies flow in an unstable phase. In this respect it turns out that entropy is also a measure of society's wealth.

The entropic approach provides also another way to evaluate inequality. While for constant background density equal to the inverse of the monetary unit the entropy provides a measure of society's wealth, if we change the background measure to the value $1/\mu$, where μ is the mean income, the thus calculated entropy is a measure of inequality. Calling the latter quantity *standardized entropy* and denoting it as $\Phi_\mu[\underline{x}]$, after algebraic manipulations (Koutsoyiannis and Sargentis, 2021) we get:

$$\Phi_\mu[\underline{x}] = \Phi[\underline{x}] - ln\frac{\mu}{\lambda} \tag{4.9}$$

The mathematical formulation of maximum entropy shows that the exponential distribution has maximum entropy Φ_μ=1. In Pareto distribution and the two-parameter gamma distribution, (the behavior of which is opposite to Pareto), entropy Φ_μ=0.884, significantly lower than exponential (**Figure 4.15**). In the extreme cases of total equality Φ_μ=-∞ and in total inequality Φ_μ=0

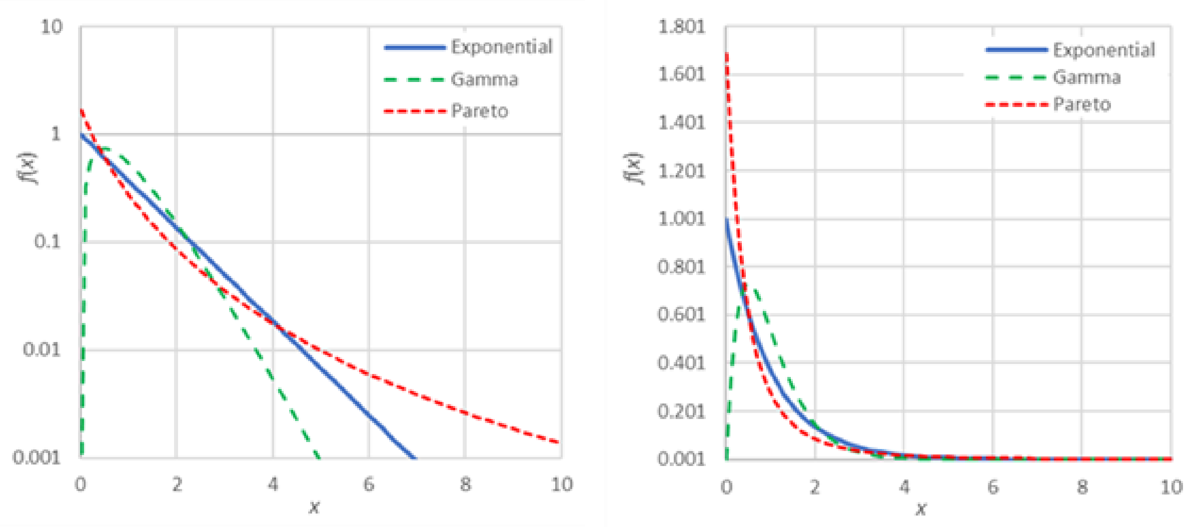


Figure 4.15 Comparison of the entropy maximizing distribution (for Lebesgue measure $\beta(x) = 1/\lambda$) with two other distributions, in terms of their probability density functions $f(x)$.

Two opposite forces modify the natural (exponential) distribution:

1. An organized society redistributes income and wealth through their transferal from the richer individuals to the purer by means of several mechanisms (e.g. taxation). As a result of redistributions, (a) poverty below a low level is eliminated; (b) the middle class, becomes more populated and amplified; (c) the rich lose income.
2. On the other hand, the actions of economic elites, pursuing a greater share of the community's wealth, tend to modify mostly the income distribution tail, converting it from exponential to power-law (Pareto). The effects of this force on the income distribution are to: (a) increase the number of poor; (b) diminish the middle class; and (c) benefit the richest.

Chapter 5. Agricultural Land or Photovoltaic Parks?

One of the most important aspects of the global shift towards sustainability is the transition to Renewable Energy (RE) technologies. The shift to renewables introduces further challenges within the WEF nexus. A characteristic example is the worldwide expansion of photovoltaic (PV) energy, also emerging from the attractive financial opportunities offered, which has resulted in an expanding occupation of agricultural land, since the latter offers significant advantages for installing PV panels. Hence, the motivation of this research is the growing concern over the degradation of agricultural and livestock production, as a result of the occupation of agricultural land for the establishment of PV power stations. For this reason, an attempt is made to investigate the competitive relationship between PV power plants and food production. As a case study, we consider the area of Thessaly, which is one of the keys for the primary-sector in Greece and the biggest agricultural area in Greece. The vast expanse of flatland, in combination with the abundance in solar resource, favours the development of PV systems, attracting a large number of investors. Our analyses aim at the assessment of transforming the plain from a food production area to an energy production area.

Since the beginning of the 21st century, the penetration of RE sources has been growing rapidly, and their share in the electricity mix is expected to further increase. Despite the large advantages of RE over conventional fossil fuels, there is a growing concern over the globe that large-scale RE infrastructures will displace other land uses, thus resulting in severe socio-economic and environmental impacts and irreversible alterations to landscapes (Manta et al., 2020; Ioannidis et al., 2020; Ioannidis et al., 2019; Ioannidis and Koutsoyiannis 2020).

After hydroelectric and wind energy, PV energy is the third most important form of RE worldwide. Global PV capacity has substantially grown from around 5 GW in 2005 to 714 GW in 2020[I]. This expansion is explained by the rapid fall in costs for solar PV, on the one hand, and the financial and legislative motivations provided at the national and international level (e.g., the EU), on the other. In this context, one of the most typical conflicts among RE and land resources involves the development of PV solar plants in rural areas, and particularly over agricultural lands.

There are multiple reasons making agricultural lands so much attractive for the deployment of PV systems at the large scale. It is well-known that electrical power of solar PVs is a conversion of the incoming solar radiation, direct and diffuse, which depends on the geographic location and it is also strongly influenced by the local topography (Mamassis et al., 2012). On the other hand, the efficiency of PV panels, although primarily depends on the technical characteristics of the specific system (silicon type, cell layout and configuration, panel size, color of protective backsheet, etc.), is also significantly affected by the local microclimate, mainly the temperature. It is recognized that the most

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[I] IRENA, Renewable capacity statistics 2021, International Renewable Energy Agency (IRENA), Abu Dhabi, ISBN: 978-92-9260-342-7, 2021.

suitable land conditions for maximizing PV potential are croplands, grasslands and wetlands, which are characterized by plentiful insolation, light winds, moderate temperatures and low humidity (Adeh et al., 2019). Apparently, croplands are more suitable since they combine a relatively low cost for land reservation, easy accessibility to the road and electrical grid network, and minimal interventions for the preparation of the installation terrain (e.g., grading). Hence, they are strongly preferred by investors seeking for plain areas with such beneficial characteristics, to deploy large-scale solar parks (indicatively, a solar park of 1 MW capacity needs a development area of about 2.6 ha). On the other hand, an increasing number of land owners and farmers find more gainfulness to grant their lands to energy investors, in order to ensure a steady and low-risk income, which may exceed their net profit from agricultural production.

Under this premise, from the beginning of RE expansion there is a long-standing discussion on the impacts of capturing agricultural land for the installation of large-scale PV systems (Späth, 2018; Guerin, 2019; Dias, 2019). Apart from the obvious question, i.e., whether is it possible to fulfill the needs for food and energy under limited land resources (Nonhebel, 2005; Sacchelli et al., 2016), PVs at agricultural areas are also associated with environmental degradation, including landscape deterioration (Sargentis et al., 2019; Sargentis et al., 2021), land take, soil degradation, as well as loss in traditional cropland and biodiversity (Delfanti, 2016).

However, recent advances under the water-energy-land-food nexus approach have brought in light innovative solutions for overcoming the conflicts between energy and land uses and co-developing the same land area for both solar PV power and conventional agriculture. In this respect, there is a global interest on the so-called agrophotovoltaic or agrivoltaic systems (Dinesh, 2016; Dupraz, 2011; Pascaris, 2021), which are suitable for shade-tolerant crops and they also offer quite significant advantages with respect to PV efficiency. The experience reported so far is quite encouraging. Nevertheless, it is generally accepted that such synergetic schemes are economically effective under specific climatic conditions (i.e., arid or semi-arid) and for locations with intense competition for land resources, e.g., islands (Weselek, 2019).

Overview of the food-land-energy nexus in Thessaly

The district of Thessaly extends over an area of 1 403 600 ha in central Greece, where 403 045 ha is the cultivated land (**Figure 5.1**), thus covering over 10% of the country's agricultural land[I]. The extensive agricultural production in the plain of Thessaly is facilitated by the topography and the fertile land resources.

Forty per cent of cultivated land is irrigated, which puts pressure on both surface and groundwater resources, since irrigation of crops is the largest consumer of water (**Table 5.1**). The estimated annual water intake for all uses is 1 422 hm^3 and 24% concerns

[I]Hellenic Statistical Authority, Agriculture and livestock. Available online: https://www.statistics.gr/el/statistics/agr /- (accessed 27 June 2021).

Thessaly, Περιφέρεια Θεσσαλίας Available online: http://www.gaiapedia.gr/ (accessed 27 June 2021).

surface water, while 76% comes from drilling groundwater[I] (Koutsoyiannis et al., 2008). The annual deficit of groundwater is 474 hm^3, and is caused by the intensive and unsustainable use mostly of groundwater.

The annual crops are fully mechanized in all production stages from sowing to harvest. In order of magnitude, modern farming uses annually 25 GJ/ha[II] (Smith , 2019; Jiang et al. 2019; Davis and Hatfield, 2007; Coughenour et al., 1985; Smil, 2004; Smil, 2004; Singh et al., 2002; Canakci et al., 2005; Kander, 2011; Schnepf, 2004; Vreni, 2015) so we can assume that annual energy needs for the cultivation are about 8 million GJ (or 2.8 TWh). For comparison, the total energy demand in Greece is about[III] 319 TWh, on annual basis.

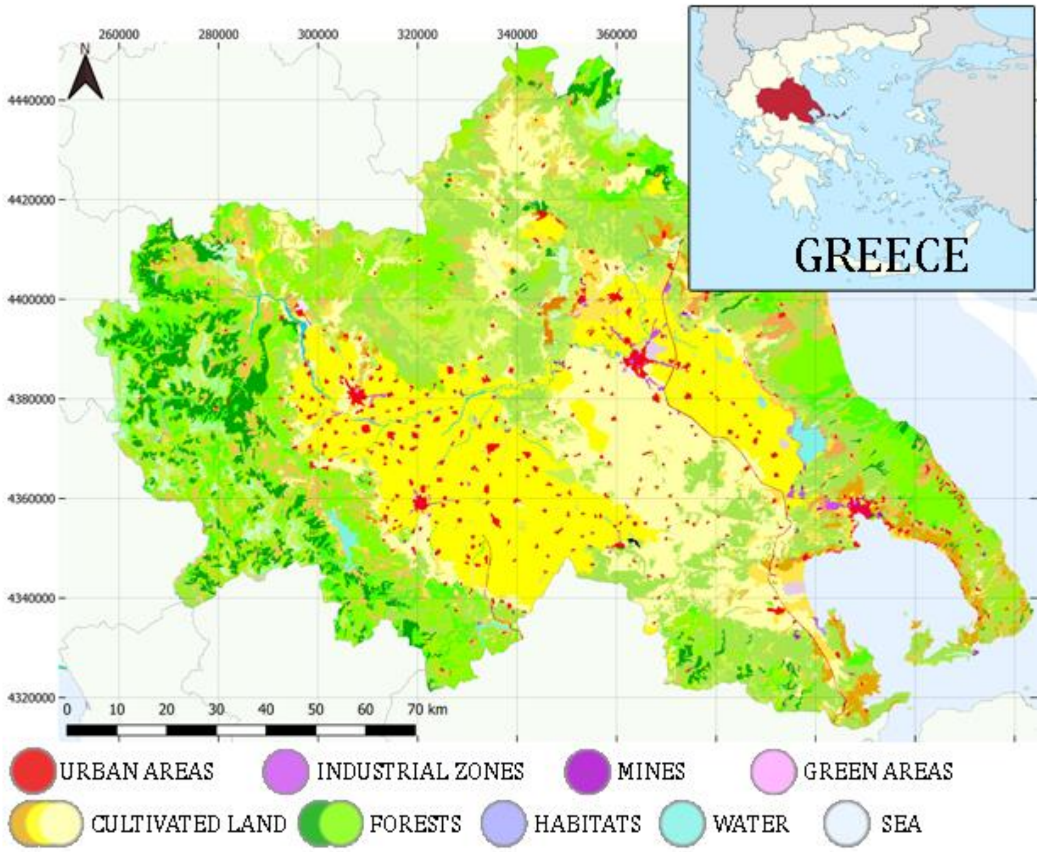


Figure 5.1 Land use of Thessaly[IV].

[I]Surface water and Grandwater sources in Thessaly. Επιφανειακά και Υπόγεια Υδατικά Συστήματα, Υδάτινοι Πόροι και Περιβάλλον Θεσσαλίας (ΥΠΕΘΕ). 1η Αναθεώρηση ΣΔΛΑΠ, ΥΔ Θεσσαλίας (EL08), Available online on : http://wfdver.ypeka.gr/wp-content/uploads/2017/12/EL08_SDLAP_APPROVED.pdf (accessed 27 June 2021).

[II] Energy for Agriculture. Available online: http://www.fao.org/3/X8054E/x8054e05.htm (accessed 27 June 2021).

[III] Greece: Energy Country Profile. Available online: https://ourworldindata.org/energy/country/greece (accessed 27 June 2021).

[IV] Data retrieved on 2022-02-17 by Hellenic Ministry of Environment and Energy; Geospatial data, Διαδικτυακή Πύλη Γεωχωρικών Πληροφοριών Υπουργείου Περιβάλλοντος και Ενέργειας (ΥΠΕΝ). Available online: http://mapsportal.ypen.gr/maps/?limit=20&offset=0 (accessed 27 June 2021).

Table 5.1 Water consumption in Thessaly

Type of consumption	Water quantity (hm^3)
Irrigation (2013)	1306
Municipal water	94
Livestock	13
Industry	9
Total	**1422**

After wind energy, solar energy, mainly by means of PV parks, is the mostly developed source of renewable energy in Greece. It is remarkable that the sharing of solar energy to the electricity mix of the country increased from less than 0.3% to 9.0%, in the last decade. In particular, the Thessalian plain is strongly beneficial for installing PV panels, since it is a vast flat land, receiving an average annual solar energy[I] of 1440 to 1590 kWh/m^2.

In recent years, the interest of investors in Greece has been focused on RE, also raised by significant financial incentives provided by national and the EU legislation. The installation of renewables in Greece is controlled by the Regulatory Authority for Energy (RAE). RAE is an independent authority established by Law 2773/1999[II], which harmonized the Greek legal order with EU Directive 96/92/EC[III] and is empowered to monitor the operation of all sectors of the energy market. **Figure 5.2**, **Figure 5.3** show the land uses over Thessaly, while the licensed solar parks exceeding 1 MW[IV].

According to recent Greek law (valid from March 2020)[V], the maximum allowable solar power capacity in agricultural land of Thessaly is 2 758 MW. The solar capacity so far is 1 711.5 MW, while the licensed parks cover ~1% of cultivated land. Based on approximate data from the Global Solar Atlas[VI], we estimate that the current solar energy production in Thessaly is 1 485 kWh/kWp. This means that currently Thessaly produces about 9 million GJ (about 2.5 TWh). Assuming that all potential solar capacity allowed by the law is installed, the produced annual energy will be approximately 15 million GJ (4.2 TWh), which exceeds with the energy needs for food production in the entire area of Thessaly.

I Laboratory of Atmospheric Physics of the University of Patras. Climatological Maps of Sollar Energy in Greece, Greek Network of Solar Energy, Ελληνικό Δίκτυο Ηλιακής Ενέργειας, 2002–2012. Available online: https://www.atmosphere-upatras.gr/solarmaps/Thessaly (accessed on 27 June 2021).

II Greek low 2773/1999, (ΦΕΚ 286/Α/22-12-1999). Available online: http://www.et.gr/ (accessed 27 June 2021).

III Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A31996L0092 (accessed on 27 June 2021).

IV Regulatory Authority for Energy (RAE), Geobase map, ΡΑΕ, Ρυθμιστική Αρχή Ενέργειας, Γεωπληροφοριακός Χάρτης. Available online: https://geo.rae.gr/ (accessed 27 June 2021).

V Greek low 4643/2019 (ΦΕΚ 193/Α/3-12-2019) Available online: http://www.et.gr/ (accessed 27 June 2021).

VI Global Solar Atlas. Available online: https://globalsolaratlas.info/map?c=39.461644,22.142944,9&s=39.374867,22.355804&m=site (accessed 27 June 2021).

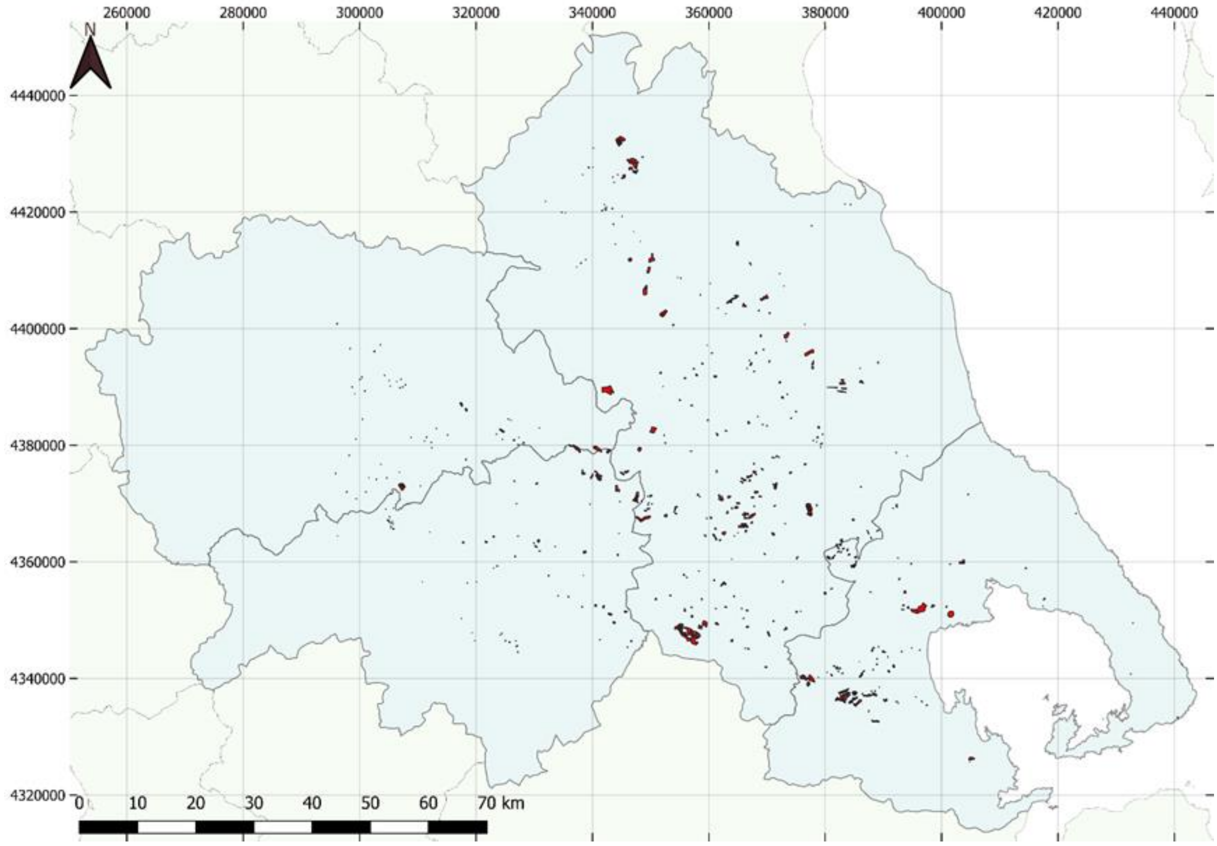
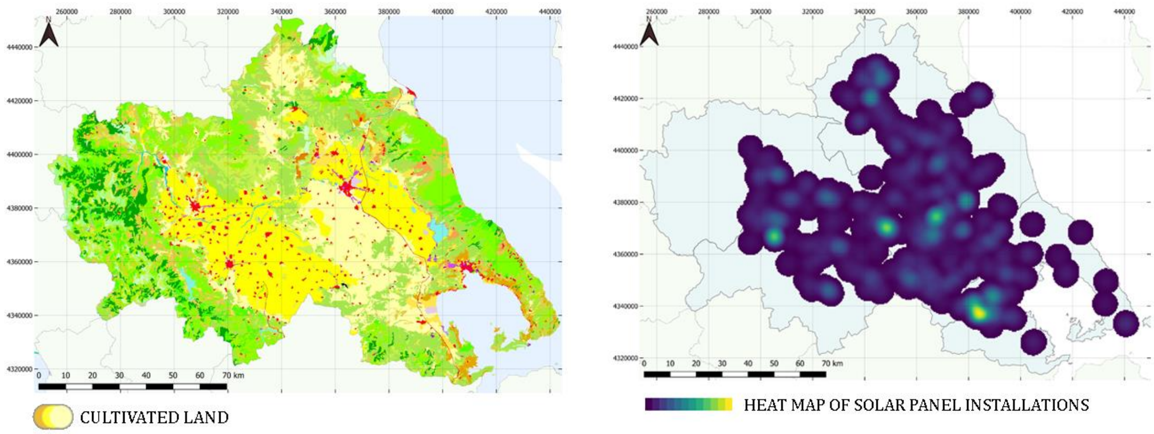


Figure 5.2 PV panels larger than 1 MW in Thessaly's cultivated land[I] (source: Siamparina, 2021).



(a) (b)

Figure 5.3 (a) Land use of Thessaly; (b) Heat map of the installation of PV panels lager than 1 MW in Thessaly's cultivated land (source: Siamparina, 2021).

Quantitative analysis

In order to evaluate the conflicts and possible synergies between the three resources of interest, i.e. food, land, and solar energy, we employ an economic comparison of PV panels development vs. agricultural activity, having as "common denominator" the

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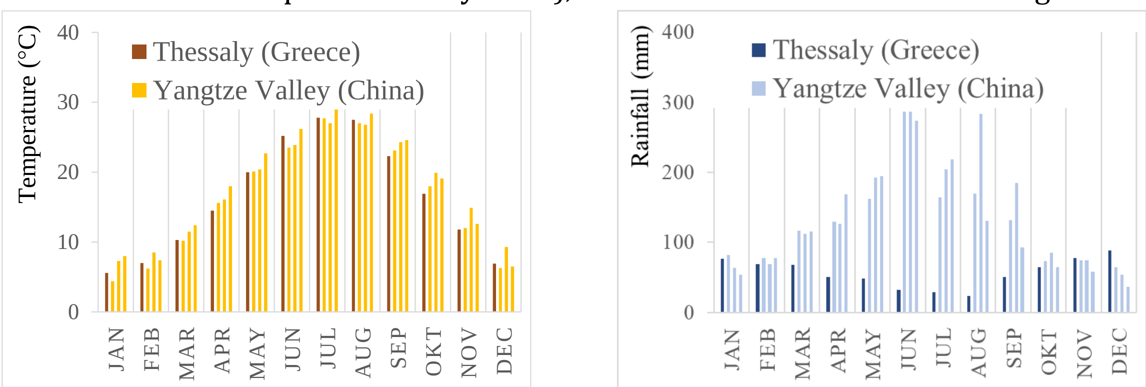
[I] Regulatory Authority for Energy (RAE). Geobase Map, PAE, Ρυθμιστική Αρχή Ενέργειας, Γεωπληροφοριακός Χάρτης. Available online: https://geo.rae.gr/ (accessed on 27 June 2021).

associated occupied area (Siamparina, 2021). As a proof of concept, we considered two alternative cultivations, namely wheat, which is the traditional agricultural product of Thessaly, and kiwifruit. The latter is native to the Yangtze Valley of northern China and Zhejiang Province on the coast of eastern China (Morton 1987). Currently, the main region of kiwifruit cultivation in China is the central and lower Yangtze River Valley.

Climatic data shows that kiwifruit native land has the same range of temperatures with Thessaly but totally different characteristics of rainfall (**Figure 5.4**). Specifically, the annual average rainfall in Thessaly is about 500 mm (Koutsoyiannis et al., 2008) and the average of three different areas in Yangtze River valley is about 1600 mm. In order to optimize the kiwifruit production and adjust cultivated land of Thessaly's plain, to the environmental conditions of Yangtze River valley, farmers need 7000–8000 m^3 of water per hectare for irrigation[I] (Holzapfel et al., 2000). On the other hand, the water needs of wheat are much more limited and they do not exceed 1500 m^3/ha.

Two types of analyses were conducted. The first involved the comparison of the three alternatives on a unit area basis (per hectare). The main outcomes are summarized in **Table 5.2**.

Since the total energy consumption per capita in Greece for domestic uses is about 110 GJ[II], one hectare of PV panels can fulfill the energy needs of 19 people. On the other hand, the daily food caloric supply per capita in Greece is about 3350 (5.2 GJ annually). Under the hypothetical context that people fulfill their food needs exclusively by wheat or kiwifruit, we conclude that one hectare of cultivated land equals the caloric needs of 10–19 and 20 people, respectively (annually needs ~912,500 kcal). We remark that while kiwifruit is more efficient from a market point-of-view (one ha can produce up to 40 t, in contrast to wheat that produces only 4–7 t), it needs much more water for irrigation.



(a) (b)

Figure 5.4 Climate data of Thessaly (Greece) and different areas in Yang-tze Valley (China)[III].

[I] Cultivation of kiwifruit in Greece. Available online: Shorturl.at/doA23 (accessed on 27 June 2021).

[II] Greece: Energy Country Profile. Available online: https://ourworldindata.org/energy/country/greece (accessed on 27 June 2021).

[III] Climate Data for Cities Worldwide. Available online: https://climate-data.org (accessed on 27 June 2021).

Digression 5.A: PV panel, cultivation of wheat and kiwifruit

Table 5.2 PV panel, cultivation of wheat and kiwifruit (annually quantities in Thessaly per ha)

		Consumption	Production	Conversion of annual needs
PV panels	Energy	151 GJ *	2255 GJ	energy needs of 19 people; average in Greece
	Water	**	-	
	Food	-	-	
Wheat	Energy	19.5 GJ[I]	55.4-97 GJ ***	10-19 (people; food)
	Water	0-1500 m^3 [II]	-	
	Food	-	4-7 t	
Kiwifruit	Energy	30.5 GJ [III]	100.48 MJ****	20 (people; food)
	Water	7000-8000 m^3 [IV]	-	
	Food	-	40 t	

*Embodied energy of panels[V], apported in 20 years of use.
** Hidden water must be in the consumption of the construction of PV panels which cannot be estimated.
*** 1kg wheat=3310 kilocalories[VI].
****1kg kiwifruit =610 kilocalories[VII].

The second analysis involved the development of a real-world PV park in Central Thessaly, that extends over an area of 1.3 ha (Singh, 2002). The total power capacity of the plant is 500 kW. For the estimation of mean annual energy production, we considered the typical value of 1485 kWh/kWp, increased by 15% under the assumption of applying a solar module tracking system. Taking an investment period of 20 years, a financial analysis was employed (Siamparina, 2021), and contrasted to the development of the two

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[I] Visser, C.D.; Buisonjé, F.; Ellen, H.; Stanghellini, C.; Voort, M.V. State of the Art on Energy Efficiency in Agriculture, Country data on energy consumption in different agroproduction sectors in the European countries, 2012. Available online: https://www.semanticscholar.org/paper/State-of-the-Art-on-Energy-Efficiency-in-Country-on-Visser-Buisonj%C3%A9/72f757a4a816fca1bbad065ddb67ff91eac53531 (accessed 27 June 2021).

[II] Gemptos, F. The irrigation of whead, Το πότισμα του σκληρού σιταριού: Πόσο αποδίδει η άρδευση; 26 March 2019, Available online: shorturl.at/gvIVZ (accessed 27 June 2021).

[III] Mohammadi, A.; Rafiee, S.; Mohtasebi, S. S.; Rafiee, H. Energy inputs – yield relationship and cost analysis of kiwifruit production in Iran, Renewable Energy, Volume 35, Issue 5, 2010, Pages 1071-1075, ISSN 0960-1481,https://doi.org/10.1016/j.renene.2009.09.004.

[IV] Kukuryiannis, V. and Vasilakakis, M. (1997). Kiwifruit production and research in Greece. Acta Hortic. 444, 43-48 DOI: 10.17660/ActaHortic.1997.444.3 https://doi.org/10.17660/ActaHortic.1997.444.3

[V] Piasecka, I.; Bałdowska-Witos, P.; Piotrowska, K.; Tomporowski, A. Eco-Energetical Life Cycle Assessment of Materials and Components of Photovoltaic Power Plant. Energies 2020, 13, 1385. https://doi.org/10.3390/en13061385

[VI] Calories 24. Wheat. Available online: https://calories24.com/int/calories-in/wheat (accessed 27 June 2021).

[VII] Calories 24. Kiwifruit. Available online: https://calories24.com/int/calories-in/kiwifruit (accessed 27 June 2021).

alternative food sources, i.e., kiwifruit and wheat. **Figure 5.5** illustrates the financial flows for:

(a) Solar parks; based on recent prices of electricity produced by PV parks (2021)

(b) Financial needs and aspects of the cultivation of kiwifruit in 2021 prices

(c) Financial needs and aspects of the cultivation of wheat in 2021 prices

The financial analysis indicates that an investment to kiwifruit is highly efficient (almost the same with PV panels), and needs less than a half of the investment for PV panels development. The time needed for the amortization of the investment cost for kiwifruit crops is about 7 years, as for PV panels it is around 12 years.

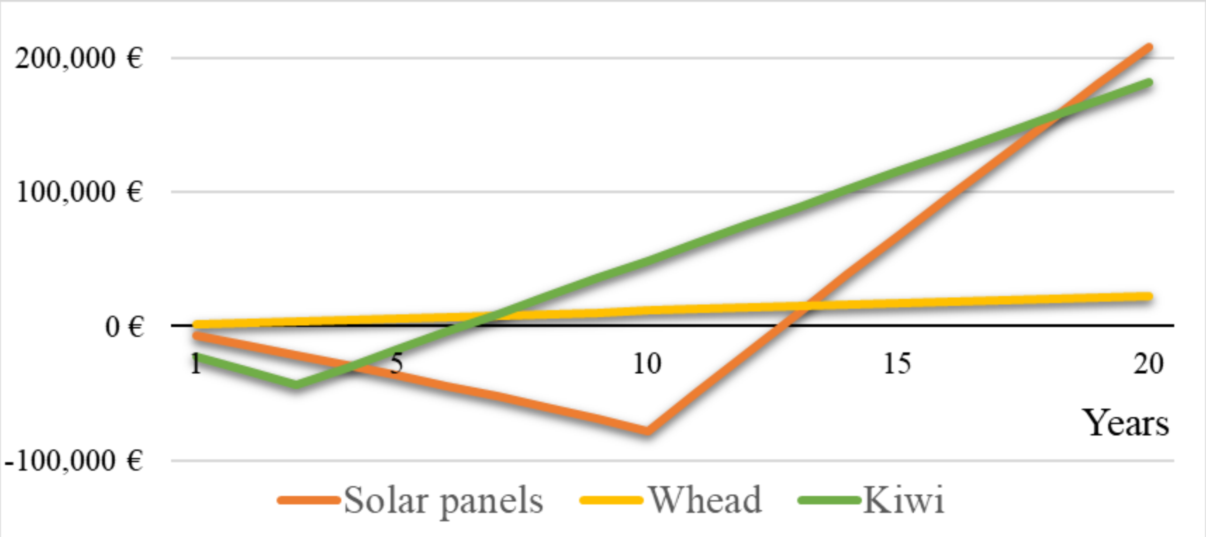


Figure 5.5 Cumulative financial outflows and inflows for different activities (source: Siamparina, 2021).

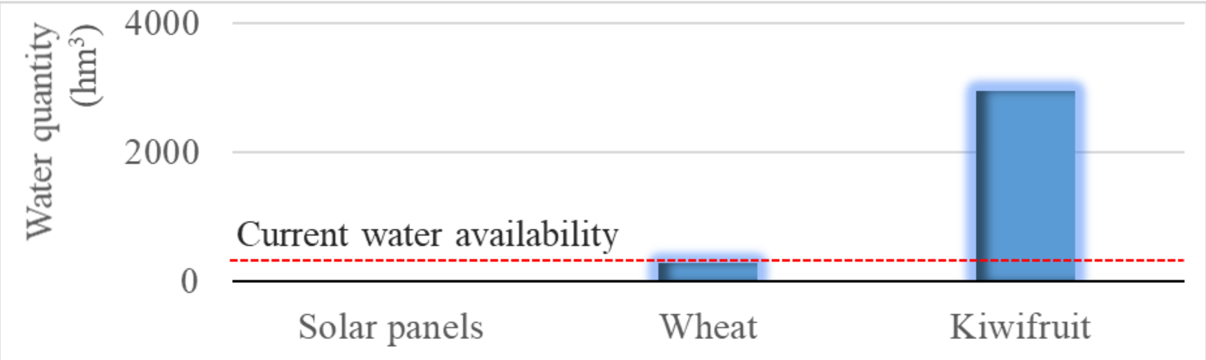


Figure 5.6 Water needs for Thessaly plain if there were only wheat or kiwifruit.

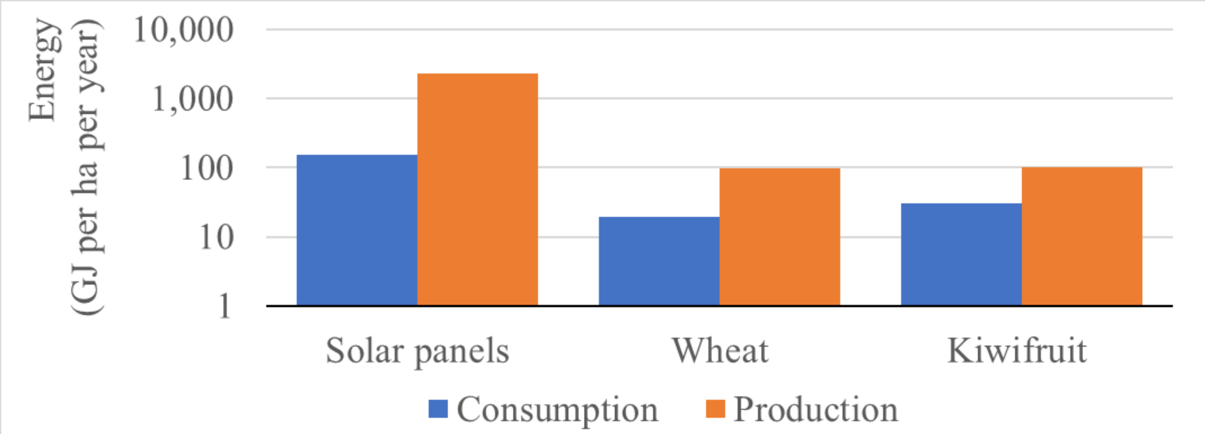


Figure 5.7 Annual energy needs and energy production per ha (energy by food is converted from calories to Joule).

Under an extreme scenario of agricultural development based on kiwifruit over the entire Thessaly, the total water needs will reach 3 000 hm^3, while the available surface water resources are only 340 hm^3 (Koutsoyiannis et al., 2008) (**Figure 5.6**). Obviously, this a non-sustainable option, given that the groundwater resources of Thessaly are under substantial stressing.

Finally, in **Figure 5.7**, we plot the energy balance of the three alternatives, on a life-cycle basis. In terms of pure production, the PV development is by far more beneficial.

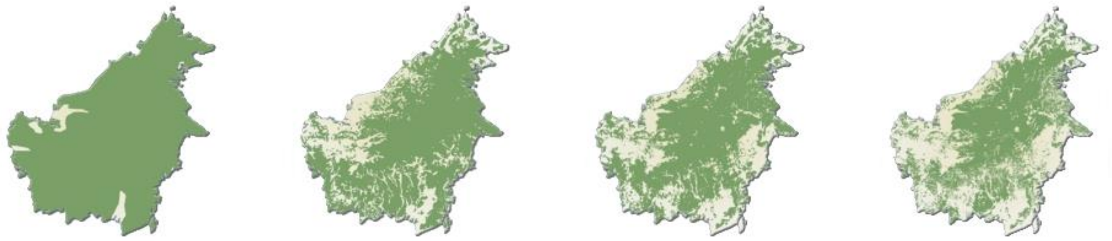
Chapter 6. Clustering and growth, partitioning and protection

«αἰεὶ τὸν ὁμοῖον ἄγει θεὸς ὡς τὸν ὁμοῖν» (Οδύσσεια, ρ 218)
"All ever, the god is bringing like and like together." (Homer-Odyssey)

6.1 Ecosystems

Ecosystems are characterized by dynamic transformations involving spatial clustering. In order to show how the proposed stochastic tool could be applied in the study of ecosystems we present the quantification of the evolution of clustering for three case studies:

(a) the deforestation of Borneo (**Figure 6.1**, **Figure 6.3**a),
(b) the deforestation of the Amazon (**Figure 6.2**, **Figure 6.3**b) and
(c) the evolution of water bodies in Greece (**Figure 6.4**, **Figure 6.5**, **Figure 6.6**)



(a) (b) (c) (d)

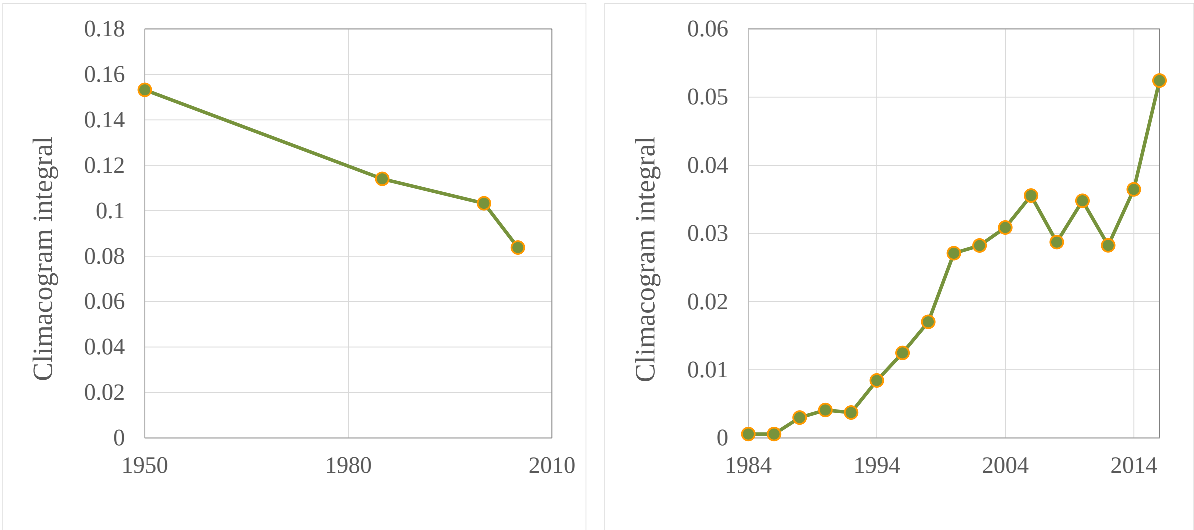
Figure 6.1 Deforestation in Borneo, declustering of forests 1950-2005[I] (a) 1950; (b) 1985; (c) 2000 (d) 2005.

In these examples, we can see the demolition of the forests' clustering in Borneo, and the evolution of clustering of dry lands and urban areas in the Amazon Forest. An interesting insight is provided, showing the evolution of water bodies in Greece, as new artificial lakes are created, resulting in amplification of natural variability. Such an argument in favor of the integration of dams in the landscape was recently proposed (Ioannidis and Koutsoyiannis, 2020). Note that increasing of clustering of water bodies is associated with the construction of large-scale dams and it is related to the economic growth; increasing clustering appears in periods of increasing Gross Domestic Product GDP (**Figure 6.6**).

[I] Creator Credit Hugo Ahlenius. Available online: https://www.grida.no/resources/8324 (accessed on 15 September 2020).

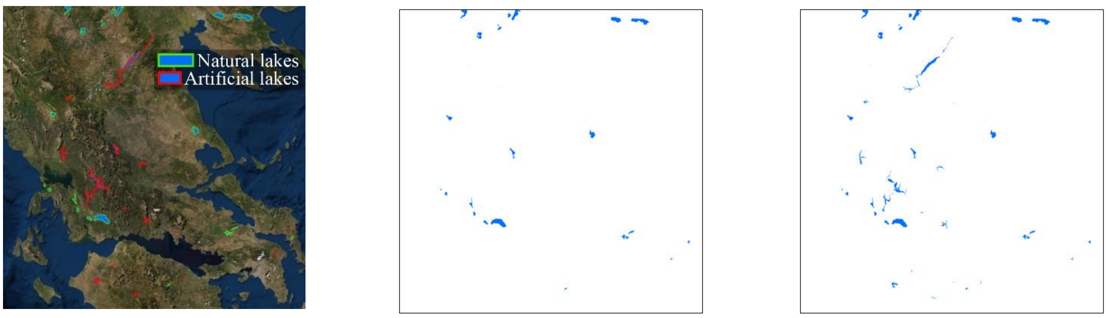
(a) (b) (c) (d) (e)

Figure 6.2 Deforestation of the Amazon, creation of clustering of dry land and urban areas inside a forest[I] (**a**) 1984; (**b**) 1992; (**c**) 2000; (**d**) 2008; (**e**) 2016.



(a) (b)

Figure 6.3 Rate of alteration of clustering through time of (a) demolition of fosters' clustering in Borneo; data from **Figure 6.1**; (b) evolution of dry-lands' clustering in Amazon; data from **Figure 6.2**.



(a) (b) (d)

Figure 6.4 Evolution of water bodies in Greece as new artificial lakes are created (a) overview map of the area with natural and artificial lakes in 2020; (b) layer of the map: lakes 1960; (c) layer of the map: lakes 2020.

[I] The Human Impact on the World's Forest. Available online: https://www.visualcapitalist.com/human-impact-on-forests/ (accessed on 15 September 2020).

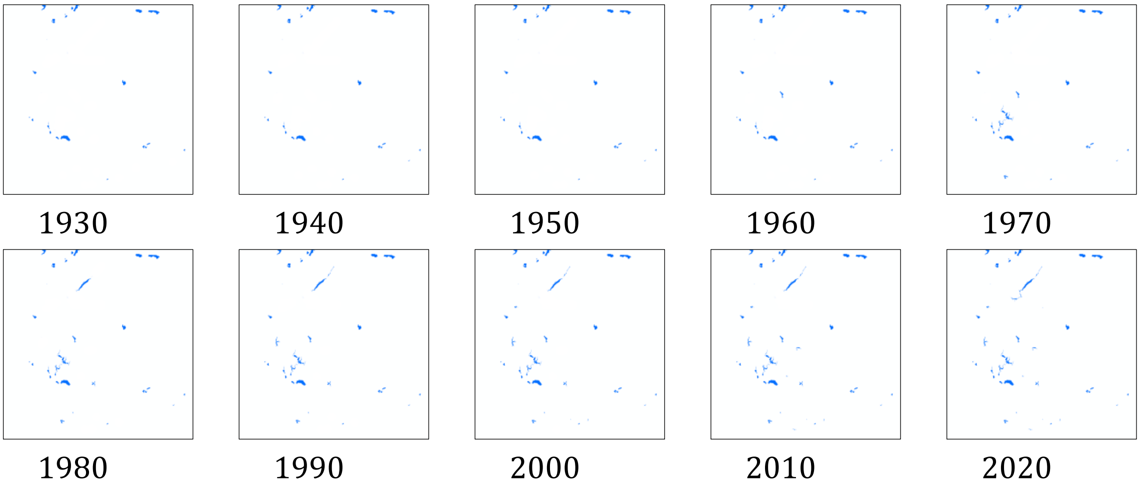


Figure 6.5 Evolution of water bodies in Greece as new big dams are constructed and new artificial lakes are created.

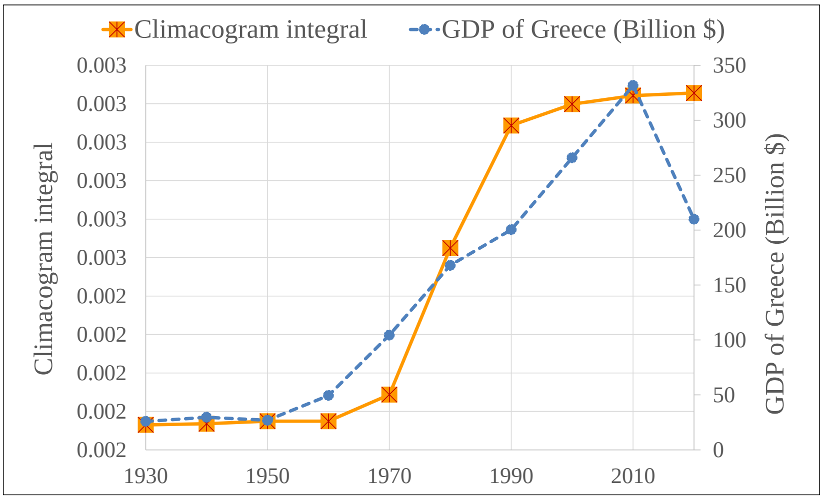


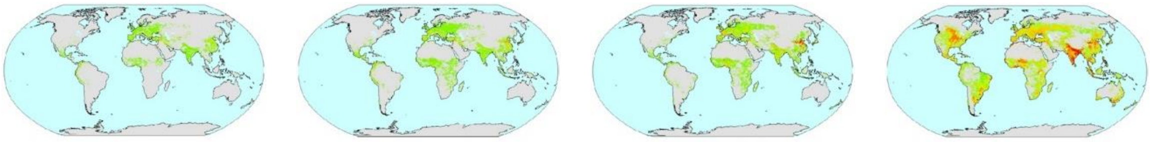
Figure 6.6 Rate of alteration of clustering through time of water bodies in Greece through the construction of large dams; related to GPD of Greece.

6.2 Evolution of human social clustering

Large-scale infrastructure projects are necessary when the human population is clustered and organized in large units. In order to understand and describe the changing scale of infrastructures, it is necessary to first assess the evolution of human social clustering. This is facilitated through the investigation of spatial databases. To this aim, we employ our stochastic methodology to characterize the temporal evolution of spatial information regarding human social clustering.

The beginning of human civilization was signalled by the organization of systematic agriculture through the clustering of cropland areas (**Figure 6.7**) and the formation of human clustering structures, i.e., societies that stabilized in space forming cities and transforming their environment (**Figure 6.9**). We evaluate related historical data to quantify the evolution of clustering in the global and local scale. **Figure 6.7** shows the evolution of cropland areas from 1000 BC to 2000 AD worldwide, derived from (Klein

Goldewijk et al., 2011), whereas **Figure 6.9** shows the evolution of settlements in London[I] from 1 AD to 1900 AD. It is interesting to note the radical increase in the rate of clustering occurring in both cases after 1700 AD (Figure 14), i.e. in the period after the industrial revolution.



(a) (b) (c) (d)

Figure 6.7 Evolution of cropland area; historical data (**a**) 1000 BC; (**b**) 1000AD; (**c**) 1700AD (**d**) 2000 (Klein Goldewijk et al., 2011).

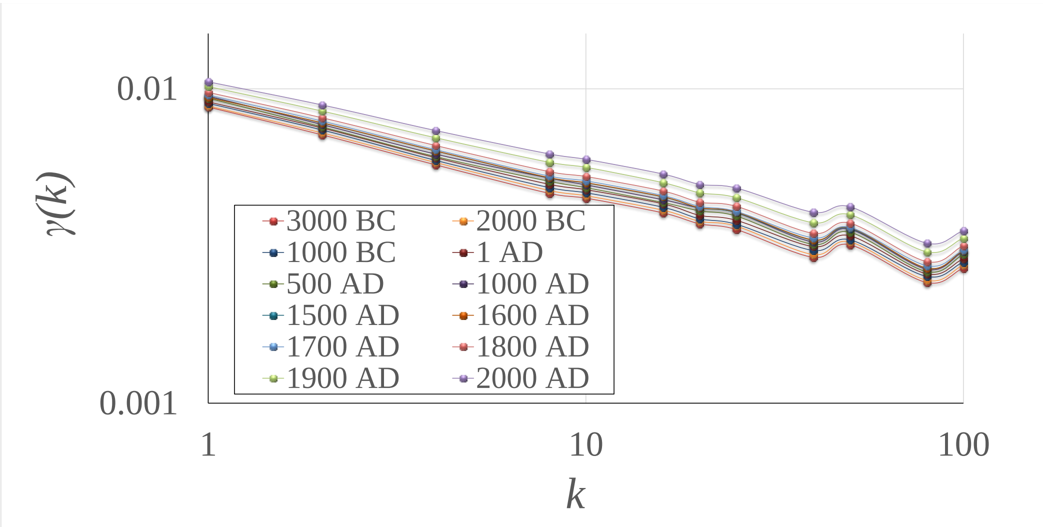


Figure 6.8 Climacograms of cropland areas.

(a) (b) (c) (d) (e)

Figure 6.9. Evolution of London; historical data (a) 1AD; (b) 1500AD; (c) 1700AD; (d) 1850AD; (e)1900AD[II].

[I] Data retrieved on 2022-02-17 https://www.theguardian.com/cities/2014/may/15/the-evolution-of-london-the-citys-near-2000-year-history-mapped

[II] Source: https://www.theguardian.com/cities/2014/may/15/the-evolution-of-london-the-citys-near-2000-year-history-mapped (accessed 17.2.2022)

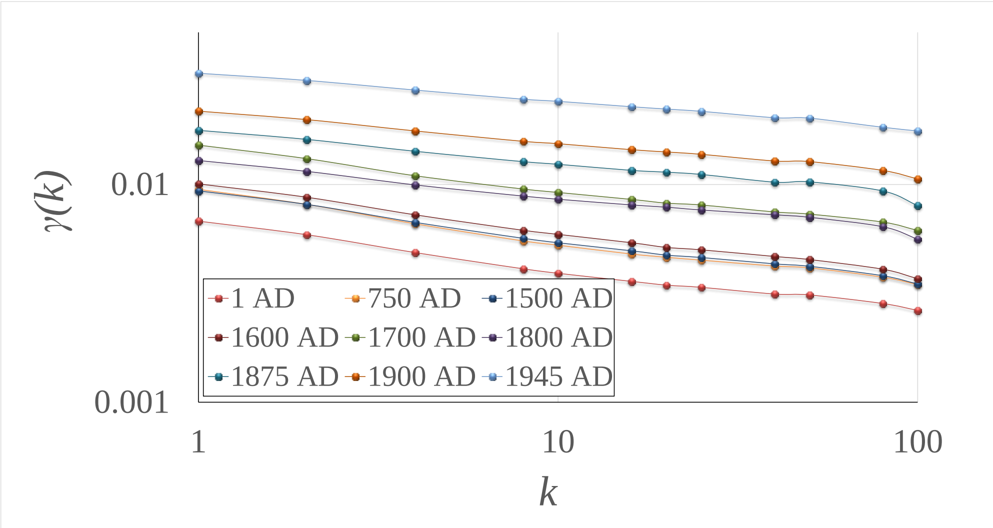
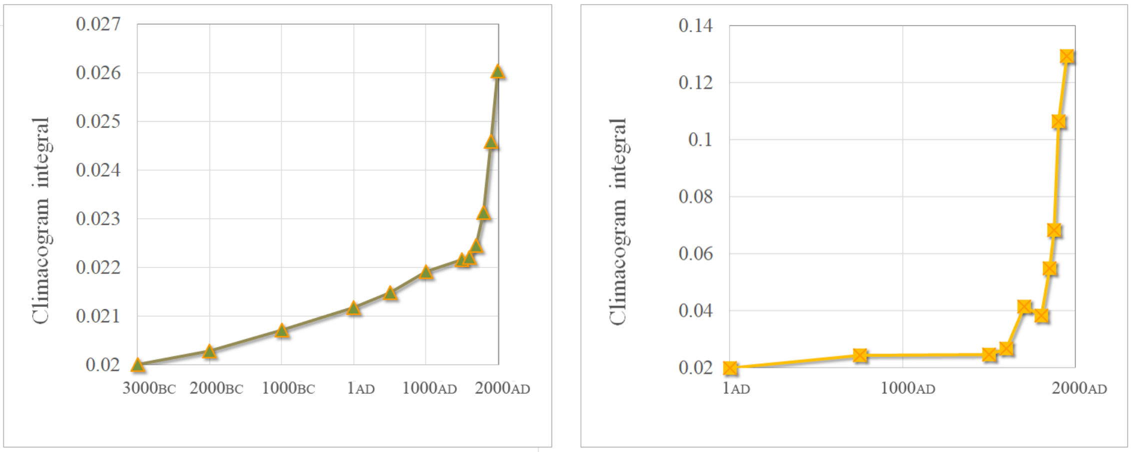
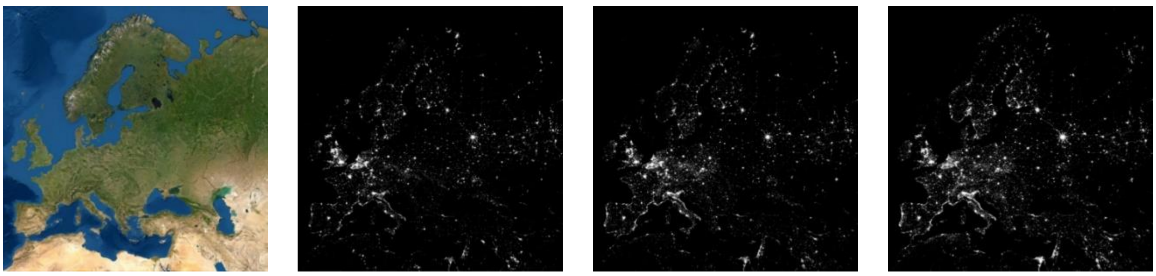


Figure 6.10 Climacograms. Clustering of urbanization of London.



(a) (b)

Figure 6.11 Rate of alteration of clustering through time of (a) cropland land historical data (b) evolution of urbanization in London area.



(a) (b) (c) (d)

Figure 6.12 (a) Europe and its night lights in (b) 1992, (c) 2002, (d) 2012.

Next, we explore spatial data pertaining to urbanization taking place in the past century. The first information source examined is the spatial distribution of satellite night lights. The night lights have been widely used as an index of the population and density of settlements (Elvidge et al., 1997), economic activity (Chen and Nordhaus 2011), consumption and distribution of electricity (Chand et al,. 2009), poverty and development status (Elvidge et al., 2009), and human exposure to natural disasters such as floods

(Ceola et al., 2014). An example showing satellite images from city lights in Europe is shown in **Figure 6.12** **Figure 6.12** (a) Europe and its night lights in (b) 1992, (c) 2002, (d) 2012.while their respective climacograms are shown in **Figure 6.13**.

Clustering is also useful in human societies as clustering of humans created what we now know as civilization. In order to support the modern way of living, growth is based on economies of scale (Koutsoyiannis, 2011). We can notice this in infrastructures, in cities, in production of goods, even in natural resources. As was argued by Sargentis et al., (Sargentis et al., 2020), economies of scale require clustering and societies are interconnected with the evolution of clustering. An example of the clustering of Europe cities and the relation to growth is given in **Figure 6.14** evaluating the clustering of night lights which have been widely used as an index several social issues. The example depicts that even the population in Europe was almost stable in the period 1990-2020, the increasing of clustering of the cities of Europe, meant also the increasing of Gross Domestic Product (GDP) per capita (Figure 10).

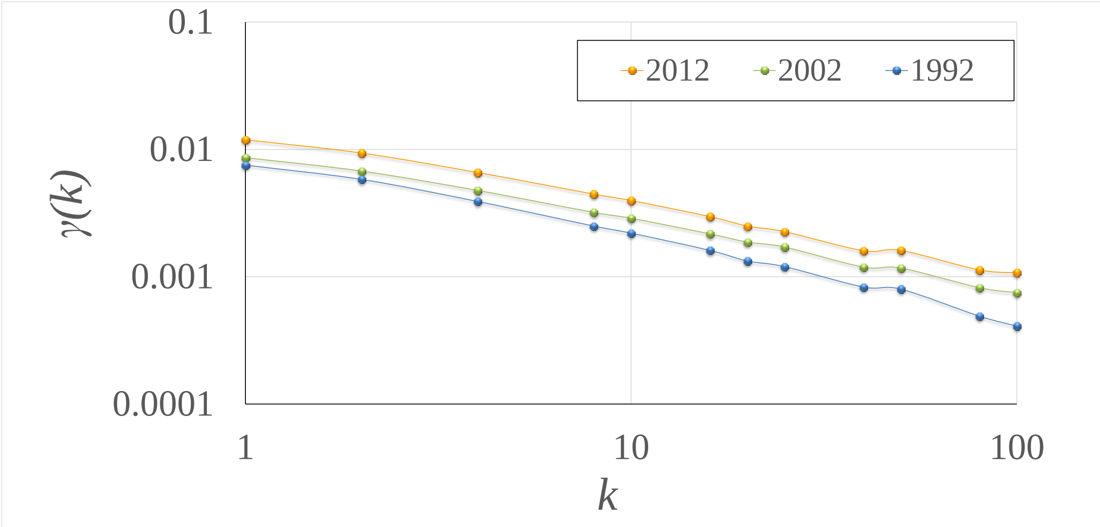


Figure 6.13 Climacograms of the images of night lights of Europe.

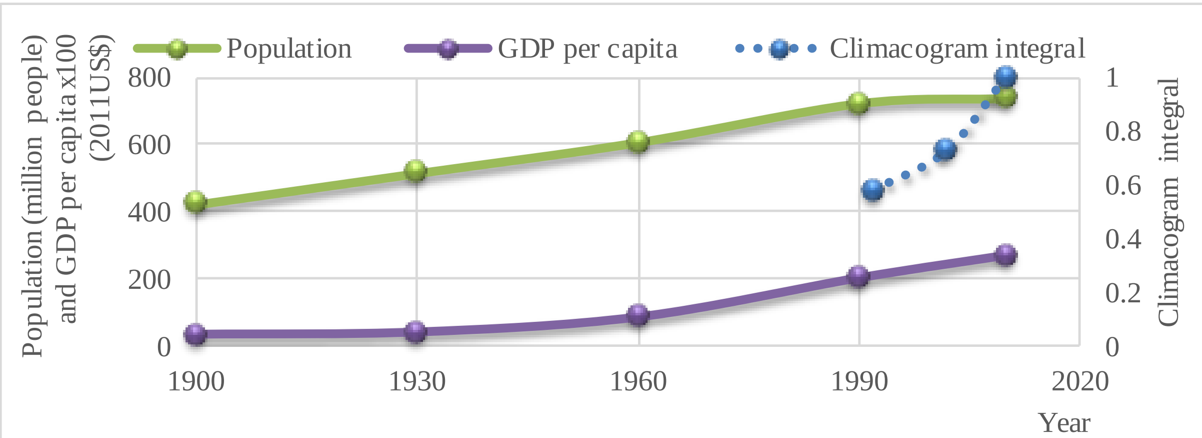
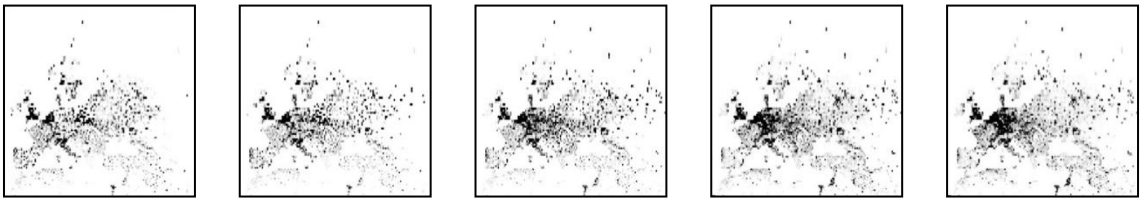


Figure 6.14 Europe: population; GDP per capita; and climacogram integral of Europe's night lights.

The second information source examined is the spatial dataset on land uses. Large-scale geospatial data, including land-cover types, are obtained from the Historical

Database of the Global Environment, HYDE 3.1 (Klein Goldewijk et al., 2011), of the National Centers for Environmental Information, National Oceanic and Atmospheric Administration, NOAA. HYDE datasets are based on Food and Agriculture Organization of the United Nations agricultural statistics and land use[I] (FAOSTAT) over the period 1960 - 2010, a variety of other historical information prior to 1960, datasets for wood harvest by FAO and urban land extent in combination with assumptions of other land cover change (e.g., forest areas, which are estimated by MODIS equipped satellites). This dataset is chosen because it contains valuable temporal information on urbanization.

The land cover dataset is provided in form of NetCDF files at a spatial resolution of 0.5×0.5 degrees of latitude and longitude. Therefore, the size of each grid cell expands from 1.3475×10^7 m^2 to 3.088224×10^9 m^2. In addition, land cover geospatial data are provided at annual time resolution using the WGS84 reference coordinate system. The longest record spans the years 1770-2010, but our studied period spans from 1900 to 2010. Land cover annual maps report the percentage of grid cell area belonging to each of 28 land cover types, from which we focus on the urban land cover type. An example showing the extension of urban land cover in Europe is shown in **Figure 6.15**, while their respective climacograms are shown in **Figure 6.16**.



(a) (b) (c) (d) (e)

Figure 6.15 Europe in Mercator projection of urbanization in (a) 1900; (b) 1930; (c) 1960; (d) 1990; (e) 2010.

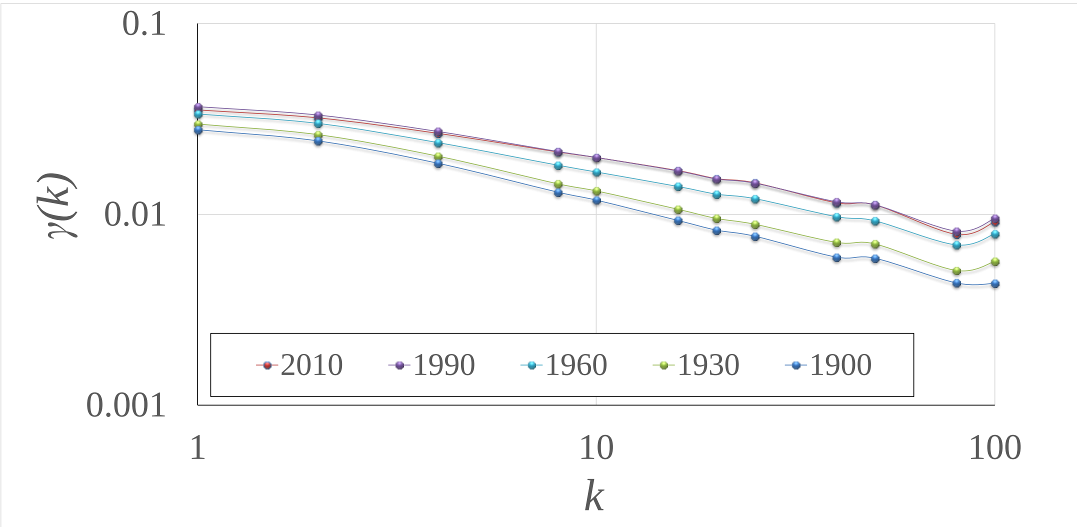
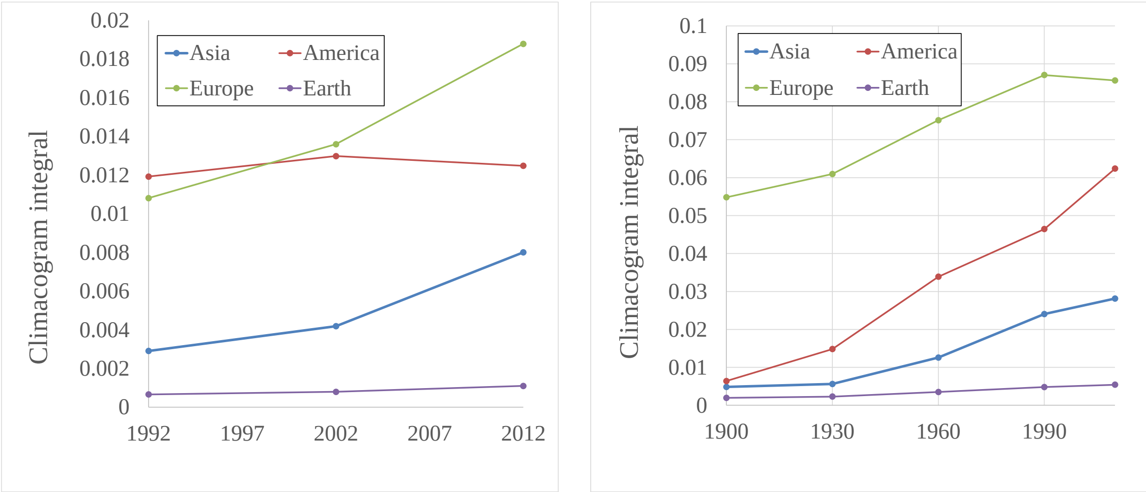


Figure 6.16 Climacograms of urbanization's clustering in Europe.

[I] Available online: FAO https://www.U.org/faostat/en/#data/RL (accessed 2.3.2022)

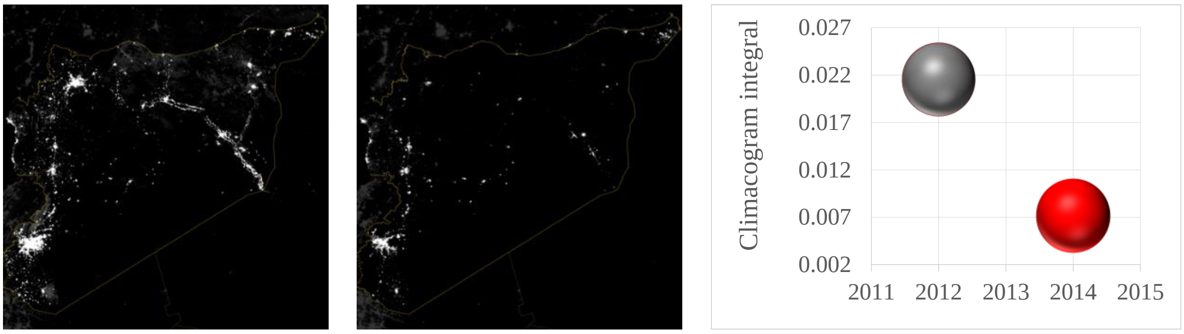
All studied images along with the complete climacogram analysis for Europe, Asia, America and the globe is presented in **Appendix: Chapter 2** and summarized in **Figure 6.17**.



(a) (b)

Figure 6.17 Temporal evolution of urban clustering from evaluation of (a) city lights and (b) urban land cover percentages.

The temporal evolution of human social clustering from both information sources is presented in **Figure 6.17**. Overall the analyses support the case for increased human social clustering during the 20th century in all three continents, i.e., Asia, Europe and America. A few differences arise from the comparison of the period that the information sources overlap, i.e., from the 1992 to 2010. Namely, although urbanization appears increasing in terms of land use in America, this trend is not confirmed by the evaluation of night lights for the same period, which appear slightly decreased. On the contrary, the night lights in Europe have majorly increased during this period, despite the relative stability in the urban land use cover.



(a) (b) (c)

Figure 6.18 Satellite night lights of Syria [I] (a) 2012; (b) 2014; (c) Rate of alteration of clustering before and after war.

[I] Data retrieved on 2022-02-17 by https://www.nytimes.com/interactive/2015/03/12/world/middleeast/syria-civil-war-after-four-years-map.html?mc_cid=bbef5eadb7&mc_eid=236cd449ae&_r=0

These differences indicate the virtue of considering both information sources, as night lights appear to be a better index of population density whereas the land use cover is more reflective of the spatial expansion of urban land uses.

From this point of view, it appears that urban expansion has been more prominent in America, whereas Europe has experienced increased population density. Last, Asia shows consistent increases in both information sources over the last decades.

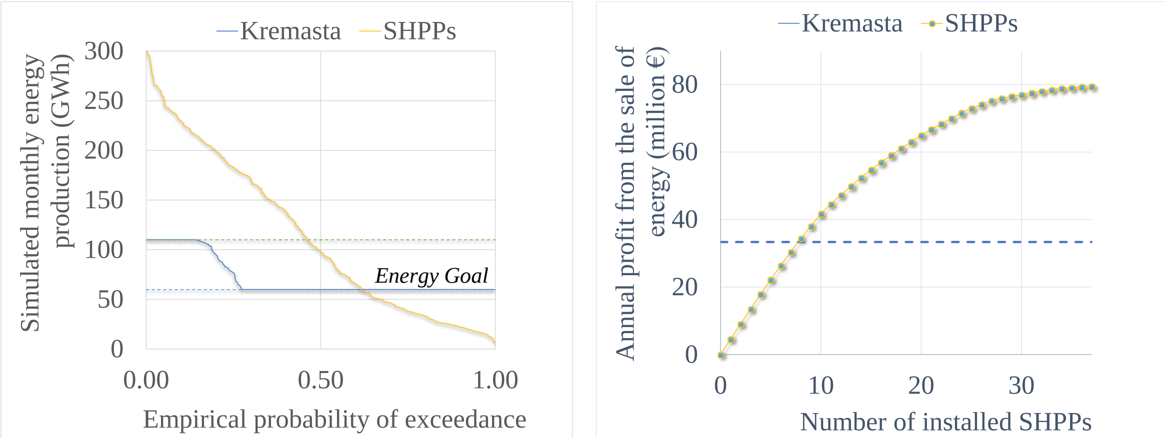
Note that threats as war and natural disaster demolish clustering of human social structures **Figure 6.18**.

An example of clustering effect is the development of the large-scale infrastructures for the exploitation of natural resources (Sargentis, 2019). A special case are hydroelectric projects which have a completely different way of construction and operating philosophy, depending on their size. In order to compare the advantages and disadvantages of small hydroelectric projects in relation to large ones, Bairaktaris (Bairaktaris, 2020) examined the wider area of the Achelous River basin, where the largest hydroelectric plant of Greece, Kremasta dam, is being "replaced" with as many Small Hydroelectric Plants (SHPPs) as needed in order to achieve an equivalent installed capacity.

Due to the large number of required stations, a standard design method was developed for their design, aiming to produce the most accurate energy and economic results possible for each of the installation sites. Through this and in the context of the proposed delustering of the region, 37 small stations are planned on the bed of the Achelous River, and its tributaries Agrafiotis and Tavropos. Thus, it becomes possible to compare the energy and the techno-economic current status of Kremasta with the hypothetical scheme of the 37 SHPPs.

Kremasta's construction cost, has been reported by the construction company[I] 84 781 000 US1974$ (381 937 825 € after adaption in current prices). The total cost of 37 SHPPs is estimated 446 995 079 €. With the same installed power, theoretically SHPP project can produce 60% more energy (**Figure 6.19**a). However, **Figure 6.19**b shows that the system of SHPPs does not provide guaranteed amount of energy, in contrast to Kremasta that catches the target of 59.9 GWh/month at 100% of the time. Also, through the large-capacity of reservoir's Kremasta, production of energy is delayed from the physical inputs and covers the power peaks of interconnected electrical networks. Evaluating the clustering of natural resources (in this case the water basins) of **Figure 6.20** with stochastic method, in **Figure 6.21** we note the increase of clustering.

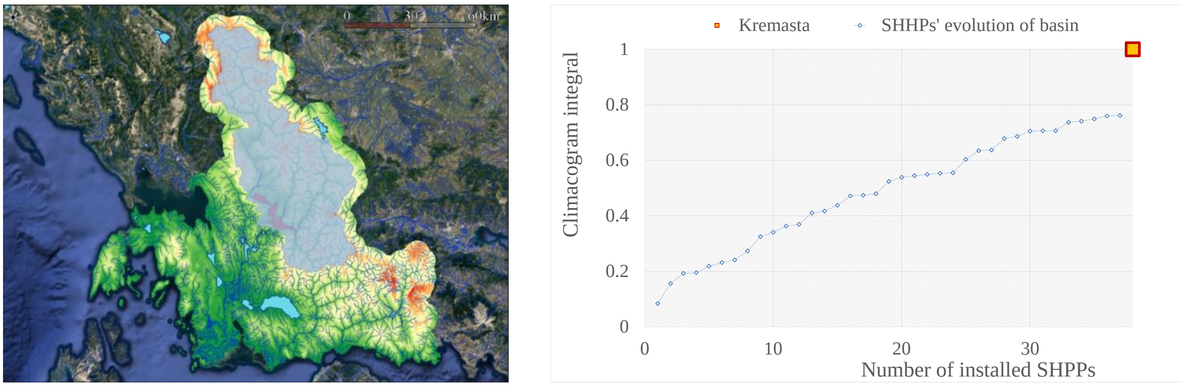
[I] ECI-Engineering Consultants INC. Kremasta Project Report, Technical Report prepared for Public Power Corporation (ΔΕΗ). 1974.



(a) (b)

Figure 6.19 (a) Comparative diagram of annual profit from the sale of energy; (b) Monthly energy-probability curve of Kremasta compared to the SHPPs (source: Bairaktaris, 2020).

Figure 6.20 Addition of SHPPs and the evolution of water basin (source: Bairaktaris, 2020).



(a) (b)

Figure 6.21 (a) The water basin of Kremasta; (b) Rate of the evolution of clustering of the basins with the addition of SHPPs, water basin clustering of Kremasta (blue dashed) (source: Bairaktaris, 2020).

More detailed data analysis of this section is presented in **Appendix: Chapter 2**

6.3 Athens water supply system

Organized societies require robust infrastructures, among which hydraulic projects, such as water supply and drainage systems, are most important. Because of its long history, Athens offers a useful study case in this respect. Due to its dry climate, it has suffered from water insufficiency and had to develop technology to deal with this problem since ancient times. During its history, the periods of social and cultural progress have been associated with successful management of water-related problems. The current water supply system is highly sophisticated and reliable and is a result of decision making based on social, technical and economic criteria, over time. Here we study the development of the Athens water supply system from the beginning of the previous century and we present historical information for the capital intensity of the implementation of various phases of the modern water supply system, as well as the price of water and the cost of large infrastructure of hydraulic works. To this aim, a systematic investigation had to be carried out to convert past prices and costs to their equivalents today, along with an assessment of the exploitation of natural resources with the specific hydraulic projects.

To evaluate the water supply system, the cost of constructing smaller reservoirs in Greece was correlated to the cost of the existing reservoirs, which feed the water supply system. To this aim, an economic model was developed to simulate the price of water and the cost of water storage with the size of reservoirs.

The findings of this study explain that if the people of Athens had chosen the construction of smaller reservoirs instead of the existing large-ones, the price of water and therefore the cost of living in Athens, would be significantly larger. We also observe that changing the scale of water infrastructures does not deviate from the so-called “0.6 rule” (Koutsoyiannis, 1979) which quantifies the relationship of project scale and its cost (see details below). This result supports the utility of the so-called economies of scale in the development of large cities and aims to contribute to the debate on the necessity of large-scale water infrastructures.

Our analysis does not consider risk analysis methods. For the latest issues and particularly the risk analysis methods of critical infrastructure as well as their effectiveness for assessing services in utilities, the interested reader may consult references (Pietrucha-Urbanik and Tchórzewska-Cieślak, 2018; Koutsoyiannis and Mamassis, 2018).

It is obvious that the natural water resources of Attica are not sufficient for the water needs of an ever-growing population and therefore resources that are far from the city had to be conveyed to Athens.

A short summary of the history of the water supply system of Athens may be useful in order to introduce the reader to the context of the study. The ancient system was in use in the 20th century, after maintenance in the 19th century, while the history of the modern system dates from the 1920s with the construction of large-scale infrastructure. However, we were able to find data for the water costs from some years before, namely from 1913 (view more in **Appendix: Chapter1**).

Digression 6.A: Analysing data for Athens water supply system

For the first step of the methodology:

(a) The social conditions of the 20th century, which explain the growth of population and the development of the city.
(b) The water supply system and the related costs.

For the second step we analyse:

(c) Historical financial data, converting them to today’s equivalents.
(d) Other data related to water supply such as the average consumption per person per year, total (cumulative) supply capacity of the system per person per year and supply to demand ratio.

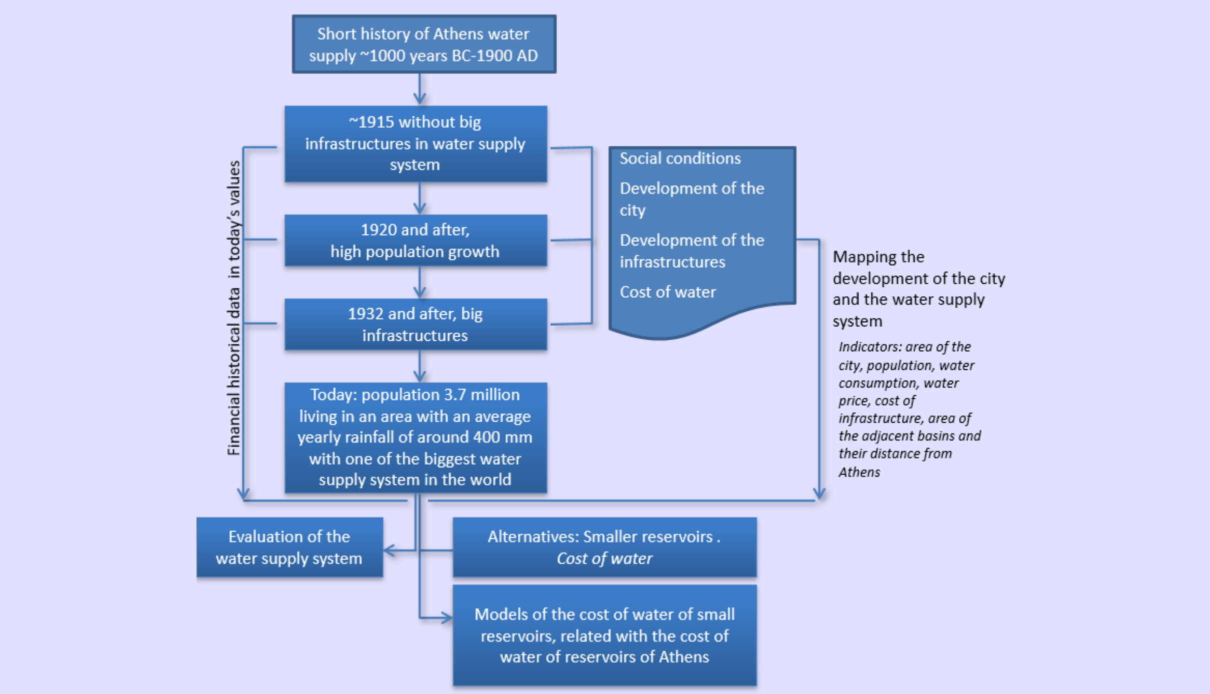


Figure 6.22 Illustration of the main points of the methodology.

Social conditions

It is estimated that Athens in 4th century BC had 160,000 inhabitants (Russel, 1958). At the time of Handrian, in the 1st century AD, the population was estimated at 30,000 (Hansen, 2006). Ancient Athenians had developed particularly long aqueducts, for their era, which are admirable both for their extent and durability, as some are still in operation. Like their ancestors, modern Athenians are able to combine the convenient and healthy way of living in a dry climate by using advanced technology to transfer water from less dry areas. The difference however is in scale, as now they can transfer water in larger quantities and across longer distances, from the wetter western part of Greece. The aqueduct's longest path from Evinos to Athens (Acharnae Water Treatment Plant) is about 217 km (without counting the passage across the Mornos reservoir).

The great change in the scale of the city of Athens took place as soon as it was chosen to become the capital of the new Greek state (**Figure 6.22**). The establishment of the capital city caused a large influx of new residents. From around 12,000 in 1834, their number doubled over the next decade (Biris, 1938; Mavrogonatou, 2012; Mavrogonatou, 2009). However, the prediction of 40,000 inhabitants by the architects who designed of the new city (Kleanthis-Schaubert) did not happen before the 1860s and the "milestone" of 100,000 inhabitants was not overtaken before the late 1880s.

(a) **(b)**

Figure 6.23 View of the city of Athens **(a)** painting by Richard Temple (1809-1810)[I] **(b)** view of the city of Athens (2018).

The causes of this growth are related to the function of the city as an administrative and not an industrial-productive centre. Piraeus was the industrial-productive centre next to Athens and also an important harbour. The evolution of Athens in the 20th century is connected to the history of modern Greece with its characteristic phases of mutation: the Asia Minor Disaster (1922), the Second World War (1939-45) and the internal immigration of the population after the civil war (1946-49), since the anonymity of the big city helped conceal the political friction and the tragic incidents of the civil war.

During the 20th century Athens was developed as the centre of Greece (**Figure 6.24**), generating ~20% of the GDP of Greece. Big capital investments were needed for the construction of modern infrastructure (i.e. Athens is the only city in Greece with Metro and more).

The development of the water supply of Athens

Athenians of the classical era were drinking water from wells, a few springs and from the Peisistratian (Tassios, 2007) aqueduct which was built around 530 BC and is in operation until present date. The longer Hadrianic aqueduct was built in 134 AD.

Until the beginning of the 20th century, the water supply of the city was from ancient hydraulic works (Chiotis and Chioti, 2012), mostly the Hadrianic aqueduct, wells and other small-scale hydraulic infrastructures. The price of water was determined on a subjective basis and the management of the water was made with the criteria and traditions of the Ottoman Empire (e.g., increased corruption meant that in many cases the manager would alter prices according to relation with the customers, bribes etc.). It is also estimated that, at the time, more than half of the income from water sales were lost (Gawsmann, 1940).

As the city started to grow, the old system became inadequate and large hydraulic projects had to be constructed. **Figure 6.25** and **Table 6.1** show the development of large hydraulic works during the 20th century in Athens (Koutsoyiannis and Mamassis 2018; Stergiouli and Hadjibiros, 2012; Patsis, 1924; Gausmann 1932).

[I] Source: Hobhouse, J.C. A journey through Albania and other provinces of Turkey in Europe and Asia, to Constantinople, during the years 1809 and 1810, Printed for J. Cawthorn, London 1813.

Attica is a dry area, with an average yearly rainfall of around 400 mm, so the city has to supply water from basins whose distance from Athens continuously increased, ranging from 25 to 180 km away. Today, the people of Athens, are living in an area of 462 km^2, and consume water resources from an area of 3 906 km^2. The development of the city was combined with the covering of its streams (Seretli, 2014).

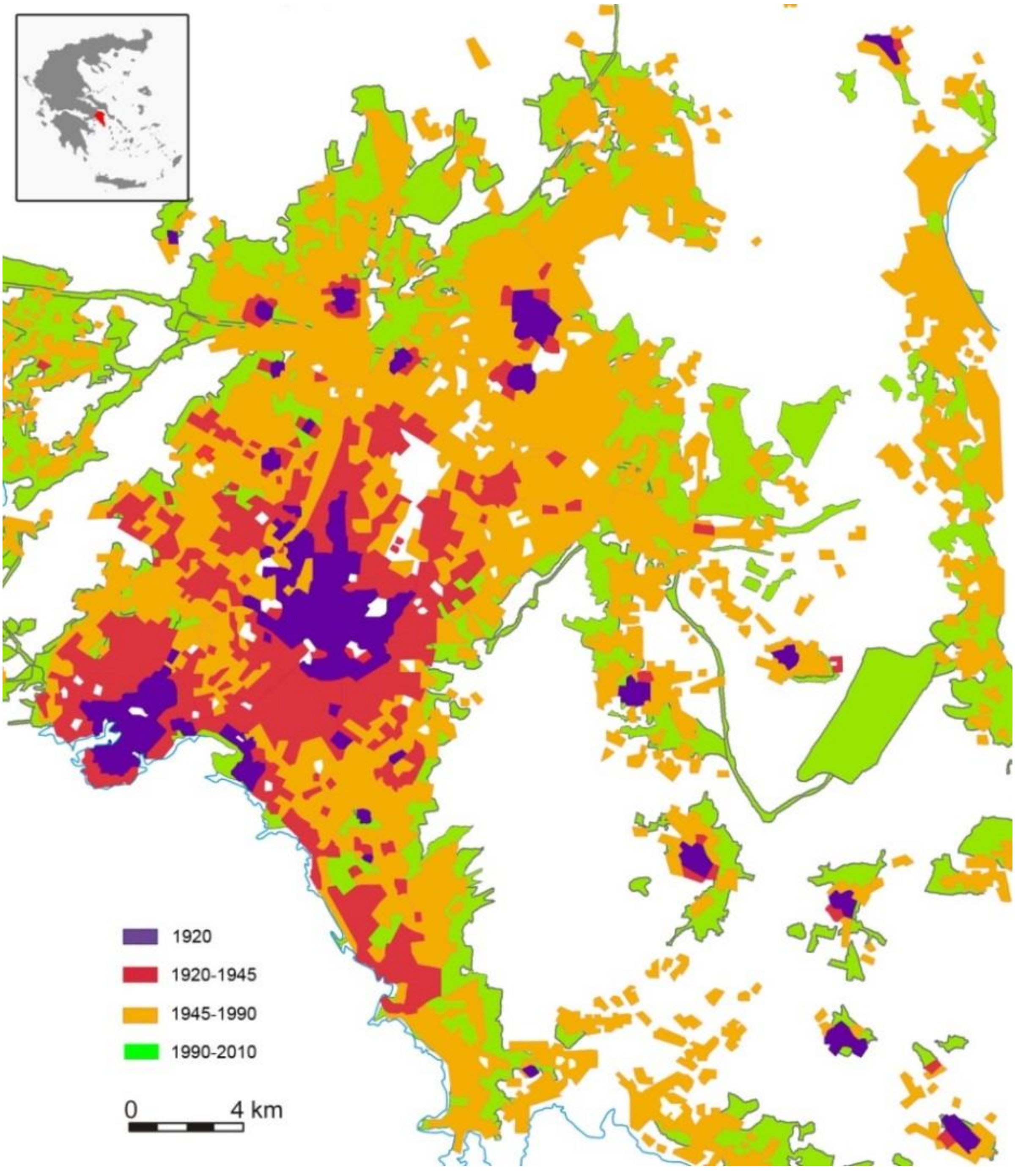


Figure 6.24 The urban development of Athens over the past 100 years.

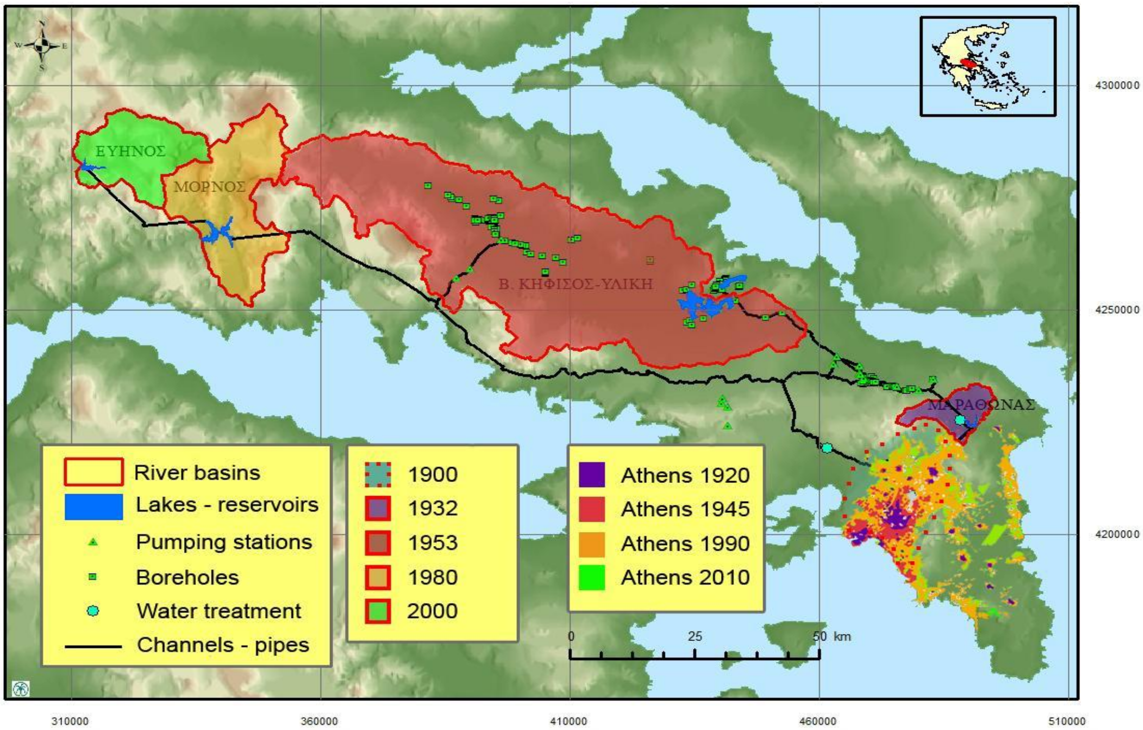


Figure 6.25 The development of the water supply system of Athens.

The inflows in **Table 6.1** depend on the annual hydrological balance of the basins. In surface works, inputs represent the mean inflow, while in groundwater projects the pumping capacities. The system capacity is estimated by historical data in view of the depletion conditions of each historical system configuration. The total capacity after the construction of Evinos is estimated by simulations.

Data and examination periods

In the analysis that follows we examine the socio-economic conditions before construction and after the construction of large-scale projects. Social, urban and technical data were compiled from relevant studies and were further processed. Older demographic, urban and technical data were easily accessed and compared to contemporary data, but the same could not be said for the economic data. Since the value of money is changing, in order to be able to assess economic data, a correlation of the value of currencies in which the costs and prices were measured at the time to the present currency had to be obtained.

The calculations were more and more difficult as we went back in time. Indeed, both finding data on the price of water and hydraulic infrastructures and converting them to current € becomes more difficult. From 1959 onwards, official data for the price of water have been published, including the conversion of drachmas in current €. From 1922 to 1959, some satisfactory data can still be found but not always from official sources. Finally, from 1910 to 1922 data were based on limited literature and the conversion of drachmas to € was made using ad hoc approaches, as there was no relevant literature to resolve this issue formally.

It should be noted that the value of currencies, and money in general, depends on highly complex parameters including social conditions, wars, financial changes, devaluations and revaluations. The further we go back in time, the drachma conversion in current € becomes more of a rough estimate than an accurate calculation. **Appendix: Chapter 1** provides a description of the bibliographic data and financial methods used in each time period based on data availability.

Digression 6.B: The evolution of the water supply system of Athens

Table 6.1 The big infrastructures of the water supply system of Athens[I] (Koutsoyiannis and Mamassis, 2018; Koutsoyiannis et al., 2002)

Time	Infrastructures	Basin area km^2	Inflows hm^3	Storage capacity hm^3	Total (cumulative)system capacity, hm^3/year
Water supply system					
1900	Wells and Hadrianic aqueduct	381	~10	-	~10
1932	Marathon	118	14	32	24
1953	Hylike	2467	295	585	244
1980	Mornos	588	235	630	300
1990	Boreholes	-	55	-	326
2000	Evinos	352	278	112	513
Sewer system					
1958	Main sewer of Athens (outflow in Keratsini)		Capacity 1 296 000 m^3/d		
1980	Twinned Main sewer of Athens (outflow in Keratsini)		Capacity 1 296 000 m^3/d		
1990	Parakephisios sewer of Athens (outflow in Akrokeramo)		Capacity 1 728 000 m^3/d		
1994	Operation of phase A of wastewater treatment in Psyttalia		700 000 – 800 000 m^3/d		
2004	Operation of phase B of wastewater treatment in Psyttalia				

Data processing and analysis

The analysis is focused on the system operation by defining its operational-economical technical and social indicators. As the boundary conditions are changed over time, with the construction of the new components of the infrastructures, we estimate the operational variability from historical data (Raso et al., 2018).

Figure 6.26 shows the capital investments for the water supply system of Athens. It is observed that if the same infrastructure were constructed today, the cost would be, as an order of magnitude, 1000 €/person (3,263,000,000 €/3,700,000 inhabitants). If we consider that a typical house for a family of four persons in Athens in 2018 costs about 100,000 € and that ≈5% of the cost is the plumbing infrastructure inside the house, the

[I] EYDAP: Available online: https://www.eydap.gr/ (accessed on 30 January 2019).

investment of the public hydraulic infrastructure represents a roughly equal amount of private hydraulic investment and, with their sum representing about 10% of cost.

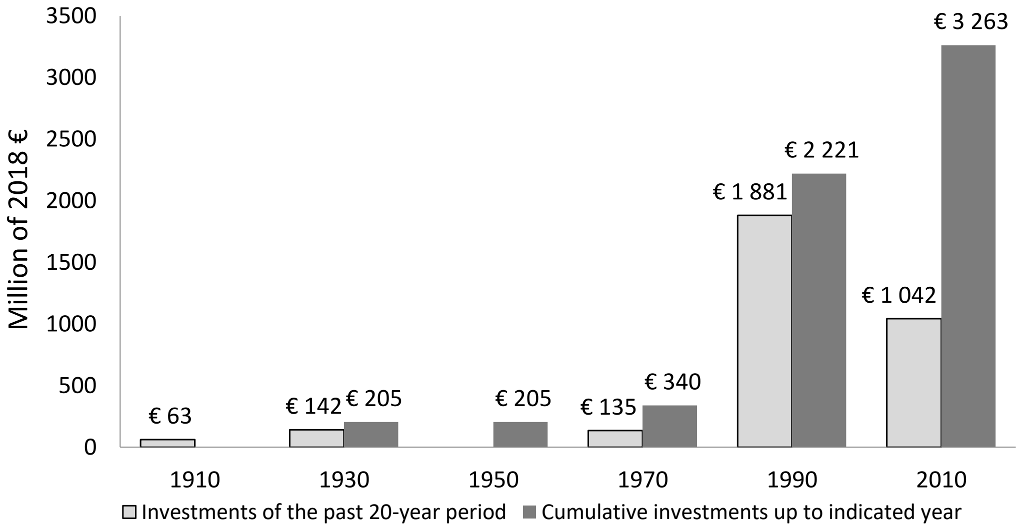


Figure 6.26 The capital investment of large water infrastructure[I] (supply, management and treatment) (millions of 2018 €) (Hekimouglou, 2014; Savvides et al., 1988; Papadaki, 2011; Stavrianakis, 2002; Sinos and Raftopoulos 1948; Makropoulos et al., 2010a; Makropoulos et al., 2010b; Merkouris, 1913).

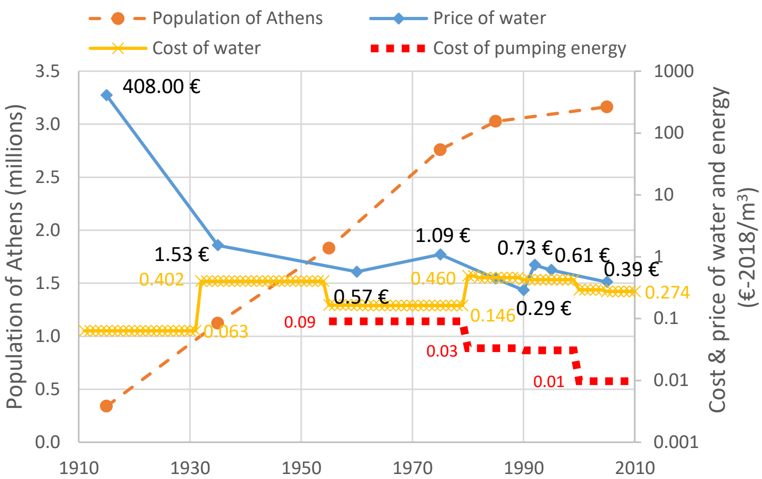


Figure 6.27 The evolution of the population of Athens over the last 100 years, cost and price of water of Athens and cost of pumping[II] (Koutsoyiannis and Mamassis, 2018; Gawsmann 1940; Makropoulos et al., 2010; Cooley, 2016).

[I] EYDAP, ANNUAL FINANCIAL REPORT (newsleter) Period from January 1, 1999 to December 31, 1999.

EYDAP, ANNUAL FINANCIAL REPORT Period from January 1, 2017 to December 31, 2017 In accordance with IFRS & Law 3556/2007.

Technical Chamber, Mornos Folder, Newsletter, issue 1549, January 16, 1989.

Ministry of Governmental Policy of Greece, Public Relations Service, Five Years of Economic Progress, 1967-1972, Athens 1972.

[II] EYDAP, Historical water price lists, 2008.

ULEN, What Athens pays for water, 1940.

Figure 6.27 shows the evolution of the population of Athens over the last 100 years alongside with the cost and the price of water. The population of Athens comes from census data. The water price and cost were converted to 2018 € as already described. To determine the cost of water per m^3 the capital recovery factor was based on an assumed interest rate of 6%, which is the most typical assumption in similar cases (for example, the Department of Water Resources of California (Cooley, 2016) uses this value to analyse the benefits and costs of water projects).

The first dramatic drop in price from 1910 to 1935 (**Figure 6.27**) can mostly be attributed to the construction of the first dam (Marathon) and the construction of the water distribution network (started 1926). Price is also reduced in the period from 1930 onwards, at a much slower rate. In the period before the construction of the Mornos dam, roughly from 1970 to 1980, the price was increased as a result of the unexpected high cost of that dam. An increase of the water price also happened during the prolonged drought of 1988–1995 to discourage water consumption, in a period of water scarcity for Athens (Xenos et al., 2002).

Figure 6.28 shows the average water consumption per person and the total (cumulative) capacity per person and is used as an indicator of the availability of water and the correlation between the abundance of the resource and its consumption. The supply-demand ratio, also plotted in the graph, is useful to evaluate these curves. As the total capacity increases, so does the consumption of water. It is possible that the abundance of the resource contributes to overconsumption alongside GDP increase and technological development. **Figure 6.28** also demonstrates why Mornos dam was necessary due to the spectacular decrease of the supply-demand ratio between 1960–1980 (before the construction of Mornos dam).

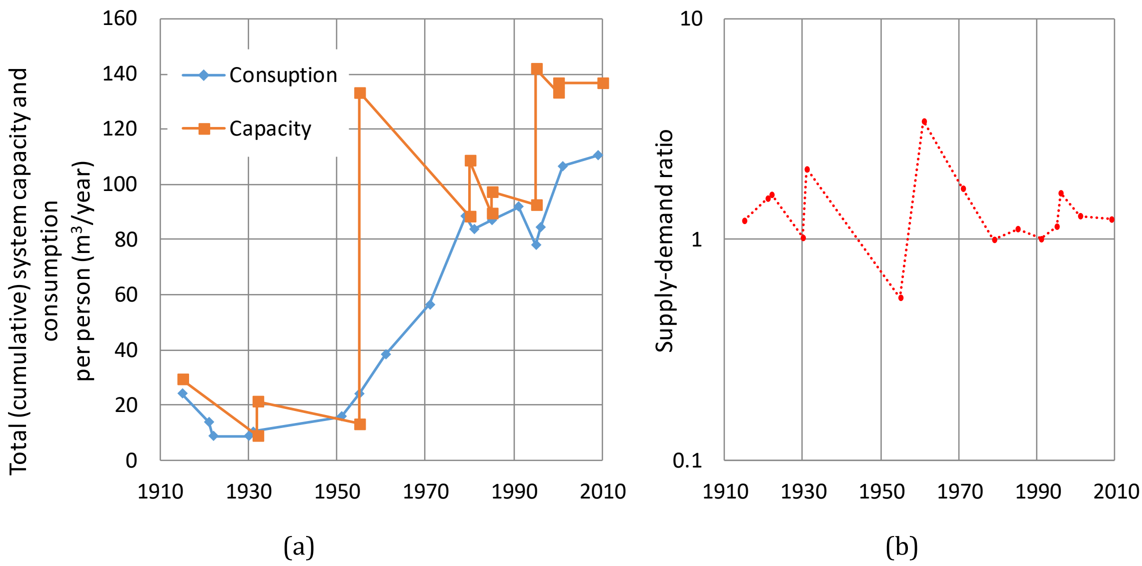


Figure 6.28 (a) Average consumption per person per year and total (cumulative) supply capacity of the system per person per year (data from: Koutsoyiannis and Mamassis, 2018). (b) Supply to demand ratio.

Observing **Figure 6.28**, it can be noted that before 1955 people in Athens lived with less than 20 m^3/year (55 L/d); the life style leading to that low consumption is described in historical documents (Gausmann, 1932; Hekimouglu, 2014). Thereafter, water consumption increased substantially but once again during the period of the seven-year drought (1988–1995), it dropped as a result of the demand management measures, including engagement of people, increasing-block tariffs and penalization of some water uses (Xenos et al., 2002). The entire campaign was very successful and despite the long duration and the severity of the drought there was no system failure.

Figure 6.29 shows the coevolution in time of the distance of the reservoirs with their supply. The increased distance arguably limited the effect of economies of scale, which if distances were shorter would have been expected to be even more noticeable.

Figure 6.30 shows that the area of the city has grown about 10 times in 100 years and the area of the catchments utilized for water supply has increased accordingly. It is interesting that this trend is almost linear even though the conditions (i.e., consumption per person) are changing

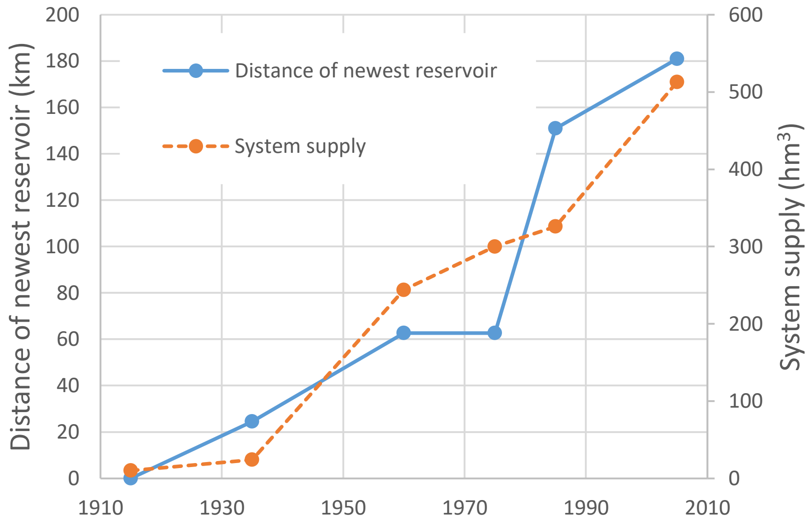


Figure 6.29 he coevolution of the distance of reservoirs from Athens with the water system supply (data from: Koutsoyiannis, 2006).

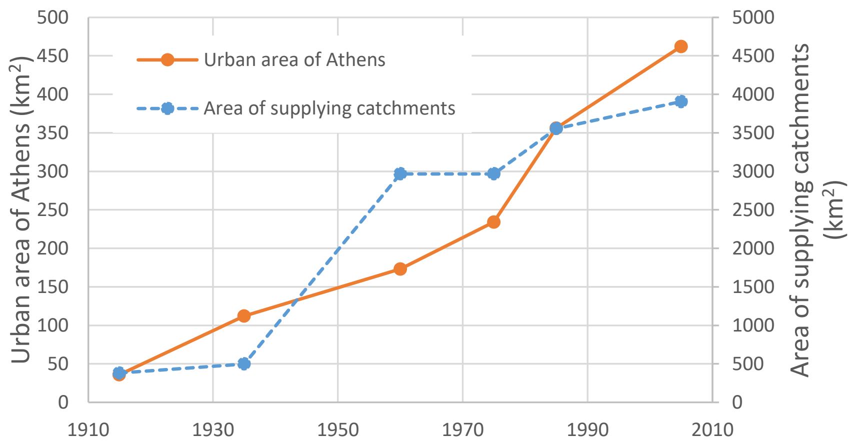


Figure 6.30 The coevolution of the area of the city of Athens with the surface of the catchments that supply water to the city (data from: Koutsoyiannis and Mamassis, 2018; Avelidi, 2010).

The management of the water resources

The construction of the system of reservoirs and aqueducts of Athens has been combined with the development of a sophisticated methodology for its management (Koutsoyiannis and Mamassis, 2018; Koutsoyiannis and Economou, 2003, Efstratiadis et al., 2004). The highlights of the methodology are:

(a) Stochastic modeling of natural processes rather than invoking fictitious outputs of climatic models for future scenarios. In particular, a prominent characteristic that had to be modelled was the drought persistence, which stochastically can be captured by the Hurst-Kolmogorov dynamics (Efstratiadis et al., 2004). The software system developed for this purpose is named Castalia (Efstratiadis et al., 2014) and can perform either in continuous simulation mode or in forecast mode. The theoretical background of the methodology can be found in Refs. (Koutsoyiannis, 2000; Koutsoyiannis 2016).

(b) Real optimization of the hydrosystem's performance. In contrast to the traditional techniques based on deterministic optimization (e.g., linear programing) or simplified stochastic methods (e.g., stochastic dynamic programming), for the management of the Athens water supply system a sophisticated stochastic optimization methodology was developed. This combines system parameterization through parameterizing the system's operation rules, stochastic simulation and optimization of the parametric rules. This methodology is thus known as parameterization-simulation-optimization (Koutsoyiannis and Economou, 2003).

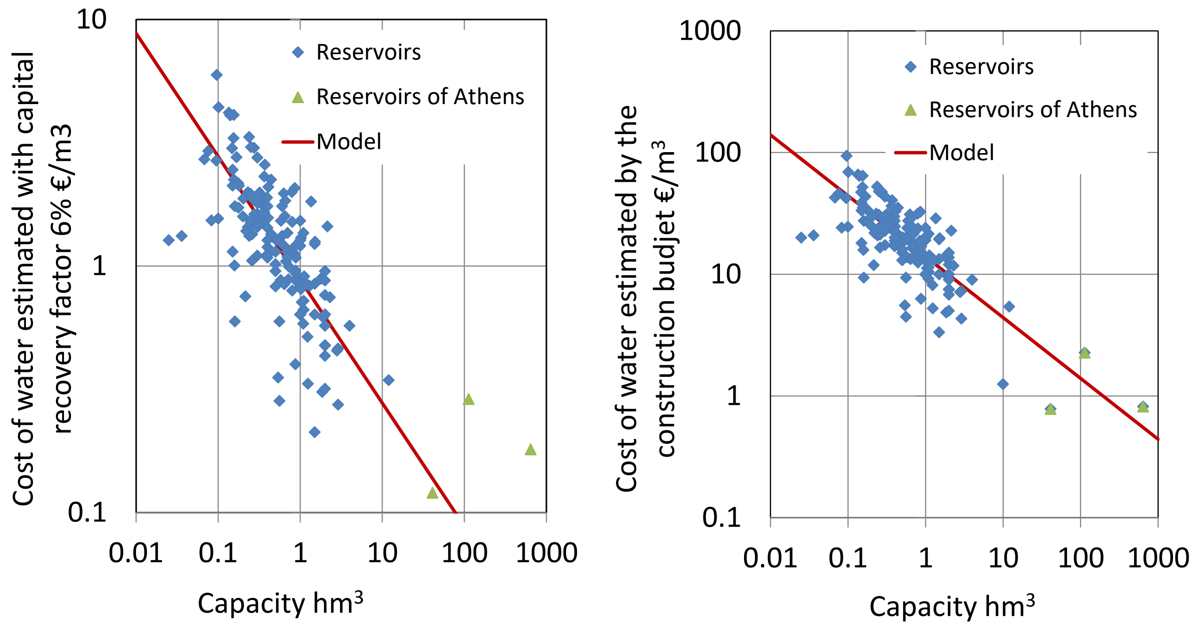
(c) Water demand management. Applying this methodology, the system was able to cope, effectively and without failure, with the extreme seven-year drought of 1988–1995, while other cities with similar or milder problems may have used inefficient methodologies.

Cost vs scale

It is interesting to compare the large-scale works of Athens with alternative small-scale works, to investigate the differences in economic indexes, had the Athenians chosen smaller projects. To this aim we used data from the "Geographical database of small reservoirs in Greece" (Euthimiou and Theodoropoulos, 1997) and constructed the plots shown in **Figure 6.31** in terms of cost versus reservoir size (measured by the reservoir storage capacity). In **Figure 6.31**a the cost is the total budget for the reservoir construction per m^3 of reservoir storage while in **Figure 6.31**b the cost is the annual capital recovery (assuming an interest of 6%) per m3 of water withdrawn from the reservoir. Hylike, which is part of the water supply system of Athens, was not included because it is a natural lake from which water is pumped.

We additionally observe (see caption of **Figure 6.31**) that in both cases the cost is inversely proportional to the square root of storage. Therefore, if the water supply system of Athens was designed with smaller reservoirs by one order of magnitude, the cost would be more than three times larger, both in terms of total budget and per m^3 of water. In case it was designed with even smaller reservoirs, say 1 hm^3, the cost of infrastructure would be 22.5 €/m³ of storage, instead of 1.29 €/m³ and the cost of the water would be about 1.41 €/m³, instead of 0.19 €/m³.

Changing the scale of water infrastructures does not deviate substantially from the so-called "0.6 rule" (Koutsoyiannis, 1979; Tribe, 1986). The "0.6 rule" states that the increase in cost and the increase in capacity, raised to the power 0.6, are inversely proportional. The definition of the rule (Haldi, 1961), was based on a wide range of equipment types and 87% of estimated exponents were found to fall in the range 0.3 to 0.9. It is interesting that the rule is verified also in water infrastructures of Athens.



(a) (b)

Figure 6.31 The cost of water of small reservoirs, related with the cost of water of reservoirs of Athens **(a)** estimated by the cost of infrastructures **(b)** estimated with capital recovery factor 6% (data from (Euthimiou and Theodoropoulos, 1997)). The models, fitted by least squares, are $y = 13.95\,x^{-0.5}$ for (a) and $y = 8.9\,x^{-0.5}$ for (b).

Figure 6.31 demonstrates that the development of the water supply system of Athens was successful in taking advantage of the economies of scale to achieve a stable price of water as well as a consistent supply to meet the water demand. Arguably, if Athenians had chosen a smaller scale of reservoirs the cost of living in Athens would be significantly increased. At the moment and given the existing hydraulic infrastructure, with adequate future planning, the water supply system of Athens can even expand to provide water to other smaller cities close to Athens, such as Korinthos. Thus, water management is necessary to implement economies of scale for the development of the city. In this respect, from economic viewpoint, it is preferable for other cities close to Athens to use the Athens water supply system than to develop independent water supply systems.

It is interesting to note that the system development had also considered several alternatives in different period. For example, in the beginning of the development the alternative scenario of conveying water from the Stymphalian lake, Peloponnesus, was studied (Merkouris, 1913). The cost of the related infrastructures would be almost the same as the cost of the Marathon project. However, if this alternative was chosen, with an aqueduct in a Peloponnesus the system expansion would be difficult or even impossible.

Discussion

Despite agglomeration effects that relate to size, there is a strong suspicion that the best places to locate new growth are in smaller rather than larger cities, reflecting the trade-off between economies of scale and congestion, which both increase as cities get bigger. The implications are controversial. The age-old question of what the "optimal" size for a city is has ever been and still is open. Athens is an example of big scale city as it generates ~20% of the GDP of Greece but the area of water resources for the supply system is about 3% of Greece.

In view of the increase of population in the 20th century and its relationship to water supply, relevant questions are: Was this migration of citizens justified? Could the people have chosen an area of Greece with more abundant water resources instead of living in the relatively arid area of Athens? The cost to construct the water infrastructure for Athens to host such a large population was certainly higher than in other cities which were closer to water sources, but obviously that was not a concern of people. Most probably, they did not ever worry about it and claimed "the right to the city" without anxiety about water availability and technical difficulties of the water supply system.

6.4 Wildfires: Partitioning and protection

Partitioning of the forests

Partitioning of the forests is not a novel idea. For example, anti-fire zones share the same logic but it can be argued that in practice they have often been found to have limited effectiveness in the evolution of fire[I]. Several studies propose the facing of fires, based on prevention measures focusing on land uses (Xanthopoulos et al., 2020; Ribeiro et al., 2020; Arianoutsou, 2007; Mermoz et al., 2014; Syphard et al., 2014), and alternative forests mitigation measures. Bajocco and Ricotta (2008) note:

> *For most land-cover classes, fire does not occur as expected from a random null model; rather, it behaves selectively, showing marked preference (or avoidance) in terms of fire number and fire size.*

Moreira et al. (2011) note:

> *From a management perspective, land cover (related to vegetation structure and fuel loads) is the only landscape variable influencing fire behaviour that can be manipulated.*

Mapping the evolution of fire in the case-study of the fire in Euboea in August 2021, we investigate the role of clustering of the forest in the evolution of fire, and the role of partitioning as one of the fundamental mechanisms that could have stopped the disaster. In order to keep the memory active when forests will be again in danger (on average after

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[I] Beighley, M.; Hyde A. C. Portugal Wildfire Management in a New Era. Assessing Fire Risks, Resources and Reforms. Available online: https://www.isa.ulisboa.pt/files/cef/pub/articles/2018-04/2018_Portugal_Wildfire_Management_in_a_New_Era_Engish.pdf (Accessed 17 January 2022)

10-20 years), a new approach is proposed, based on the dependence of fires' evolution to the clustering of the forests.

According to that, the aim of the proposed methodology is to ensure the preservation of forest partitioning by the creation of Sustainable Clustered Forest Zones (SCFZ). SCFZ will be linear or circled zones at least 500 m thick, aiming to support multi-purpose utilities, mainly focused around the WEF nexus. Considering the scale of disaster such as that of the examined Euboea wildfire which will be described analytically as a case study in the next section, it is reasonable to consider the loss of a small part of the forest in order to safeguard a much larger area. The target of the SCFZ is the creation of Sustainable Islands (SaI), which are defined as forest areas isolated by nonflammable land. SCFZ could act as protection against larger and more uneven disasters. An example of the forest partitioning is given in **Figure 6.32** for the north part of the forests of Euboea Island.

The difference of SCFZ to classic anti-fire zones is, other than their size, the fact that they are attributed with new land uses, which will promote the maintenance of these area in synergy with local communities. It is possible that SCFZ could be perceived negatively by inhabitants and visitors as development works in forest areas are considered as a threat to wildlife and to scientific fields of landscapes (Sargentis et al., 2019; Ioannidis et al., 2022; Ioannidis and Koutsoyiannis 2020).

However, in the way the modern societies are formed in order to protect valuable resources all of these parameters have to be considered.

Greek philosopher Castoriadis (2001) noted that: "Humans develop ecological consciousness when they confront the waste they produce."

By analogy to the case of wildfires, the burnt areas can be considered as the "waste" from the uncontrollable evolution of fires, while the ecological consciousness is the realization of the need to protect forest, even if the required measures require funds or transformations of forests shape which might be perceived negatively.

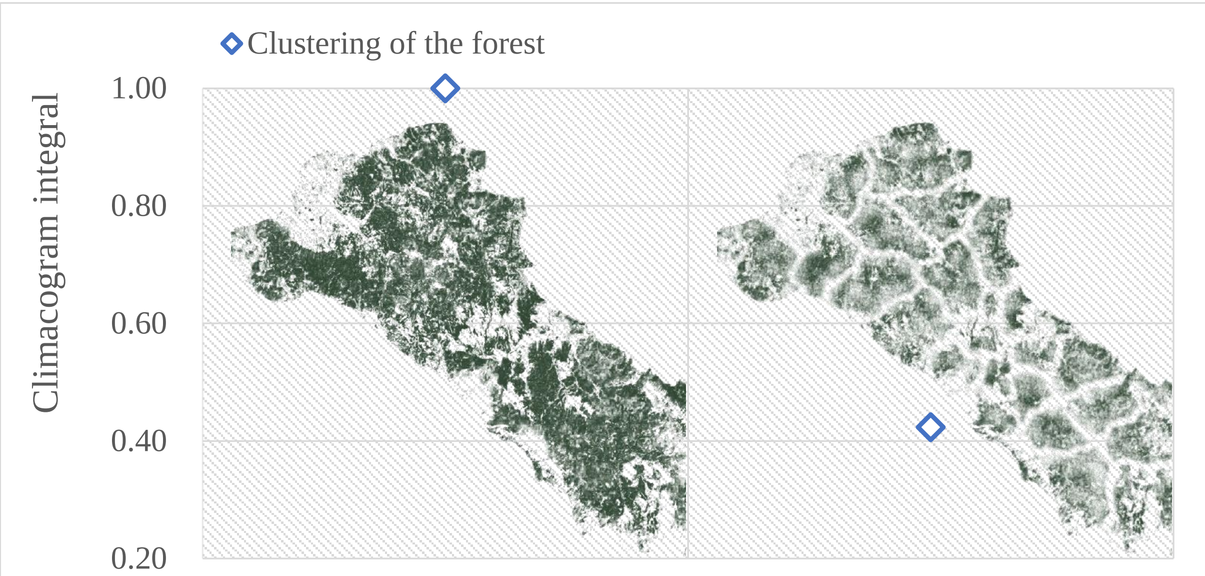

Figure 6.32 In the left, the clustering of the forests before the fire, in the right, a theoretical partitioning of the forest with SCFZ.

Usually, it is the tendency of governmental bodies to neglect anti-fire zones when the threat of fire is forgotten. Therefore, it is argued that in order to actually maintain and embrace these zones there must be a motivation for the community. We have seen in wildfires that one of the most effective motives for protection is to preserve property and utility. Therefore, SCFZ could replace the classic anti-fire zone as a slice of land with motives for exploitation by local communities.

The fire in Euboea in August 2021

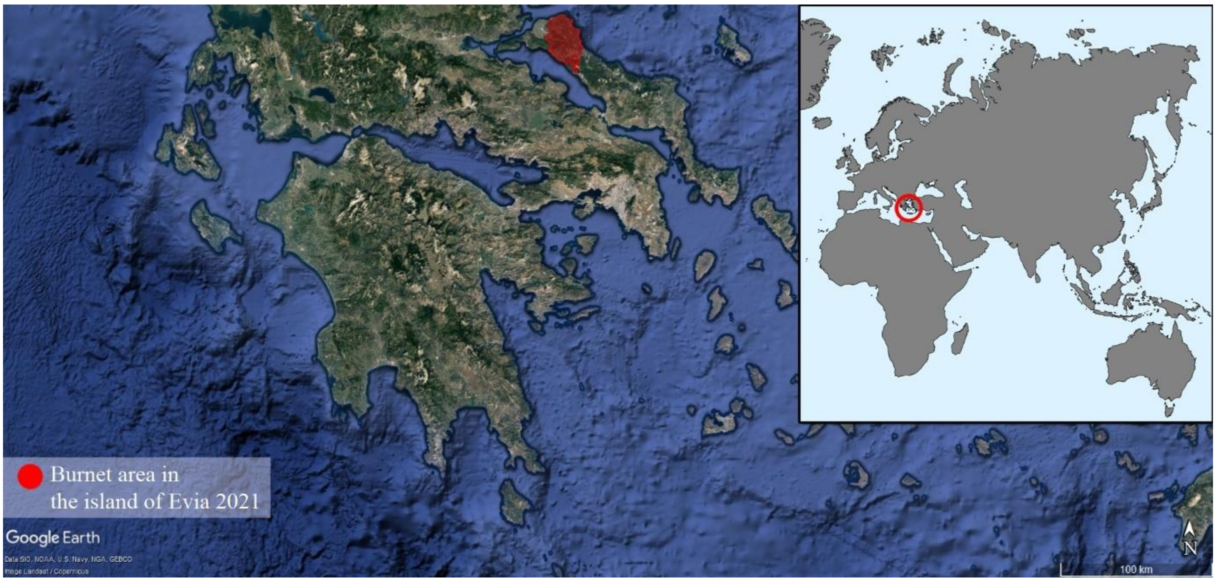

Figure 6.33 Burnt area in the island of Euboea 2021[I].

Figure 6.34 Frontpages of big international newspapers in 9 August 2021 had the theme of the Euboea's fire including the photo by Konstantinos Tsakalidis with 81 old women escaping from her burnt house in the area Gouves Euboea[II].

The fire in the island of Euboea in August 2021 burnt 52 900 ha (**Figure 6.33**) including areas recognized as landscapes of high quality and biotopes characterized by Natura and

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[I] Google Earth Pro, Version 7.3.3.7786, Map publisher NOAA, U.S. Navy, NGA, GEBCO, June 2021,

[II] 9 August 2021. Frontpages of the bigest newspaper of the world. Available online: https://www.marieclaire.gr/art-lifestyle/body-mind/newsroom/h-kravgi-tis-81chronis-giagias-stin-evvia-protoselido-stis-megaliteres-efimerides-tou-kosmou/ (Accessed 15 Oktober 2021)

Corine[I]. Interestingly, recent related studies[II] did not take into consideration that the landscapes were in danger but rather considered the urbanization and the development as possible threats.


ΤΑ ΝΕΑ
Αποκλειστικό «Ἐμπρηστές μέ... ἄγνωστες προθέσεις»
ΦΛΟΓΕΣ ΕΧΟΥΝ ΖΩΣΕΙ ΤΗΝ ΛΙΜΝΗ ΕΥΒΟΙΑΣ
Ἐντοπίσθηκαν αὐτοκίνητα μ' ἐμπρηστικές φωτοβολίδες

ΤΑ ΝΕΑ
Για την κατάρρευση του κράτους
Κατακραυγή
63 νεκροί
110 χωριά
400.000 στρέμματα
Κάηκε το Άλσος σώθηκαν τα Αρχαία
ΑΣΤΕΓΕΣ ΧΙΛΙΑΔΕΣ ΟΙΚΟΓΕΝΕΙΕΣ
1.000.000 € επικήρυξη για εμπρηστές

ΤΑ ΝΕΑ
ΣΑΒΒΑΤΟΚΥΡΙΑΚΟ
ΠΡΟΒΛΕΨΕΙΣ-ΣΟΚ ΓΙΑ ΤΗΝ ΕΛΛΑΔΑ
ΤΙ ΜΑΣ ΠΕΡΙΜΕΝΕΙ

(a) (b) (c)

Figure 6.35 Frontpage of the newspaper «TA NEA», (a) 26.8.1977, (b) 27.8.2007, (c) 7.8.2021[III].

This event was covered by the largest media organizations worldwide (**Figure 6.34**). Even though, the Euboea 2021 fire was highlighted as extreme, it is interesting to note that there were smaller but similar events in the area (in the same order of magnitude, i.e. more than 20 000 ha) in 1977 and 2007 (**Figure 6.35**).

We would expect that people should learn from the past. However, this did not happen, neither proper infrastructure was made and in addition, neither the firefighters had proper equipment to control the fire.

Annually burnt areas in Euboea is on average ~6 per cent of the burnt areas in Greece. The importance of the 2021 event is that burnt area in Euboea was 47 per cent of the burnt areas in Greece, while also in 2021, the 3rd record of burnt areas occurred (2000—2021) (**Figure 6.36**)

During 2007 only small scale/intensity fires occurred in the island of Euboea before the large scale-high intensity fire of 2021. Herein, this event was an expected outcome given the long time-accumulation of fuels in the forest.

Figure 6.37 summarize the evolution of fire in Euboea 3—11 August 2021.

[I] Filotis. Data base for Hellenic nature (Φιλοτης. Βάση Δεδομένων για την Ελληνική Φύση) Available online: https://filotis.itia.ntua.gr/biotopes/(Accessed 5 February 2022)

[II] Mamatsi, Ch. Evaluation, review and specific aspects of the Regional Spatial Planning and Sustainable Development of the Region of Central Greece, Lanscape (Αξιολόγηση, αναθεώρηση και εξειδίκευση Π.Π.Χ.Σ.Α.Α. Περιφέρειας Στερεάς Ελλάδας, Τοπίο) Helenic Republic, Ministry of Environment and Climate Change, Department of Spatial Planning (Ελληνική Δημοκρατία ΥΠΕΚΑ, Δ/νση Χωροταξίας), February 2014. Available online: https://dimoslevadeon.gr/wp-content/uploads/2015/07/2-topio.pdf (Accessed 5 February 2022)

[III] Historical digital record of newspapers "TOVIMA" & "TANEA" «TOBHMA» & «TANEA» (in Greek) http://premiumarchives.alteregomedia.org/ (Accessed 15 Oktober 2021)

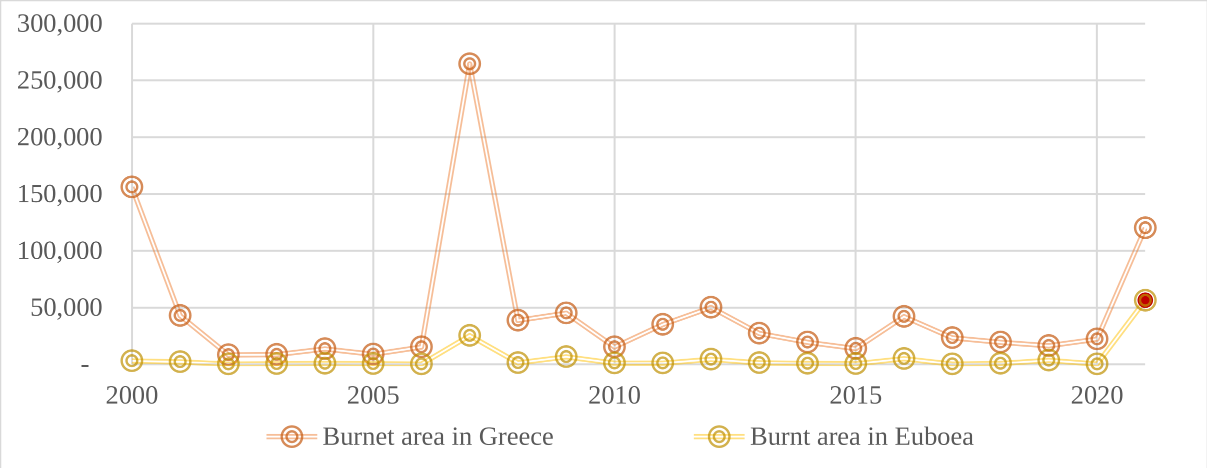

Figure 6.36 The evolution of wildfires in Greece and Euboea (2000–2021)[I].

Figure 6.38, **Figure 6.39**, **Figure 6.40**, shows temperature and wind, both meteorological parameters, (adapted graphically by https://www.meteoblue.com/ [II]) and significantly contribute to the fire in Euboea (**Figure 6.41**) between 2-12 August 2021.

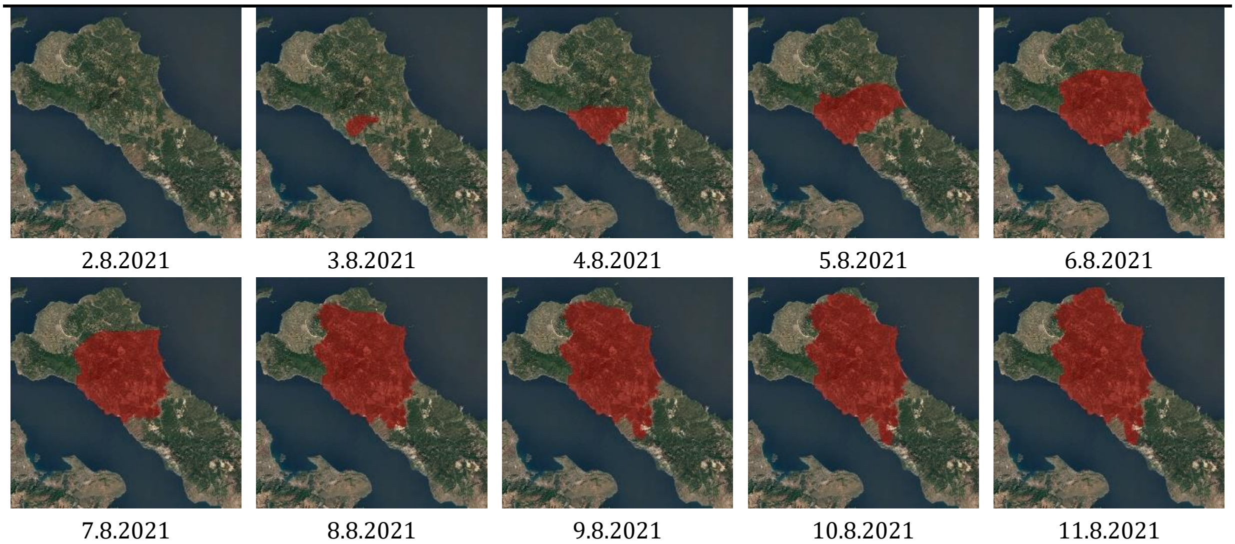

Figure 6.37 The total area of the fire was adapted by Firehub[III] (Kontoes et al., 2013). The evolution of the fire, adapted graphically in Google Earth by satellite imaginary[IV], calibrated by the reports of: 112 Emergency Communications Service[V].

[I] Data retrieved on 2022-01-17 by Hellenic Fire Service database. Available online: https://www.fireservice.gr/el_GR/synola-dedomenon (Accessed 17 January 2022)

[II] Meteorological data. Available online: https://www.meteoblue.com/ (Accessed 15 Oktober 2021)

[III] Firehub. Available online: http://ocean.space.noa.gr/diachronic_bsm/ (Accessed 15 Oktober 2021)

[IV] EUMETSAT, NASA/NOAA/GSFC/EOSDIS, Suomi-NPPVIRS, NWS/GFS, FIRMS. Available online: https://zoom.earth/ (Accessed 15 Oktober 2021)

NASA WORLDVIEW, Available online: https://worldview.earthdata.nasa.gov/ (Accessed 15 Oktober 2021)

[V] 112 Emergency Communications Service: 112 Greece. Available online: https://twitter.com/112Greece (Accessed 15 Oktober 2021)

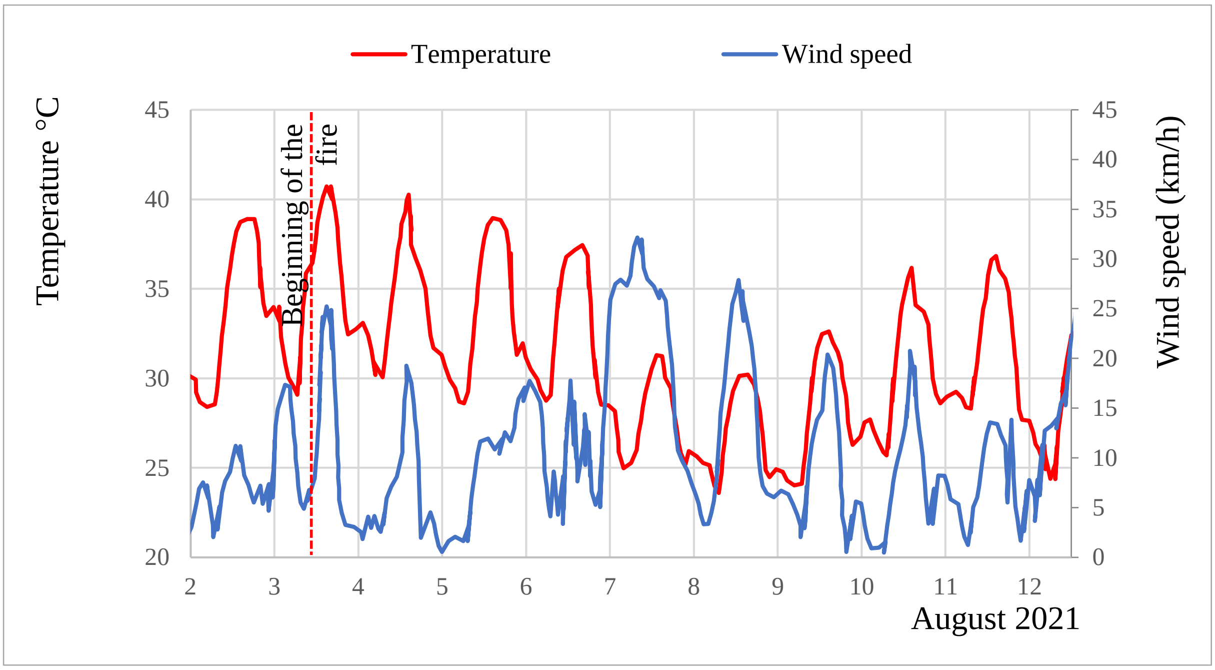

Figure 6.38 Temperature and wind speed in the area of Euboea[I].

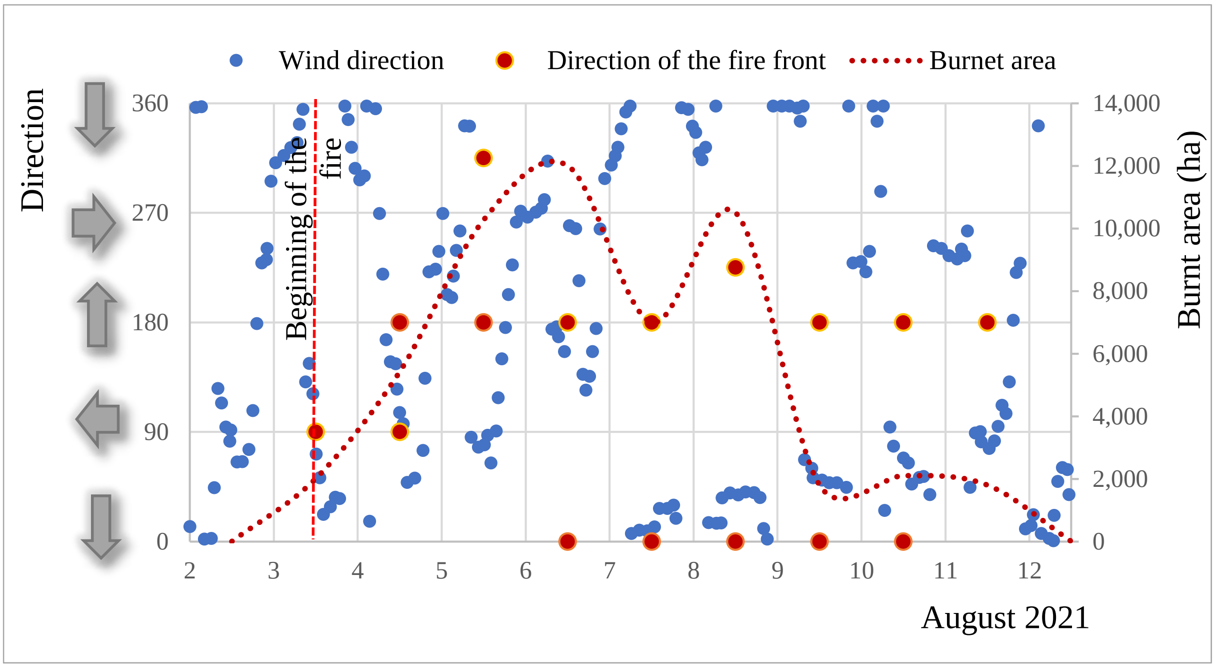

Figure 6.39 Wind direction (blowing to); 0, 360 North, 270 West, 180 South, 90 East[II].

[I] Source: https://www.meteoblue.com/

[II] Source: https://www.meteoblue.com/

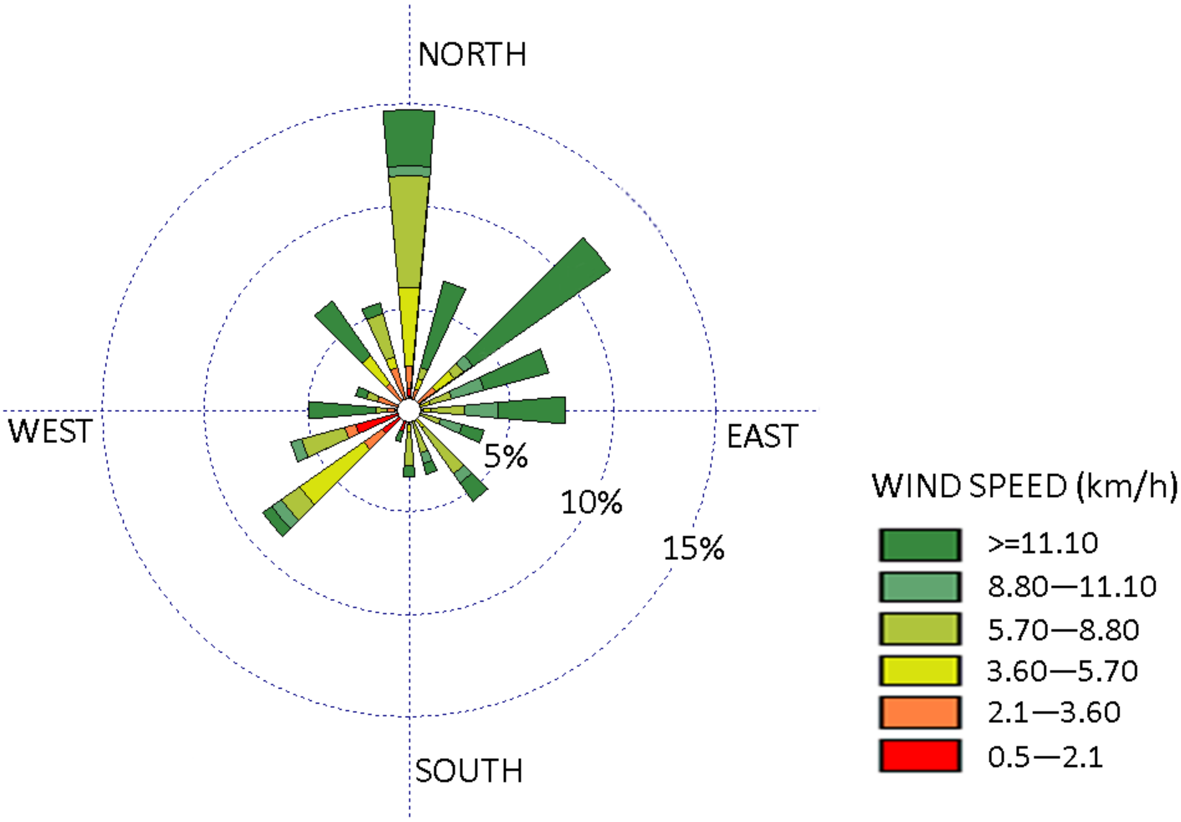

Figure 6.40 Windrose diagram. Euboea 3-11 August 2021. Wind direction (blowing to)[I].

(a) (b) (c)

Figure 6.41 Fire in Euboea: 6.8.2021.

The first issue to be examined in fires' triangle is temperature; we can notice that in the beginning of the fire, high values of air temperature were observed. Data from previous days also show high values of daily temperatures.

[I] Source: https://www.meteoblue.com/.
Image created by WRPLOT View Lakes Software, WRPLOT VIEW software VERSION 8.0.2, Available online: https://www.weblakes.com/software/freeware/wrplot-view/ (Accessed 2 February 2022)

The second issue in fires' triangle is oxygen rate, which can be increased and renewed with the speed of the wind. In this fire we did not find a correlation between the evolution of the fire, and the speed or the direction of the wind.

The third issue in fires' triangle is fuels. With digital processing of satellite images, we present the clustering of the pine trees of the wider area. The fuels in this wildfire are pine trees, and in **Figure 6.42** we show the evolution of fire between 3^{st}—11^{th} August.

Before the fire, the forests in the north Euboea were partly cultivated. As the last big fire happened more than 20 years ago, under the pine trees the forest had herb and shrub layers under the pine trees which helped the evolution of the fire. Fortunately, there were not litters spread in the area. However, there were secluded places with litters which were burned. In addition, a cold wave named Medea happened between 13—16 February 2021[I], many branches and trees were broken, no one took care to pick them up[II]. This flammable material dried up in the summer and was a supplementary layer that favored the spread of the fire.

A closer look at the fire, shows that fire is driven where the pine trees were clustered. Herein we can assume that forests' clustering was the most important issue for the evolution of this fire.

The fire had a partitioned zone of forest in its south part, therefore in first three days, fire burned mostly the northern, western and eastern areas. In the 6^{th} of August, fire was driven by two clustered forest areas in east-south and in west-south part of the fires' front and connected to the south clustering. The leak of this cost ~8 000 ha burnt areas more.

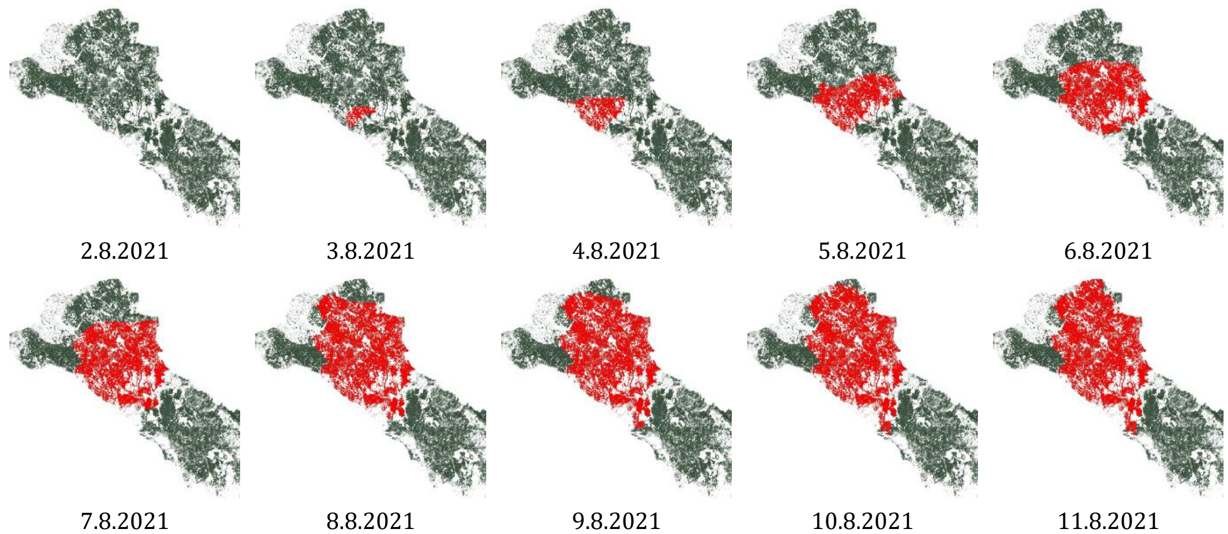

Figure 6.42 The evolution of fire, related to forests' clustering, calibrated by the reports of: 112 Emergency Communications Service.

I February 2021 Greek cold wave. Available online: https://en.wikipedia.org/wiki/February_2021_Greek_cold_wave (Accessed 2 February 2021)

II Aspects of the cold wave Medea in north Euboea. Available online: https://www.egnomi.gr/article/124067/ritinokalliergites_boreiokentrikis_eyboias_toys_afanise_mideia.html (Accessed 2 February 2021)

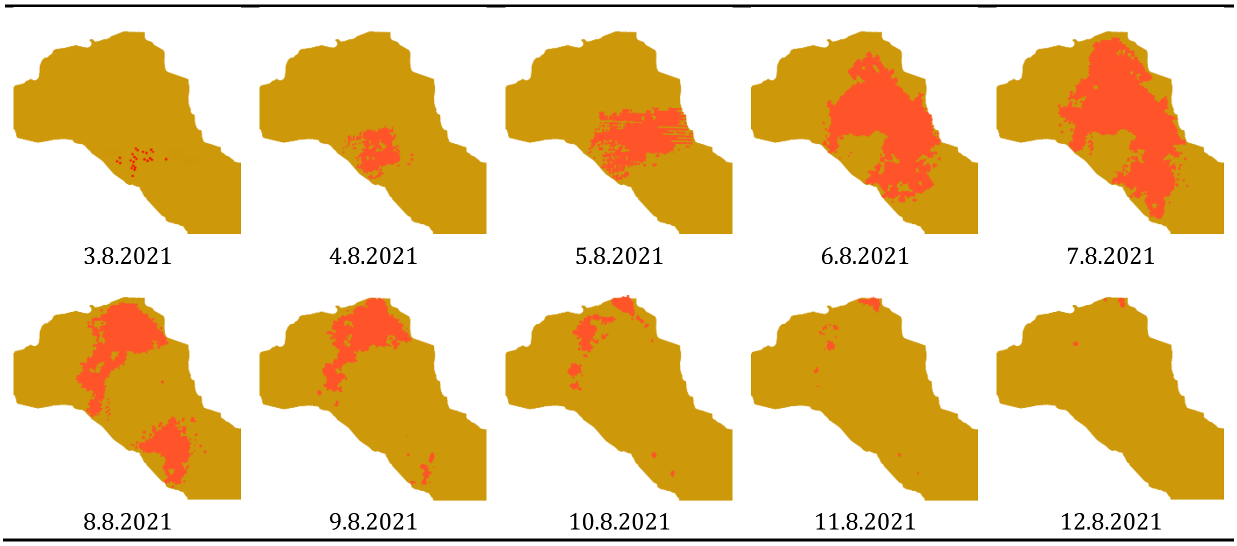

Figure 6.43 The intensity of fire as detected by satellite imaginary (EUMETSAT, WORLDVIEW) calibrated by the reports of: 112 Emergency Communications Service (112 Em. Com. S.).

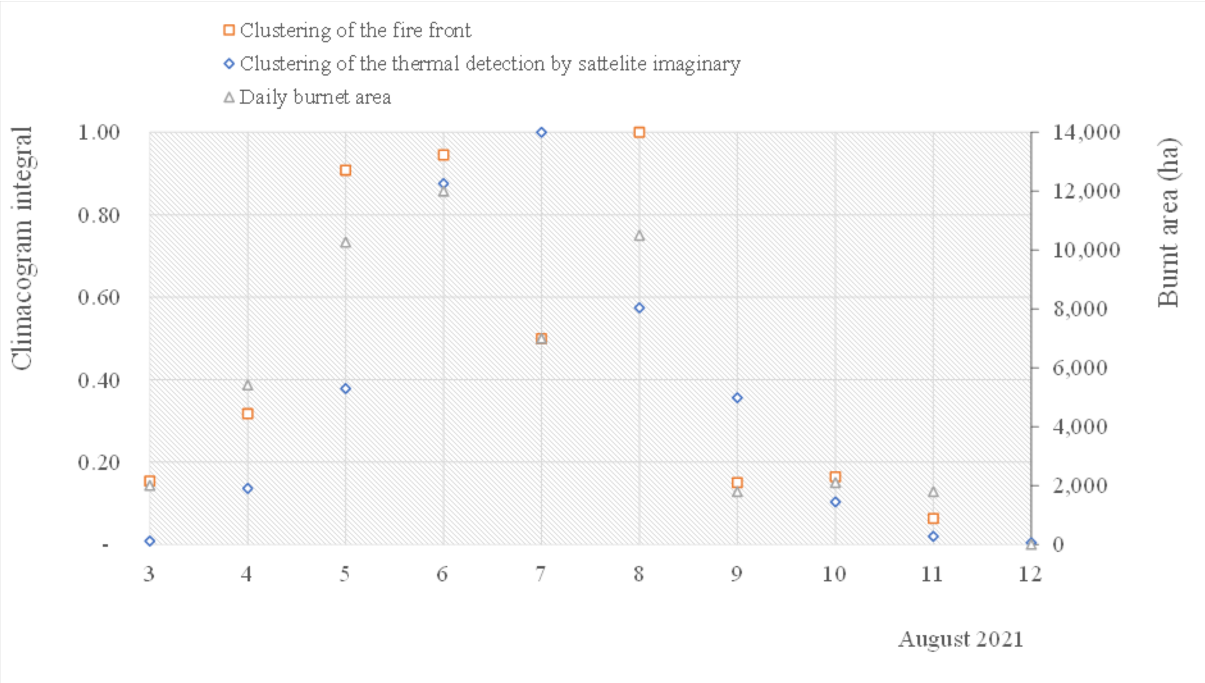

Figure 6.44 Evolution of clustering of fire front, thermal detection and daily burnt area.

Analyzing the daily evolution of clustering of the fire front (Figure 6.42) and the evolution of clustering of thermal detection by the satellite imaginary (Figure 6.43), we see that both are related to the evolution of fires and the burnt area. This is also verified by the estimated correlation through the climacogram integral (Figure 6.44).

The climacogram integral also validates the clustering of fire and the daily burnt areas. Figure 6.45, Figure 6.46, shows burnt areas in the fire incident. The evolution of fire was also supported by the intense anaglyph of the area.

The linear flatland of Krya Vrisi, cuts the island of Euboea and contributed to containing the fire and restricted the evolution of the front of the fire (Figure 6.47, Figure 6.48).

(a) (b)

Figure 6.45 (a) Burnt area; (b) Burnt areas with anti-fire zones.

(a) (b)

Figure 6.46 (a) Not burnt areas in the middle, forest without connection with the rest forest area (SI); (b) Burnt areas. In back, the flat land of Krya Vrisi which stopped the fire.

(a) (b) (c)

Figure 6.47 (a) The flatland of Krya Vrisi (b) The flatland of Krya Vrisi during the fire (c) The flatland of Krya Vrisi after the fire.

Figure 6.48 The flatland of Krya Vrisi (center of the figure). The area of the fire (left), forests unattached by the fire (right).

Before the fire, about 580 families in North Euboea exploited the forest collecting resin (**Figure 6.49**a) and about 80 families were working in logging. Others were beekeepers or had olive trees. It is estimated that 50% of the Greek production of resin (3000 tons per year) and 65% (10 000 tons per year) of the Greek production of pine trees' honey has been lost. In addition, 9 000 beehives (**Figure 6.49**b) destroyed or suffered severe damage[I].

Examining the livestock and the beehives of the area (**Figure 6.50**) we see that about 88% of these activities rely on the forest. Even the coops were out of villages, inside the forest, and many of them were burnt.

It is clear that the forest constitutes wealth for the local community and hence its destruction is an economic disaster for the community, even for inhabitants whose properties were not affected by the fire.

After the wildfire of 2021, the Greek state introduced a new law to indemnify the lost properties of inhabitants[II]. Unfortunately, this law does not answer the question: Can people recover the sustainable wealth, which they have lost?

[I] Vangelis Georgantzis, personal comunication 31.10.2021

The invisible victims of the fires - 9000 beehives and tons of honey were lost. Available online: https://www.meteo24news.gr/2021/08/Ta-afani-thimata-ton-pirkagion-xathikan-enia-xiliades-melisosmini-ke-toni-meliou.html (Accessed 15 Oktober 2021)

Euboea: 9,000 beehives and 65% of the pine honey were lost! Available online: https://www.naftemporiki.gr/story/1765769/ (Accessed 15 Oktober 2021)

We lose up to 10,000 tons of pine honey a year due to fires. Available online: https://www.iefimerida.gr/ellada/hanoyme-10000-tonoys-peykomelo-logo-pyrkagion (Accessed 15 Oktober 2021)

[II] Low 4824/2021. Available online: https://dasarxeio.com/wp-content/uploads/2021/09/n_4824_2021.pdf (accessed on 27 June 2021).

As people have now lost the forest area they used to cultivate, collect resign or logging after this catastrophe, our purpose is to give SCFZ to people to promote a sustainable development, which could be supported through the WEF nexus (Mamassis et al., 2020). Products or commodities provided by these forests constitute only a part of their value for local communities. There are more than those products in benefit of people, i.e. environmental services (clean water, air, recreation, habitat conservation, etc.) that should be considered in any forest conservation strategy. Moreover, local communities must be aware of these services and value them as incentives for forest conservation.

(a) (b)

Figure 6.49 (a) Collection of resin; (b) Beehives.

Livestock could accelerate the recovery process. However, the Greek state protects the environment according to the Greek Constitution[I] (articles 24, 117) and livestock is considered as a threat to the forests. The Greek state forbids livestock in burnt areas according to the legislative decree of 86/1969[II] (articles 66, 105, 107, 113, 114), which are replaced by the article 60 of the Law 4264/2014[III] that mentions:

> *An order forbidden grazing, issued ex officio by the forest service, prohibits the grazing of any animal in an area that has been declared reforestable.*

In other words, inhabitants which were fortunate that their livestock survived this fire, instead of grazing their livestock, will probably be forced to increase cost for animal feeding, since their livestock cannot be moved to the burnt area, or they will face a penalty that depends entirely on the chief of the local forest service. Therefore, inhabitants must quit feeding their livestock in the burnt area as, if they have to pay the feed, this activity will be damaging.

[I]Greek Constitution. Available online: https://www.hellenicparliament.gr/Vouli-ton-Ellinon/To-Politevma/Syntagma/ (Accessed 15 Oktober 2021)

[II]Forest management. Legislative decree 86/1969. Available online: http://www.fdparnonas.gr/files/ND86_69.pdf (Accessed 15 Oktober 2021)

[III]Law 4264/2014. Available online:
https://www.kodiko.gr/nomologia/download_fek?f=fek/2014/a/fek_a_118_2014.pdf&t=e518855486f0aa6e8d244d08a282e55f (Accessed 15 Oktober 2021)

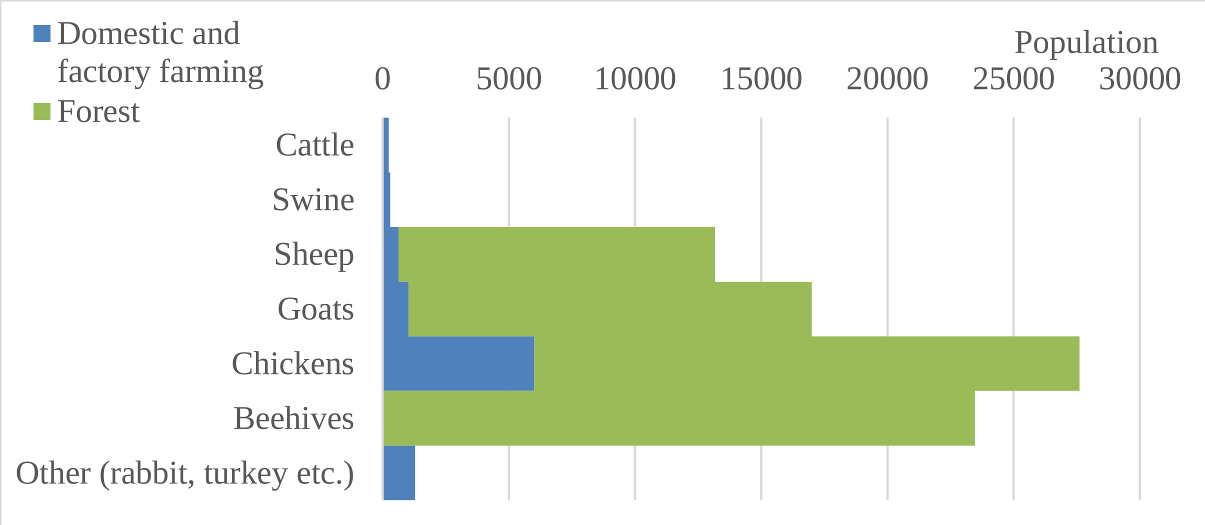

Figure 6.50 The livestock and the beehives of the municipalities "Istiaia-Edipsos", "Mandoudi-Agia Anna-Limni" by the census 2019[I].

Therefore, we give an example of SCFZ that were designed following the faint clustering of the forests in wider area of North Euboea. The partitioning is presented assuming that the forest is exploited, cultivated and livestock is grazing (**Figure 6.32**). The fire-breaks as strips of land that has been cleared of all trees, (usually linear and small), are areas which can stop fire without human intervention only 46% of the time (Chandler et al., 1983). However, these strips are prone to erosion and are not cost effective because they need to be cleared at least once a year and at last, these zones are aesthetically unpleasant.

Obviously, the partitioning process will be annoying as the natural forests are pristine and highly-perceived landscapes. However, we have to consider that in many cases the alternative is that the forest could be completely burned, and then require as long as 20 or 30 years for its rebirth. We should thus consider whether certain but small-scale impacts to forests may be preferable over a potential but large-scale disaster. It should also be taken into account that the societies developed around forests, exploit them and take advantage of their natural resources. Thus, a large-scale destruction of the forest can be catastrophic and can even lead to the collapse of such communities. Therefore, we have to consider more how to support the inhabitants and less rarely enjoy the landscape of the forest every 30-40 years. Also, we have to consider that the society will grow along with the forest, but with a high risk of destruction.

Another question we have to ask is: how in Krya Vrisi, this partitioning zone area which stopped the fire, was created?

A part of the land of Krya Vrisi was property of big landowners and another it was unexploited (forests, swamps) until the early 20th century. This land was given to immigrants who came in Greece (Mousourakis et al., 2020) from the Asia Minor catastrophe in 1922 to cultivate it (Apostolou, 2007) (**Figure 6.51**).

[I] Hellenic Statistical Authority, Livestock production in Euboea, Census 2019.

This area is an example on how, 100 years before, the Greek state, without the slightest guilt about deforestation, gave people wealth (land) to survive, which was also used for protection of the forest.

ΔΙΕΥΘΥΝΣΙΣ ΑΓΡΟΤΙΚΗΣ ΑΠΟΚΑΤΑΣΤΑΣΕΩΣ

ΤΙΤΛΟΣ ΚΥΡΙΟΤΗΤΟΣ

Ο ΔΙΟΙΚΗΤΗΣ ΤΗΣ ΑΓΡΟΤΙΚΗΣ ΤΡΑΠΕΖΗΣ ΤΗΣ ΕΛΛΑΔΟΣ

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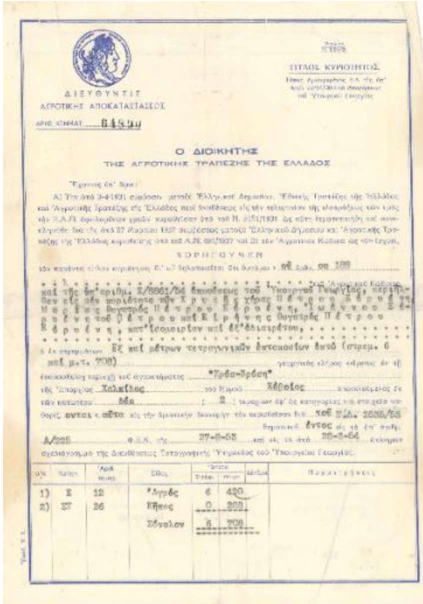

ΔΙΕΥΘΥΝΣΙΣ ΑΓΡΟΤΙΚΗΣ ΑΠΟΚΑΤΑΣΤΑΣΕΩΣ

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ΧΟΡΗΓΟΥΜΕΝ

(a) (b)

Figure 6.51 Property documents dated from 1957, referred to the law 5151/1931 which redistribute the land to the immigrants from the Asia Minor catastrophe[I].

Chapter 7. Environmental determinism vs. social dynamics

Hypotheses of social collapses typically constitute scenarios about the environmental and societal conditions. The researcher's imagination is the main tool to explain the process of the collapse. For these reasons, theories of social collapse have an intuitive charm but ambiguous significance[II]. But are the hypotheses of the conditions close to reality? Would people in the past react as a modern researcher thinks they would do?

Ancient Greek philosopher Plato in his emblematic book Republic concludes that societies are like living creatures and their existence predict also their death: Quoting from the original text[III]: "*…άλλ᾽ έπεὶ γενομένῳ παντὶ φθορά έστιν, ούδ᾽ ἡ τοιαύτη σύστασις τὸν ἅπαντα μενεῖ χρόνον, άλλὰ λυθήσεται." (…but, seeing that everything which has been born has also an end, even a constitution such as yours will not last for ever, but will in time be dissolved*)[IV]. Plato describes social organization, justice and culture as main issues for thriving societies.

[I] Redistributed land. Property documents of Eleni Kougia's great grandmother

[II] The Collapse of Ancient States and Civilizations, Edited by Norman Yoffee and George L. Cowgill, The University of Arizona Press, U.S. 1991.

[III] Plato (Πλάτων), Republic (Πολιτεία) , 546a-547d Available online: https://www.greek-language.gr/digitalResources/ancient_greek/library/browse.html?text_id=111&page=106 (accessed 6 November 2021).

[IV] Plato, Republic. Princeton University Press, Prinston 1961.

Many scientists consider that physical environment predisposes societies and states towards particular development trajectories. These aspects have been formulated in a school named as environmental determinism (Meyer, 2020).

Environmental determinism is not a new idea. It was introduced by Thomas Robert Malthus (1766-1834) in 1798 (Malthus, 1978). It was used to justify colonization (Gallaher et al., 2009; Reaves and Gibson, 2013; Cottenet, 2014), fascism[I] and Lamarckism (Szyf, 2014; Campell, 1983) describing how tropical climates encouraged generally degenerative societies, while the frequent variability in the weather of the middle and northern latitudes led to stronger work ethics and civilized societies. Environmental determinism was recovered by Eugenicists and Neo-Malthusians in the 1950s in the notion of "Carrying Capacity"[II] (Sayre, 2008; Wood, 1998; Abel, 2013; Catton, 1982; Kammen et al., 1994, Ladurie, 1987).

Lately environmental determinism is used to formulate a holistic view of worlds history. In the book "A Green History of the World: The Environment & the Collapse of Great Civilizations" Poline was trying to "probe… the extent to which the environment has shaped human history" (Ponting, 1991; Soroka, 1995). Many researchers are following his perceptions[III] (Costanza et al., 2007; Folts, 2003; Schulz, 2002; Radkau, 2013)

In the early 20th century, more than 50 years before theories of climate change became trendy (Koutsoyiannis, 2021) Ellsworth Huntington connected the demise of civilizations with climate changes (Brooks, 1947). Many researchers view climate change or deforestation (Middleton, 2012; Sheffield, et al., 2011; Ghose, 2012; Gill, 2000; Haug et al., 2003; Buckley et al., 2010; Cullen et al., 2000; Drake, 2012; Rosen, 2006; Smith, 2013; Weiss, 1982) as the main reasons of social collapses in the past. Related research predicts the future of world population growth in relation to the parallel deforestation process (Bologna, M.; Aquino, 2020).

In some cases, e.g., in the study of how the volcanic climate impacts can act as ultimate and proximate causes of Chinese dynastic collapse which are described in the recent paper by Gao et al. (2021), emphasizes the correlation between environmental factors and social dynamics. However, the authors note that:

> *Even in cases of collapse, that some dynasties persisted for up to a decade post-eruption while others collapsed more rapidly suggests the complexity of the underlying causal contributions and the inadequacy of monocausal or environmentally deterministic interpretations.*

[I] "Why We Are Antisemites" - Text of Adolf Hitler's 1920 speech at the Hofbräuhaus. Available online: https://carolynyeager.net/why-we-are-antisemites-text-adolf-hitlers-1920-speech-hofbr%C3%A4uhaus (accessed 6 November 2021).

[II] The Cambridge Economic History of Europe, The Agrarian Life of the Middle Ages, Edited by Michael M. Postan vol. 1, Cambridge University Press, Cambridge 1966.

Human Impact on Ancient Environments, Edited by C. L. Redman, University of Arizona Press, Arizona 1999.

[III] The Discourses of Environmental Collapse: Imagining the End. Edited by Vogelaar, A.E., Hale, B.W., & Peat, A. Routledge, London 2018. https://doi.org/10.4324/9781315441443

Many other researches based in archeological data do not confirm environmental determinism. Senan et al. (2013) note:

> *…in contrast to the steady population growth usually assumed, the introduction of agriculture into Europe was followed by a boom-and-bust pattern in the density of regional populations. …. we investigate the relationship between these patterns and climate. However, we find no evidence to support a relationship. Our results thus suggest that the demographic patterns may have arisen from endogenous causes.*

Other approaches do not include the environment as fundamental cause of the collapse. Through a neo-Platonic view, Tainter considers that societies are complex systems (Tainer, 1988) and complexity is necessary element for their growth. A dynamic crisis and collapse is contained in every growing social structure as complexity will reach a limit where it cannot be managed (Middleton, 2017).

Other approaches emphasize the point that civilizations are not quantities but also qualities as they contain cultural variables. The idea of cultural aspects in the dynamics of societies, moral decline and related issues were first formulated by the Islamic historian Ibn Khaldun (1332-1406) (Khaldun, 1967), who recognized the periodic rise and fall of dynasties as macrostructures in the history of civilizations. Western interest in this mechanism of collapse was formulated by Edward Gibbon (1737-1794) (Gibbon, 1869), who attributes, as does Khaldun, the collapse of the Roman Empire to moral decline.

Summarizing the above, upheavals in social stability and continuity can be said to be due to socio-political disorganization, economic weakness, and environmental or demographic trends. Changes in social dynamics appear as long-term fluctuations, first organizing, then expanding and integrating, before sinking into disorder. The scale of the collapse, the timeframes involved, the key elements that fail, and whether the outcome is catastrophic or ultimately allows for restructuring remain open questions[I] (Butzer, 2012; Nagarajan, 2006; Monastersky, 2015).

At the beginning, humans survived, perpetuated and spread as hunter-gatherers dominating on the environment, reaching a relative equilibrium (Downey, 2016), and displaying remarkable resilience (Redman, 2005). The possibility of human clustering (Sargentis et al., 2020; Klein Goldewijk et al., 2011) was very small since man needed large areas to meet nutritional needs (Sargentis, 2021). The great step to civilization was primarily due to the capability of human clustering through language and technology. Communication (hence social organization) and technology, made humans more and more efficient, giving great clustering potentials (Pennington, 1996).

Human survival presupposes the utilization and exploitation of the water-food-energy nexus and food, water and energy require constant replenishment. Hence, the nexus is the human "prey" (Sargentis et al., 2021). In prehistory, predators of humankind where the big animals. In civilized societies, notable predators are the mosquito to which one million

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[I] Crisis to Collapse: the archaeology of social breakdown. Edited by Cunningham, T., & Driessen, J. Presses universitaires de Louvain. Louvain-la-Neuve, 2021

Questioning Collapse. Human Resilience, Ecological Vulnerability, and the Aftermath of Empire. Edited by McAnany, P.A. & N. Yoffee, Cambridge University Press, Cambridge, 2010.

deaths per year[I] are attributed and pathogens such as the bacterium Yersinia Pestis (known as Black Death) responsible for an estimated reduction of the world population by c. 1/3 in the 14th century[II].

In following paragraphs, we will explain the aspects of environmental determinism in terms of carrying capacity, considering Hurst-Kolmogorov dynamics in natural resources, technology, trading, storage and social dynamics in a toy model to explain the mechanisms of collapse.

Carrying Capacity

After humans manage to face the threats of big animals, they did not have systematic predators to interact with. As water-food-energy are necessary for their survival, we consider them as their prey (Sahlins, 2013).

In order to understand the meaning of carrying capacity, we create a toy model. In this toy model we can imagine for example, a group of people trapped in an island for 1000 years where there is only a spring. The outflow of a spring can be treated as a random variable, following, for example and for simplicity, a Gaussian distribution. The carrying capacity of a place will be related to the minimum flow, which could support a specific number of people and we assume that the system would find an equilibrium around this value (**Figure 7.1**).

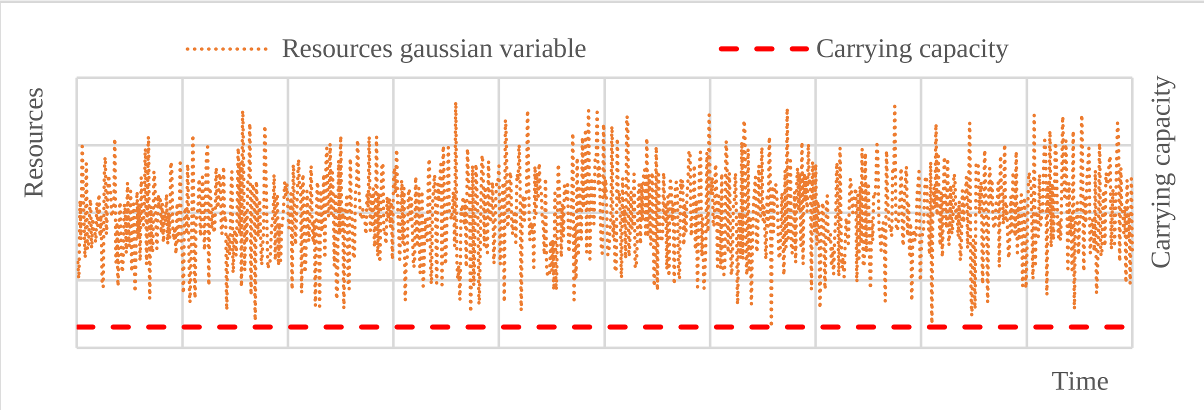


Figure 7.1 Toy model: the concept of environmental determinism. Outflows of the fountain follows a gaussian distribution. Red dash-line shows the carrying capacity of the population.

However, we note some interesting limitations in the approach of carrying capacity:

The distribution of natural resources (especially the ones related to water resources and management and inter-connected with food and energy), do not follow a white-noise behavior (i.e., with identically distributed and independent increments) and are better simulated by the so-called Hurst-Kolmogorov dynamics (Koutsoyiannis, 2010).

(a) Humans have abilities to overlap these gaps through adaptation

(b) We have to consider including the dynamic of societies

[I] World Health Organization. Malaria. Available online: https://www.who.int/news-room/fact-sheets/detail/malaria (accessed 25 August 2021).

[II] United States Census, Historical Estimates of World Population. Available online: https://www.census.gov/data/tables/time-series/demo/international-programs/historical-est-worldpop.html (accessed 25 August 2021).

The role of Hurst-Kolmogorov dynamics in environmental determinism

An important property of natural phenomena is that follows Hurst-Kolmogorov (HK) behavior, in hydrometeorological processes usually known as Long Term Persistence (LTP). It seems that in natural systems, randomness and predictability are intrinsic and can be deterministic and random at the same time, depending on the prediction horizon and the time scale (Dimitriadis et al., 2016). Particularly, all these processes are characterized by high unpredictability due to the clustering of events.

This behavior of natural systems was first identified in nature by H.E. Hurst in 1951 while working at the River Nile, although its mathematical description is attributed to A. N. Kolmogorov who developed it while studying turbulence in 1940. Koutsoyiannis (Koutsoyiannis, 2010) named this behavior as Hurst-Kolmogorov dynamics (HK), to give credit to both pioneering scientists (Sargentis et al., 2019). Interestingly, this behavior has been identified in global-scale key-hydrological-cycle processes through the analysis of thousands of stations (Dimitriadis et al., 2021) and can be also observed in social parameters as in war frequency in China which are related to the volcanic climate (Gao et al., 2021).

Although in HK dynamics the marginal distribution of the process maybe arbitrary, the most commonly used distribution is the Gaussian one, which results in the well-known fractional-Gaussian-noise, described by Mandelbrot and van Ness (Mandelbrot and van Ness, 1968), i.e., the power-law decay of variance as a function of scale $\gamma(k)$, is defined for a process (Dimitriadis and Koutsoyiannis 2018). The HK behavior is quantified by the Hurst parameter H ($0 < H < 1$). In the simplest case, the variance $\gamma(k)$ of the process at timescale k, known as climacogram, is given by

$$\gamma(k) = \frac{\lambda}{(k/\Delta)^{2(1-H)}} \tag{7.10}$$

where Δ is a characteristic timescale and λ is the variance at this time scale. For $0 < H < 0.5$ the HK process exhibits an anti-persistent behavior, $H = 0.5$ corresponds to the white noise process, and for $0.5 < H < 1$ the process exhibits LTP (clustering).

Therefore, to account for the effect of the non-white-noise behavior of the spring outflow in our toy model, we simulate the spring outflow based on the HK model (with, for example, $H = 0.8$), and by following a Gaussian distribution (described earlier), through a stochastic synthesis algorithm, and particularly, through the Symmetric-Moving-Average (SMA) scheme (Koutsoyiannis, 2000; Koutsoyiannis and Dimitriadis 2021). **Figure 7.2** shows a so generated timeseries. An environmental determinist would likely say that the society would collapse four times (red triangles).

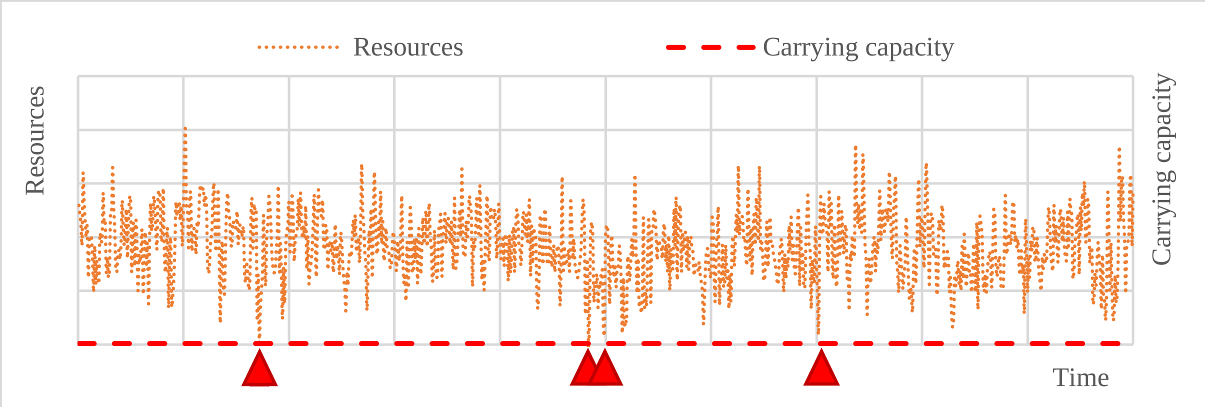


Figure 7.2 Toy model: The concept of environmental determinism with HK dynamics. Outflows of the fountain follows gaussian distribution with *H*=0.8. Red dash-line shows the currying capacity of the resources.

<u>The role of technology and trading in environmental determinism</u>

In prehistory there is a strong possibility that, this type of collapse, could not affect societies that were never "organized" in the first place. These societies were flexible, they did not have infrastructures or stable wealth and they could move to other places to find resources. This is how we could justify the switch from more socially structured and sedentary societies to smaller-scale, pastoralist, and mobile societies, with some societies constantly switching between both types of economy. This type of adaptation, some would even call "resilience".

With agricultural evolution, human societies handled more efficiently the water-food-energy nexus and they could possibly survive these gaps facing the threats of recessions in their settlements. If our group of people in the island dig a well or travel in other island close by to bring water from there, they would have more water. In order to indicate that, we add a constant quantity z at each value in the time series:

$$\underline{x}' = \underline{x} + z \tag{7.11}$$

This model is depicted in **Figure 7.3**. An environmental determinist would consider that the population could be increased. However, ancient sedentary societies, would be vulnerable to this phenomenon as these societies would thrive when there were plenty of resources but HK dynamics predicts a systemic crisis every time resources are restricted.

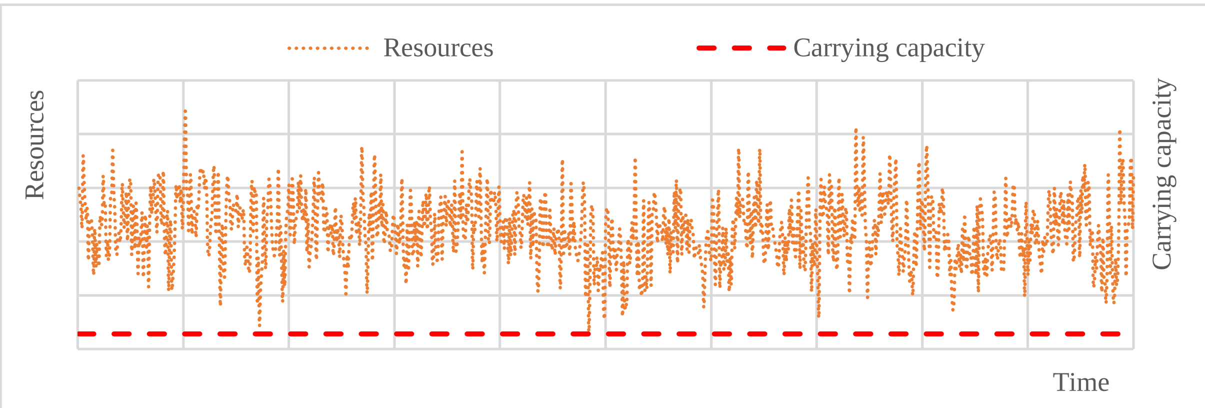


Figure 7.3 Toy model: The concept of environmental determinism with HK dynamics adding a technological step. Red dash-line shows the currying capacity of the resources.

The role of storage in improving currying capacity

Since early times people realized how nature works i.e. they developed a practical knowledge of what today we call HK dynamics. Therefore, they considered that they have to store the resources when there was abundance, in order to use them when there was scarcity. The first written mention of this concept was recorded in the Bible where Joseph advised Pharaoh to store the food in wealthy years, as he predicted that dry years will come[I]. HK dynamics is also called the Joseph effect (Mandelbrot and van Ness, 1968).

In our toy model, if we consider that people make a small dam and water withdrawals are depended by the availability of the resources, the system will become more stable increasing its currying capacity and avoid the collapses. The process can be modelled by the following equations:

$$\underline{S}_T = \max\left(0, \min(K, \underline{S}_{T-1} + \underline{x}_T - \underline{R}_T\right) \quad (7.12)$$

$$\underline{R}_T = a\underline{S}_{T-1} \quad (7.13)$$

where S is the stock in the reservoir; T is time; $\underline{x}$ is the inflow; R is the withdrawal considered proportional to the stock; a is a constant determining the release; and K is the storage capacity.

Figure 7.4 depicts the effect of available resources with the use of storage.

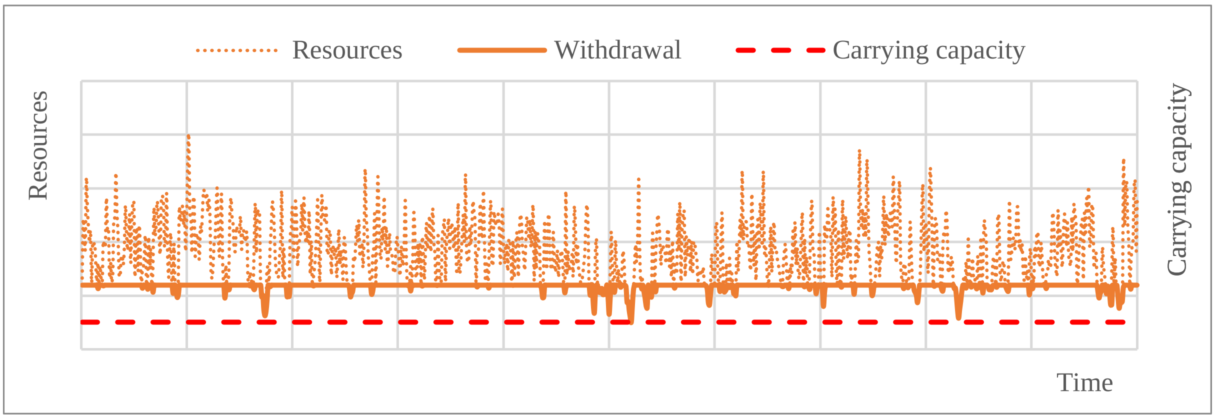


Figure 7.4 Toy model: The concept of storage with HK dynamics. Red dash-line shows the currying capacity of the population.

The role of the growth and the sustainability of resources in environmental determinism

If we combine in our toy model the advantages of technology, trading and storage increasing them in time, we could model the evolution by the following equation assuming linear changes in time of storage, and K_T and resources x'_T as follows:

$$K_T = (1 + \varepsilon T)K_0 \quad (7.14)$$

$$\underline{x}'_T = \underline{x}_T + \zeta T \quad (7.15)$$

[I] Holy Bible, Old Testament, Genesis (Γένεσις) 41 Available online: http://apostoliki-diakonia.gr/bible/bible.asp?contents=old_testament/contents_Genesis.asp&main=genesis&file=1.41.htm (accessed on 4 February 2021).

where ε and ζ are constants determining the linear relationships. The results of the new toy model are depicted in **Figure 7.5**.

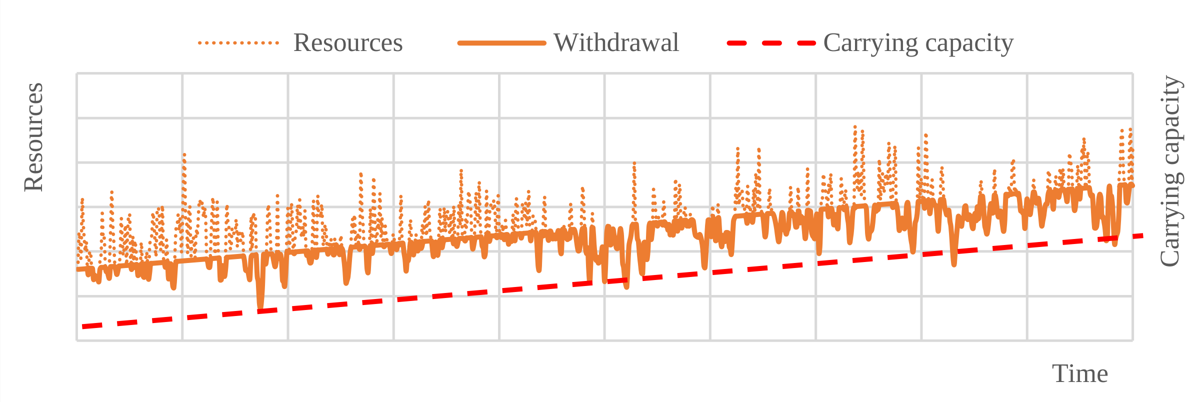


Figure 7.5 Toy model: The concept of currying capacity with HK dynamics where storage and technology are increasing.

However, if the rhythm of consumption increases, even if we have the ability the increasing of storage, we note a dynamic of collapse. If we consider the constant a in equation (the proportion of the storage released) an increasing function of time, i.e.:

$$a = a_0 + \eta T \tag{7.16}$$

where η is a constant which determine the linear relationships. The results of the new toy model are depicted in **Figure 7.6.**

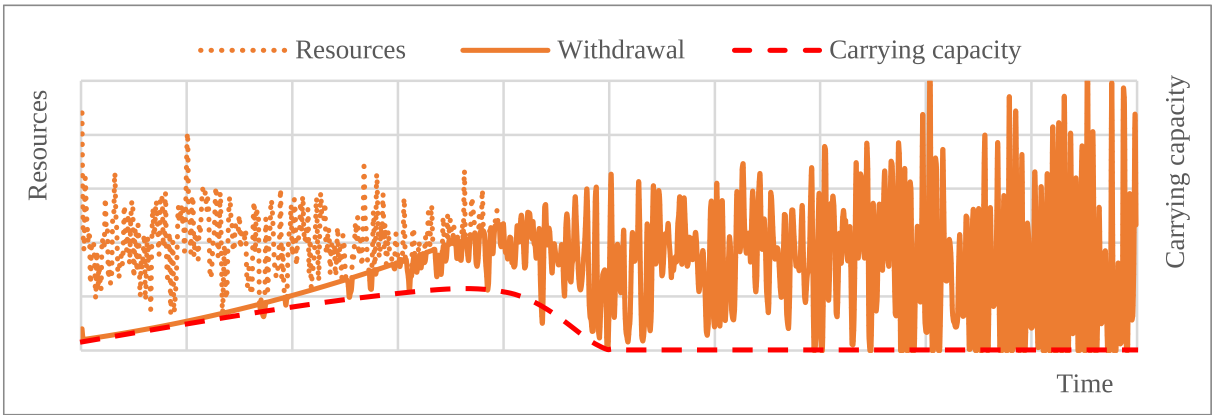


Figure 7.6 Toy model: The concept of environmental determinism with HK dynamics where storage and technology are increasing but the available resources are not consumed sustainably.

<u>An entropic view of growth and recession</u>

In the last century, a new scientific field has developed, econophysics, which combines socio-economic dynamics with the laws of physics.

Although in physics entropy is widely is often used as a measure of disorder, its universal character, stemming from its stochastic definition, features it as a measure of uncertainty. Together with the accompanying principle of maximum entropy, it forms an excellent tool to describe the dynamics of societies.

Social prosperity presupposes social constitution, which in turn presupposes social stratification and development.

From an entropic view point, we note that when the real average of the people's income increases (growth), the entropy Φ of societies, is increased. Instead of that, if the real average decreases (recession) entropy Φ is decreased. As entropy decreases instead of its natural tendency, in recession phase, societies flow in an unstable phase. In this respect it turns out that entropy is also a measure of society's wealth.

This aspect can be also connected with social crises in the abrupt limitation of resources (recession) by the HK dynamics or with non-sustainable consumption of resources.

In addition, we have to note that as growth increase societies' entropy, increase societies' the uncertainty and according Tainter, growth means the increase of sociopolitical complexity. In his book The Collapse of Complex Societies Tainter (1988) notes:

> *Collapse is a political process… A society has collapsed when it displays a rapid significant loss of an established level of sociopolitical complexity.*

Complexity is indispensable for growth. Max Roser notes[I]:

> *In a positive-sum economy your living standards are not determined by the productivity of your piece of land, but by the productivity of the economy that you are part of – the goods and services that you rely on are produced in a large-scale collaboration of millions of workers. Your economic well-being depends on them.*

The increasing of the pair of those variables (uncertainty and complexity) which are interconnected, is also related to the dynamics of collapse.

<u>An entropic view of social dynamics and stratification</u>

If social organization disintegrates (Butzer, 2012) civilization would collapse. It is believed that moral decline and extreme stratification are some of the contributing causes, while the contribution of technology, trading and storage is less obvious. For example, in the above-mentioned Biblical story, if in the years of abundance, Pharaoh kept all the surplus of the storage in order to satisfy the elite and trade it or make useless symbols of power, social crisis, starvation and collapse would be the one-way outcome.

A recession phase means a deformation of stratification. A general consideration is that the more vulnerable population in this phase is the elite (Middleton, 2012) as their existence is based in the surplus which is restricted at this time. However, it is exactly this surplus which gives to the elite the resilience in recession phases and the potential of oppressing the pour with multiple mechanisms.

Figure 7.7b tries to show how a phase of recession would affect the poor if the rich would not redistribute the wealth, in a simplified manner. The blue area shows the impacted people when resources are reduced by about 10%. In the Pareto distribution (for example in Ancient Egypt where Gini coefficient is estimated close to 0.7 (Shaer, 2021) about 80% of the population would be impacted. In the exponential distribution about 40% would be impacted. In the total equal society, as all the people are equal, one could assume that this would impact 100% of the population.

[I] Roser, M. Breaking out of the Malthusian trap: How pandemics allow us to understand why our ancestors were stuck in poverty, November 26 2020 Available online: https://ourworldindata.org/breaking-the-malthusian-trap (accessed 25 August 2021).

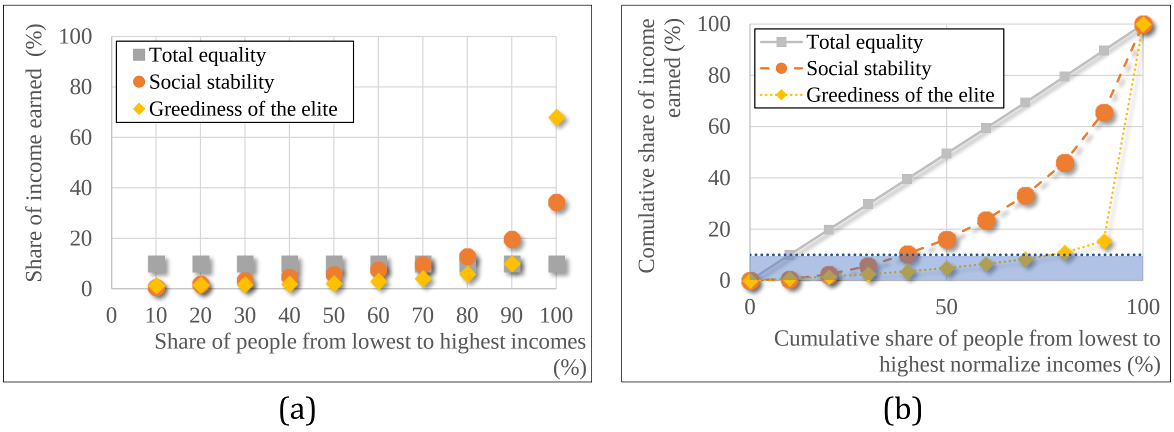


Figure 7.7 Different types of distribution of wealth. Grey rectangles show total equality with Gini coefficient equal to 0; orange circles show exponential distribution with Gini coefficient equal to 0.5; yellow diamonds show power-type Pareto distribution (greediness of elite) with Gini coefficient equal to 0.7 (a) Share of wealth (b) Lorenz curve (blue area represents a recession 10%).

History shows that stratified societies were distinguished and lasted for a long time when they prioritized a better way of living for the members of the society and this example shows the capacity of the elite to save the society from the collapse redistributing the wealth.

Digression 7.A: Summarizing elements of the study of social structure

The above considerations allow us to summarize the following methodological issues:

(a) The availability of natural resources follows HK dynamics which results in recessions and expansions in multiple phases.

(b) Humans have creative abilities such as technology and storage to overcome the phases of recession.

(c) If the rate of consumption exceeds the technology enabled resources, the society has a potentiality of collapse.

(d) The entropic approach to social dynamics suggests that:

(e) When the real average of the people's income increases (growth), entropy Φ is increased and when the real average decreases (recession by social causes, type of consumption, or environmental causes) entropy Φ is decreased.

(f) Growth of civilization means also the increasing of complexity. As entropy is a measure for both uncertainty and complexity, growth means the increasing of the both variables which give a potentiality of collapse and it is related to lower energy in the system.

(g) Exponential distribution of wealth corresponds to the optimum stable social structure.

(h) Equal distribution of wealth means an unstable social structure and less total wealth. From the entropic viewpoint, in this extreme case, entropy tends to -∞ (Koutsoyiannis and Sargentis 2021).

(i) The elites have capacities to recover recession phases. However, greediness of the elites means that, society may fall to decadence. From the entropic viewpoint, in this extreme case, entropy tends to zero (Koutsoyiannis and Sargentis 2021).

Natural tendency of entropy is to increase (provided that energy does not decrease). Every time we note entropy decreases instead of its natural tendency, societies switch to an unstable phase (Koutsoyiannis and Sargentis 2021).

A depiction of these methodological issues is shown in Figure 7.8.

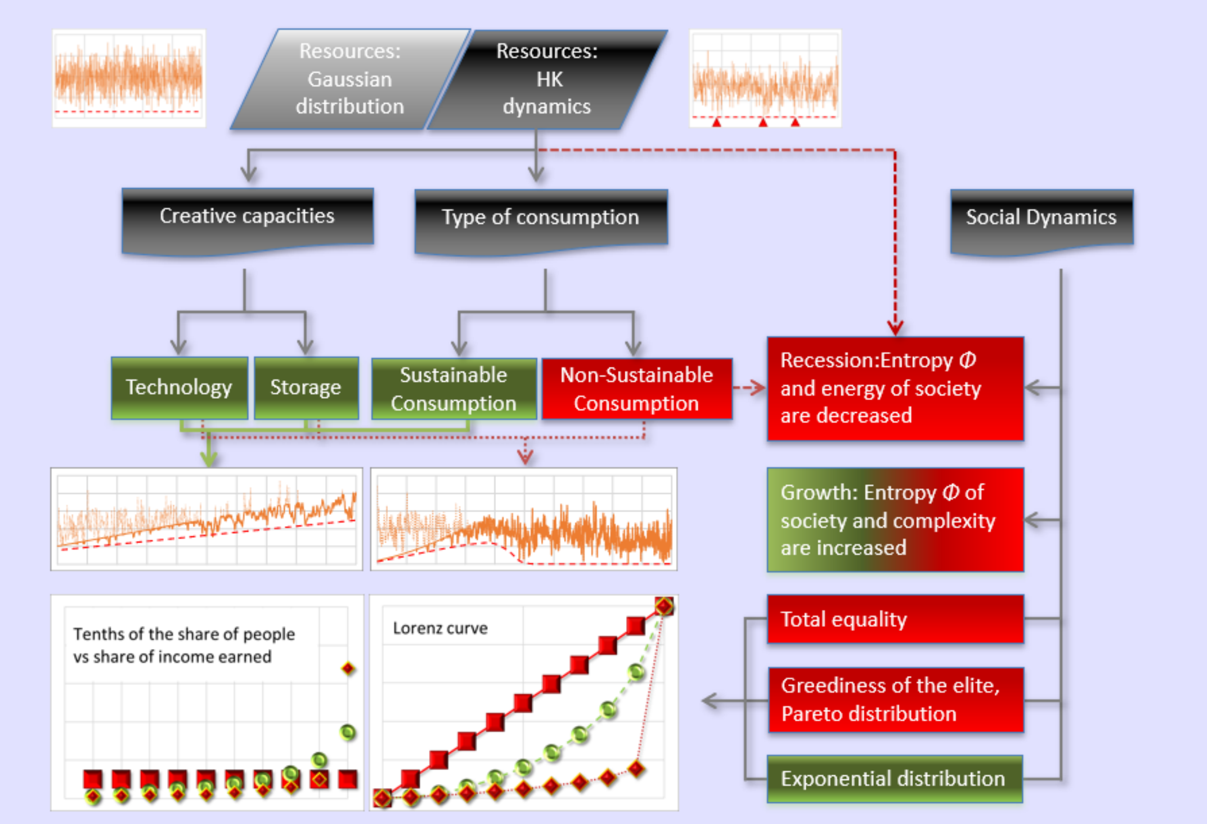


Figure 7.8 Summary of methodology. Green colour show aspects of a flourish society; red colour show aspects with dynamic of collapse.

7.1 Environmental determinism in the past

Maya: Heinberg (Heinberg, 2004) reported that complex societies that are limited to a single bioregion, such as the Classic Maya, are more likely to collapse quickly as a result of damage to the ecosystem, while those of greater geographic extent typically persist for decades or centuries longer (Stanley, 2011).

During the 8th-9th Century, the Mayans deforested large areas (Cook, 2012) in order to clear the land for agriculture and burned trees to make lime mortars for their complex constructions (Diamond, 2011) (**Figure 7.9**a). In a relevant study, it is speculated that the scale of deforestation broke down the hydrological cycle and was the reason for the drought that followed in the area during this period (Oglesby et al., 2010). Lack of forest cover contributed to soil depletion and erosion.

Obviously, civilizations often face many different types of natural disasters and usually, after a recessionary cycle, they manage to recover. For example, in the preclassical phase, Mayans had managed to survive two long-term droughts which were estimated by the analysis of stalagmites from the Yucatán (Turner and Sabloff, 2012; Hodell et al., 1995). Furthermore, in the classical phase, Mayans had to deal eight severe droughts of 3–18 years in length between 750–1050 AD (Beach et al., 2009; Hodell et al., 2007; Medina-Elizalde and Rohling, 2012). Data show that, in these periods, growth was stopped, but the important fact is that Mayans were able to recover many times. The recovery depends on the kind of the recession but certainly it requires proper social organization and coordination.

Mayans did not just disappear but abandon their cities. As crops failed because of drought, farmers and artisans immigrated, to escape starvation in a wider area. If we consider that societies in new-world were more equal than the old-world (Kohler, 2017) and Giny coefficient is estimated in order of magnitude around 0.2 (Fochesato et al., 2019). Turner et al. (Turner et al., 2012) assumes a strong possibility of conflict with an elite which showed weakness in this specific time to support the survival of the inhabitants. Elite lost their power and social organization disintegrated even if they had overlap similar gaps in the past. As farmers and artisans spread in order to survive like hunter-gatherers, from entropic viewpoint we note that entropic index of inequality $\Phi_{\mu}[\underline{x}]$ tends -∞ indicating the collapsed social structure.

In other words, the preservation of the social structure and social cohesion, is the prerequisite for the recovery of civilization.

Easter island: The first Polynesian settlers found an island with fertile soil, plenty of food, plenty of building materials and all the conditions for a comfortable living[I]. The redistribution of island resources required a complex social organization of the population (Fischer, 2005). It is alleged that trees were intensively cut to create tools for the construction of the island's monolithic monumental sculptures known as moʻai (**Figure 7.9**b). The construction of these sculptures is presumed to be the result of competition between different tribes trying to outdo each other in displays of wealth and power.

The big picture is one of the most extreme examples of society collapse: the entire forest has disappeared. As the forest disappeared, life became more and more uncomfortable - the springs disappeared and wood was no longer available. Humans starved; cannibalism replaced some of the lost food supply (Robert et al., 2020).

(a)

(b)

Figure 7.9 (a) Maya: El Castillo, at Chichen Itza[II]; (b) Moʻai facing inland at Ahu Tongariki, restored by Chilean archaeologist Claudio Cristino in the 1990s[III].

[I] Diamond, J. Easter's End, Discover, Aug 1995. Available online: https://www.discovermagazine.com/planet-earth/easters-end (accessed 25 August 2021).

[II] Maya civilization. Available online: https://en.wikipedia.org/wiki/Maya_civilization (accessed 25 August 2021).

[III] Moai. Available online: https://en.wikipedia.org/wiki/Moai (accessed 25 August 2021).

The cause of collapse: human acts or environment?
In both well-known cases we note anthropogenic factors as the cause:
- Maya: the collapse was triggered by droughts (recession) but the reason was the institutional failure from the corruption of the elite.
- Easter island: natural resources were consumed in higher rhythm than they could be renewed. The reason which led to a dynamic crisis was the inability of society to distinguish the real needs and the non-sustainable consumption for the creation of useless symbols of power.

These examples show that, even when the environment is involved as a cause of civilizations' collapse, it could be a trigger but not the cause, with social dynamics and environmental determinism nested in a complex relationship.

7.2 Environmental determinism in modern era

In modern era the technological limit and the ability of storage are constantly increasing. Therefore, environmental determinism fails systematically. Typical examples of failures are:

(a) The overthrow of the Malthusian trap by (a) the industrial revolution[I]; (b) the formation of modern economy[II]; (c) economic development[III].

(b) The recovery from the energy crisis caused by whale's oil shortages in the 19th century (Baker et al., 2004; Bardi, 2007; Yaeger, 2020) with the use of coal (O'Connor, 2014).

(c) The overthrow from the health crisis caused by the huge stock of horse's manure in cities during the late 19th century (35 pounds per day, per horse) by the cleaning of cities due to the introduction of automobiles, thus solving (Chiu, 2008; Levitt and Dubner, 2010; Brandon, 2013)

(d) The nonoccurrence of worldwide famine due to (supposed) overpopulation despite the prediction in the well-known books "The limits to growth" (Meadows et al., 1972) and "The population bomb" (Ehrlich, 1968). The Green Revolution introduced by Norman Borlaug[IV] gave an end to starvation for Asia in the 1960s (Cleaver, 1972; Hazell, 2009), Africa in the 1980s (Diao et al., 2008) and subsequent support of population growth until today.

The spectacular falsification of the predictions of 1992 AGENDA 21 of the United Nations Conference on Environment & Development such as this:

[I] Hoppe, H.H., From the malthusian trap to the industrial revolution, April 8 2013. Available online: https://themisescircle.org/features/from-the-malthusian-trap-to-the-industrial-revolution/ (accessed 25 August 2021).

[II] Roser, M. Breaking out of the Malthusian trap: How pandemics allow us to understand why our ancestors were stuck in poverty, November 26 2020 Available online: https://ourworldindata.org/breaking-the-malthusian-trap (accessed 25 August 2021).

[III] Van Zanden, J. L.; Baten, J.; Mira d'Ercole, M.; Rijpma, A.; Smith, C.; Timmer, M. How was life?: Global well-being since 1820. OECD publishing 2014. Available online: https://read.oecd-ilibrary.org/economics/how-was-life_9789264214262-en#page3 (accessed 25 August 2021).

[IV] Borlaug, N. E. The green revolution revisited and the road ahead. Stockholm, Sweden 2002 Available online https://www.nobelprize.org/uploads/2018/06/borlaug-lecture.pdf (accessed 25 August 2021).

We are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy.[I]

Since then, global poverty was reduced from 1.71 billion (1992) to 733.48 million (2019)[II], global average life expectancy increased from 63.1 to 71.4 years[III] the global share of children who are stunted 39.3% (1990) to 22.2% (2017)[IV] and the global share corresponds of the population older than 15 years that is able to read and write are from 75,3% (1992) to 86,4% (2019)[V] (**Figure 7.10**).

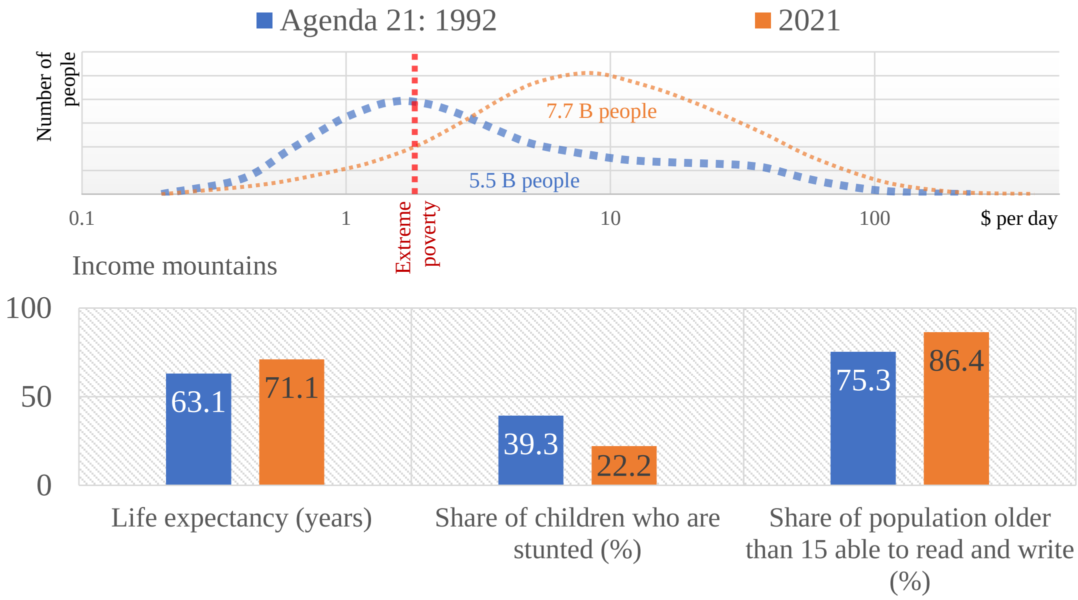


Figure 7.10 Global data from 1992 (Agenda 21), and today. Top: income mountains[VI]; Bottom: life expectancy (years), share of children who are stunted (%), share of population older than 15 able to read and write (%).

These examples show that Western thought can be influenced by environmental determinism despite its continual failures. The question is not whether the environment is related to socio-historical change, but how we can deal more objectively with coupled systems that include a large set of variables[VII].

[I] Agenda 21. United Nations Conference on Environment & Development, Rio de Janerio, Brazil, 3 to 14 June 1992. Available online https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf (accessed 25 August 2021).

[II] World Bank, PovcalNet: an online analysis tool for global poverty monitoring, Available online http://iresearch.worldbank.org/PovcalNet/ (accessed 25 August 2021).

[III] Life expectancy. Available online: https://ourworldindata.org/life-expectancy (accessed 5 October 2020)

[IV] Roser, M.; Ritchie, H. Hunger and Undernourishment. Available online: https://ourworldindata.org/hunger-and-undernourishment (accessed 25 August 2021).

[V] World Bank, Literacy rate, adult total (% of people ages 15 and above. Available online: https://data.worldbank.org/indicator/SE.ADT.LITR.ZS (accessed 25 August 2021).

[VI] Income Mountains. Available online https://www.gapminder.org/fw/income-mountains/ (acceced June 5 2021)

[VII] United Nations, 2019 Revision of World Population Prospects. Available online: https://population.un.org/wpp/ (accessed 27 June 2021).

In addition, it is difficult not to draw parallelisms with the present situation as in current conditions: the complexity of the world and the dependence of the digital civilization has reach an impressive high limit, global wealth follows a Pareto distribution (Koutsoyiannis and Sargentis, 2021), highly costs research and technological steps are far from the real needs (among other, to the useless competitions about space trips[I]), the type of resources' consumption is non-sustainable and we have not solved issues about storage capacity (for example to store energy by the Renewable Energy resources).

7.3 Minoan civilization

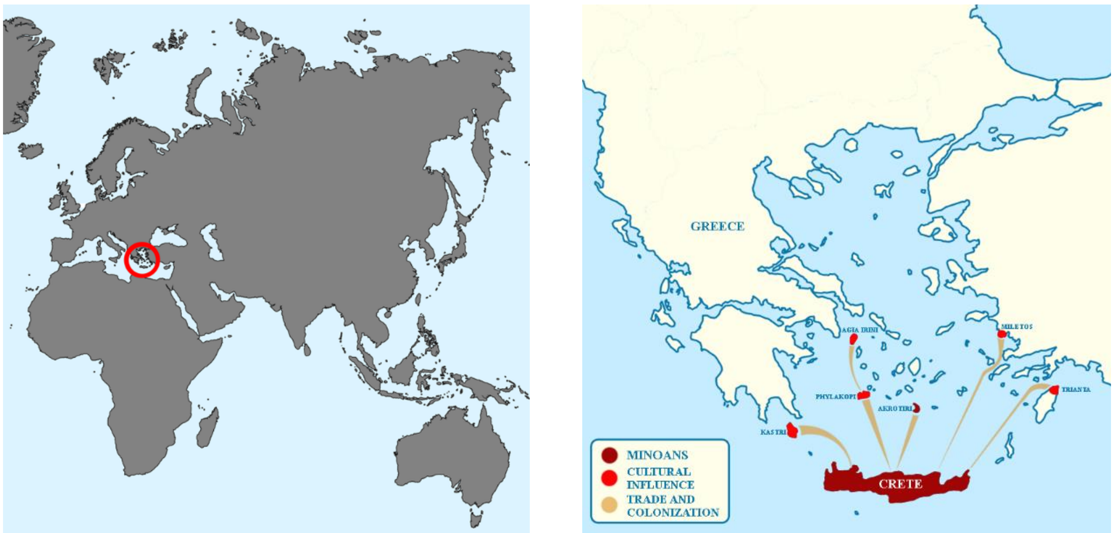
The Minoan civilization was an Aegean Bronze Age civilization which flourished on the island of Crete, the island of Santorini (Akrotiri), other Aegean islands, and in the western coastal areas of modern-day Turkey (**Figure 7.11**) from about 3200 to 1100 BC. The historian Will Durant called the Minoans "the first link in the European chain" (Durant, 1939). This statement is ex post supported by genetic indexes which indicate that: the first Neolithic migrants traveled from the Levant into Anatolia and then to eastern Crete, Greece, Sicily and central Europe (Paschou et al., 2014).

The basic stages of Minoan civilizations are:

(a) Prepalatial 3250-1900 BC
(b) Protopalatial (Old Palace period) 1900-1750 BC
(c) Neopalatial (New Palace period) 1750-1450 BC
(d) Postpalatial (Knossos, final Palace period) 1450-1100 BC
(e) Dark Ages 1100-750 BC

The Minoans represent the first advanced civilization in Europe, leaving behind massive building complexes, tools, stunning artwork, systems of writing, and a massive network of trade (Chaniotis, 2012). They constructed remarkable architectural and hydraulic infrastructure for the management of water resources, such as water supply, fountains, dams, aqueducts, highly sophisticated sewage and drainage systems, toilets, irrigation and drainage of agricultural land (Angelakis and Spyridakis, 1996; Palyvou, 2004; Palyvou, 2003; Angelakis, 2013). Minoans also developed the, syllabic scripts known as Linear A and Linear B. Linear B was deciphered by Michael Ventris in 1952 (Chadwick, 1990; Chadwick, 1987). This remarkable civilization, was only rediscovered at the beginning of the 20th century through the work of British archaeologist Arthur Evans.

[I] Williams, O. Billionaire Space Race Turns Into A Publicity Disaster , 21 December 2021, Available online: https://www.forbes.com/sites/oliverwilliams1/2021/12/21/billionaire-space-race-turns-into-a-publicity-disaster/ (accessed 25 December 2021).



(a) (b)

Figure 7.11 Minoan civilization. (a) Location; (b) Areas of cultural influence (possible colonies), trade and colonization route.

Despite the abundance of objects, images and even inscriptions from the Minoan era, it is still difficult to reconstruct the society's structure. Driessen (2015) notes that:

a kinship association in which gender differentiation combined with age and a strong sense of locality shaped Minoan identity.

Adams (Adams, 2017) assumes that there was stratification, elite and commoners, and Kristiansen and Larsson (Kristiansen and Larsson, 2005) exemplify the current state of thinking in Cretan archaeology in their synoptic study The Rise of Bronze Age Society, stating that:

the power of Cretan elites lay in 'institutionalised practices (economic, political and religious) that constituted palatial power.

As there was no mention of wars in the area of Minoans between 3200 to 1100 BC, the Minoan era was named by Evans as *Pax minoica* or Minoan peace (Evans, 1921–1935) a period during which cities did not have walls (Hirschfeld, 2010). Instead of this consideration, other archeologists believe that artistic representation of violent hobbies as boxing or bull-leaping (**Figure 7.12**), show violent social spirit (Vandkilde, 2006). This supports the theory that the Minoans had a military aristocracy (Molloy, 2012) which, according to Ferguson (Ferguson, 1990) were crucial determinants of social formation together with civil administration and religion (triadic balance). It is important to note that recent archeological evidence supports this theory (McGeorge, 2018).

Crete has pleasant weather[I] (no need for warm clothes or special protection), no big animals as enemies, and a lot of food is produced naturally by trees, small animal hunting and fishing. Therefore, an organized society was not necessary for survival needs and people could live there easily as hunter-gatherers. However, the land's morphology is

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[II] Climate Data for Cities Worldwide. Crete. Available online: https://en.climate-data.org/europe/greece/crete-10053/ (accessed on 27 June 2021).

quite heterogenous with a wide range of altitude and fertile-barren areas. **Figure 7.13** **Figure 7.14**, shows the connection between the cultivated areas of modern Crete and the archeological settlements from the Minoan era (**Figure 7.14**), indicating that the limits of fertile areas were connected to Minoan settlements.

Figure 7.12 Minoan fresco in Knossos palace, c. 1600-1450 BC.[I]

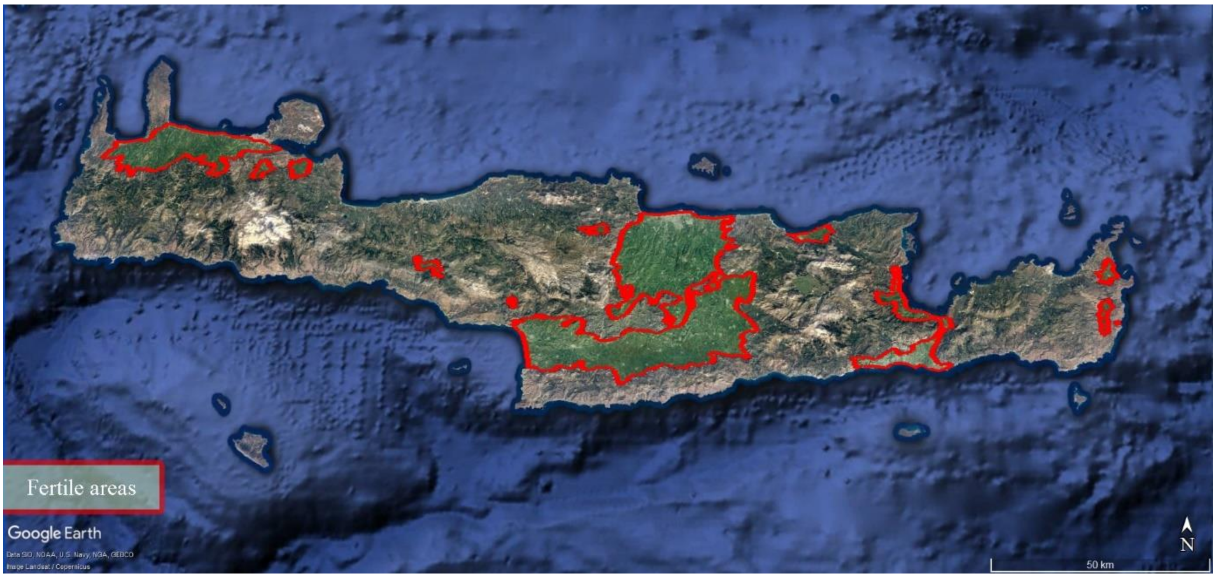

Figure 7.13 Limits of fertile areas in 2021, connected with Minoan settlements[II].

Assuming that Minoans could cultivate all areas as is done in modern times (**Figure 7.13**) with traditional methods, Knossos, Phaistos, and nearby settlements in the center of Crete could feed more than 110 000 people. In the eastern Crete, the palace of Malia could feed more than 2000 people, the area near palace of Gournia could feed more than 12 000 people and, assuming that the palace of Zacros exploited the land of Palekastro, it could feed more than 5000 people. In the western Crete, Cydonia could feed more than 25 000 people and the nearby cultivated areas of Aptera could feed about 4 000 people (Sargentis et al., 2021). In these cases, we have to imagine one more difficulty: to transfer

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[I] Acrobatics over a bull in unknown circumstances, probably ceremonial. Available online: https://en.wikipedia.org/wiki/Bull-Leaping_Fresco#/media/File:Bull_leaping_minoan_fresco_archmus_Heraklion_(cropped).jpg (accessed 25 August 2021).

[II] Google Earth Pro, Version 7.3.3.7786, Map publisher NOAA, U.S. Navy, NGA, GEBCO, June 2021, Crete the products from mainland to the cities and palaces and then to trade them (Hood and Smyth, 1980). As saffron is precious in very small quantity (current price ~90 000 € per kg[I]), it was an ideal product for Minoans to trade (**Figure 7.15**a). In addition, we can imagine one important advantage: the sea could be an important food supplier as is represented in related frescos (**Figure 7.15**b).

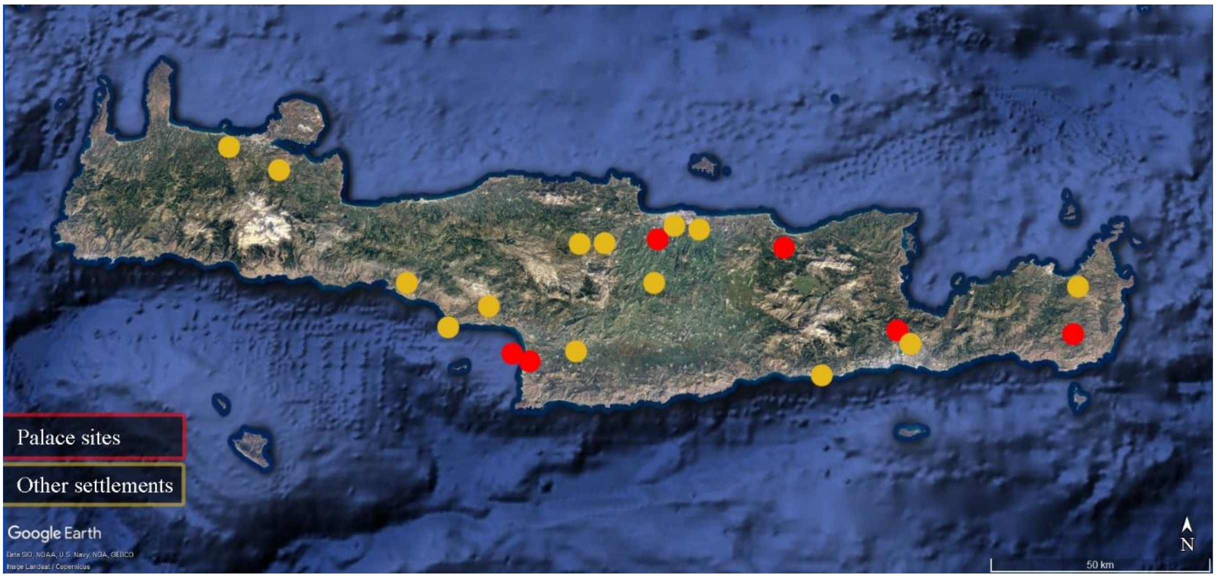

Figure 7.14 Centre Minoan Crete settlements[II].

Minoan landscapes were well organized in agricultural and pastoral areas for food production (Orengo and Knappett, 2018). The high living standards (as evidenced by hydraulic infrastructure) allowed a dense clustering of humans in cities. Castleden estimates that Knossos had a population of c.40 000 people in 1500 BC (Castleden, 2011) and according to Homer (c. 800 BC), Crete once had 90 cities (Bennet, 1996). Unlike other ancient civilizations, such as in Egypt, Mesopotamia and India, which thrived in areas with high water availability (big rivers), Greek civilizations (and Minoans) thrived in almost the same climate classification but in water deficient areas and therefore susceptible to prolonged droughts as there were no continuous water supply from big rivers in Greece. Therefore, technological infrastructures were necessary for the development in Greek civilizations (Angelakis et al., 2014; Koutsoyiannis and Mamassis, 2018).

[I] Agriculture in Greece: Saffron: The most expensive spice in the world: Σαφράν: Το πιο ακριβό μπαχαρικό του κόσμου. Available online: https://www.ellinikigeorgia.gr/safran-to-pio-akrivo-mpaxariko-kosmou/ (accessed 25 August 2021).

[II] Google Earth Pro, Version 7.3.3.7786, Map publisher NOAA, U.S. Navy, NGA, GEBCO, June 2021, Crete

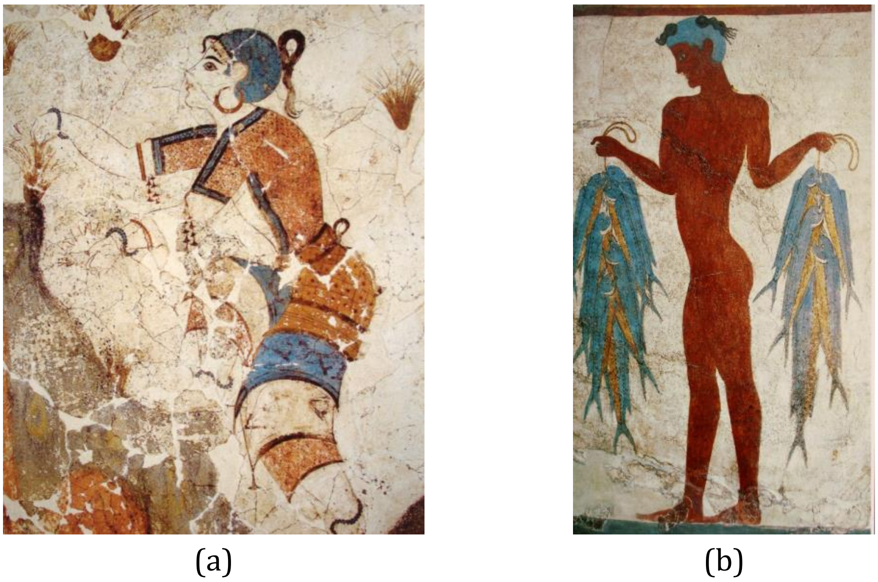

Figure 7.15 Akrotiri, Santorini c. 1600-1500 BC (a) Saffron gatherers[I] and (b) fisherman[II].

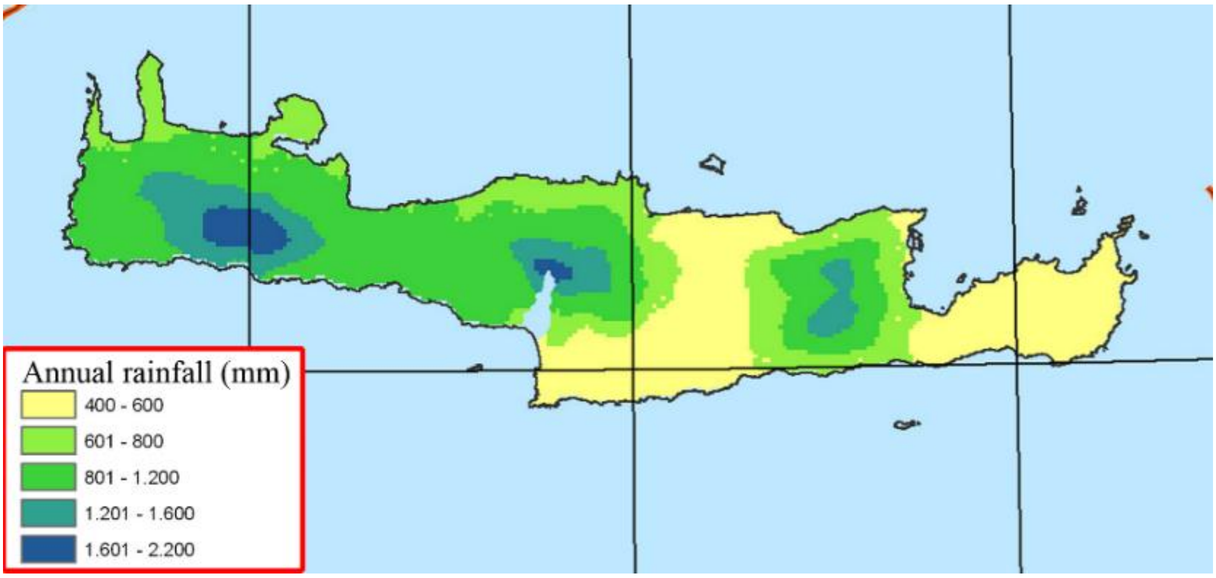

Figure 7.16 Top: Annual rainfall of Crete[III].

Whilst there are small rivers and lakes in Crete and the Aegean islands, the Minoan palace and other urban areas were not located close to them. Thus, the remarkable progress in the Minoan Era appears to be inextricably linked with the desire for peaceful

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[I] Saffron gatherers. Available online: https://el.m.wikipedia.org/wiki/Αρχείο:Cueilleuse_de_safran,_fresque,_Akrotiri,_Grèce.jpg (accessed 25 August 2021).

[II] Fisherman. Available online: https://en.m.wikipedia.org/wiki/File:Fresco_of_a_fisherman,_Akrotiri,_Greece.jpg (accessed 25 August 2021).

[III] Source: Koutsogiannis, D.; Andreadakis, A.; Mavrodimou, R.; Christofidis, A.; Mamasis, N.; Efstratiadis, A.; Koukouvinos, A.; Karavokyros, G.; Kozanis, S.; Mamais, D.; et al., National Management and Protection Program of Water Resources, Support for the Preparation of National Program for Management and Protection of Water Resources; Department of Water Resources and Environment—National Technical University of Athens: Athens, Greece, 2008; 748p. doi:10.13140/RG.2.2.25384.62727 coexistence with and adaptation to the natural environment with highly hygienic standards, protection from diseases and natural hazards (such as floods and droughts) and the comfort of non-primitive living (Angelakis, 2016; Koutsoyiannis et al., 2008; Chatzimpiros et al., 2007). Examining **Figure 7.14**, **Figure 7.16** (rainfall of Crete and Minoan settlements), the flourishment of western settlements such as Cydonia in the pre-palatial period and then Aptera after the Minoan era, we note that in their prosperity, Minoans preferred the dry places (as later did Cycladic, Athenians, Spartans etc).

The Minoans exported food, wine, olive oil, herbs, cloth dye obtained from the murex shell, and saffron spice[I] as well as other commodities and artifacts. The island's imports consisted of emery which was imported from Naxos, obsidian, tin, seals and ivory from Anatolia, copper from Cyprus and other places. These traders from various countries were dependent on each other so that their economies could not only survive, but thrive (Roberts, 2019).

Studying their way of life, we can see from frescos that the Minoans had great festivals with boats which indicated societal stratification as some boats were more decorated than others (**Figure 7.17**). We also see that they created highly sophisticated artwork, paintings, sculptures, hydraulic works and ships on which their civilization was based.

These highly sophisticated creations during the Minoan era show that there was a division of labor. It is important to distinguish that life expectancy of people from prehistory until the 1400s was no more than thirty years (Preston, 1995) and one century would mean more than three generations instead of less than one and a half in modern times. Herein we can also assume that there was a powerful educational system transferring the skills from generation to generation.

Based in the above, we can distinguish the following classes: (a) elite; (b) military class; (c) artists; (d) ship constructors; (e) sailors; (f) craftsmen (houses and hydraulic infrastructures) with high engineering knowledge and (g) farmers and pastorals.

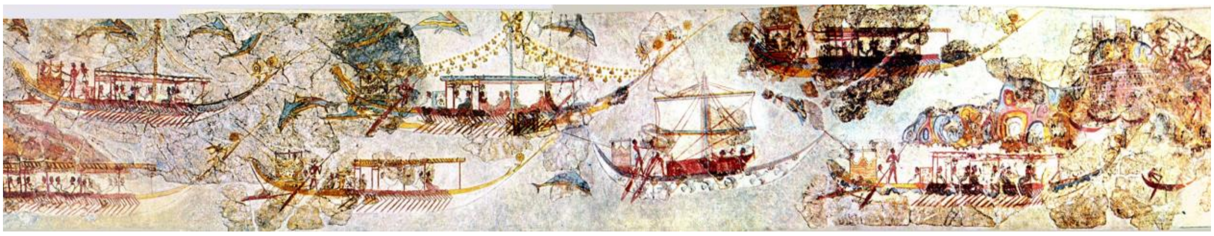

Figure 7.17 Minoan fresco, ship procession from Akrotiri c. 2000-1500 BC. Sophisticated ships with different decoration suggesting stratification. In the middle a sailing boat loaded with goods[II].

We may speculate about the role of each one of the classes. The important requirement for production is land. As land required important investment, deforestation, upgrade,

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[I] Dewan, R. Bronze Age Flower Power: The Minoan Use and Social Significance of Saffron and Crocus Flowers, Institute for European and Mediterranean Archaeology, Chronica 5:42-55, 2015. Available online: http://www.chronikajournal.com/resources/Dewan%202015.pdf (accessed 25 August 2021).

[II] Minoan ship procession. Available online: https://commons.wikimedia.org/wiki/File:AKROTIRI_SHIP-PROCESSION-FULL.jpg (accessed 25 August 2021).

and irrigation infrastructure, we can assume that the elite invested and managed the preparation of the land using craftsmen. Craftsmen created high living standards by enhancing the supply of food with irrigation. Farmers and pastorals produced food for all and surplus for trading. Artists created surpluses. Constructors made ships for sailors to trade what were not necessities, supporting also the nutritional needs with fishing (**Figure 7.18**a).

One could assume that there would be a market where people could exchange their goods but the complexity of the interaction of these classes becomes clear if we imagine a society without money and the basic goods which established the prosperity in Minoan era were of high value (infrastructures, ships) and could not be exchanged. Therefore, we can assume that the elite arranged the fees and managed the economy by controlling the interactions and the distribution of wealth. The role of elite was critical as the distribution of all the wealth was controlled by them, hence this could justify a Pareto distribution. Impressively we see that the distribution is estimated in 1500 BC with Gini coefficient equal to 0.5 (Fochesato et al., 2019) corresponding to exponential distribution, which is the most stable social structure. Even we do not know the analogies of Minoans classes **Figure 7.18**b depicts a hypothetical structure of Minoan's wealth distribution.

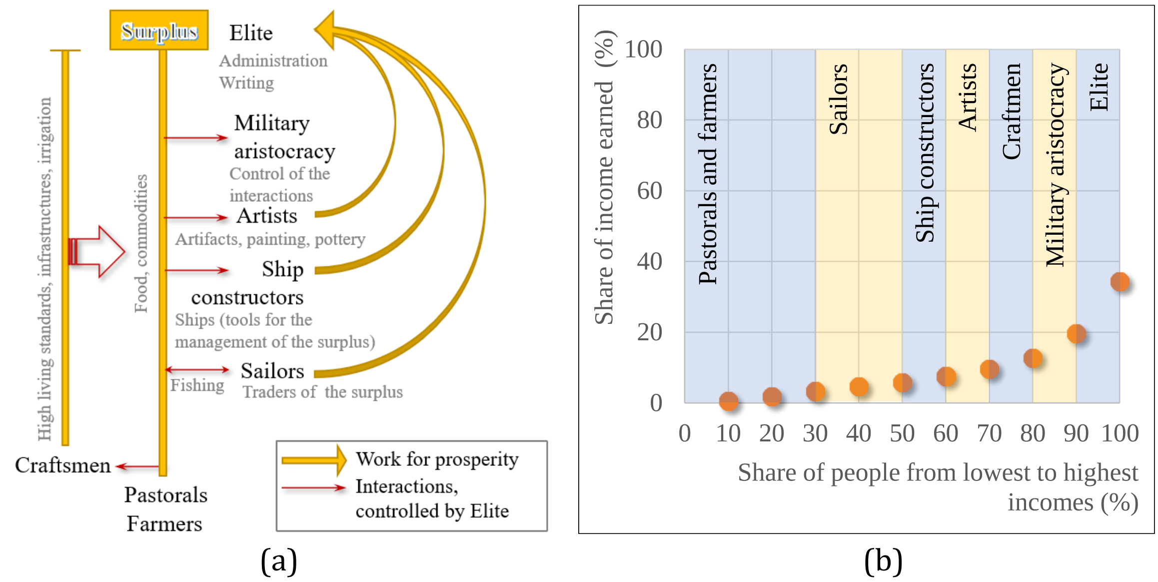

Figure 7.18 (a) Creation of wealth and interactions in Minoan society; (b) A hypothetical stratification in Minoan society with Gini coefficient equal to 0.5.

There are many studies attempting to explain the collapse of the Minoan civilization. We could distinguish them by the main cause they propose, environmental or social.

<u>Climate change</u>

Tsonis et al. (Tsonis et al., 2010) show that wetter conditions during the middle Holocene were followed by drier conditions and that around 1450 BC a long stretch of drier conditions commenced ending centuries later. The authors presented a synthesis of historical, climatic (associated with an increase in the intensity of the El Niño Southern Oscillation), geologic, and model simulations to support the hypothesis that climate change, instigated by an intense El Nino activity starting around 1450 BC and lasting for centuries (resulting from El Nino teleconnections) prolonged the drought conditions in the area and this contributed to the demise and eventual disappearance of the Minoan civilization). A related study (Markonis et al., 2016) summarized the pressures on the water resources in Crete in connection with climatic variability.

However, it appears that the Minoans had responded adequately to the changing climatic conditions during the Middle Bronze Age. At that time, the management of water resources became increasingly important, consistent with a drier climate (Betancourt et al., 2012). Technologies such as gutters, wells, and dams utilized ceramic mulches to conserve soil moisture, while the construction of many terraced hillsides was implemented during those periods (Floods, 2012; Angelakis et al., 2020). However, Minoans always had the option to move to wetter climates (**Figure 7.16**) and if there was drought in Crete, they could move in other places or in existing colonies than collapse.

Minoans were also sailors and traders and could import goods in case of drought, like what Athenians did a few centuries later.

In any case, climatic and environmental influences cannot be ruled out even if they are of secondary importance. This is consistent with what Tsonis et al. (Tsonis et al., 2010) concluded, i.e.:

> *While nobody anymore expects any civilization to get extinct because of climate, it is becoming clear that convergent events such as earthquakes and volcanic activity in synergy with climate anomalies may produce significant stress to contemporary populations vis-a-vis their social and economic development.*

Thera volcano eruption

The chronological estimates of this eruption differ: 1500—1450 BC (Marinatos, 1959; Detorakis, 1994) 1645 BC (Hammer, 1987) early 16th century BC (Pearson, 2018), 1628 BC (Sivertsen, 2009). Widely known catastrophic scenarios from Thera volcano eruption are:

Fallen tephra from Thera on the eastern side of Crete choked off the agricultural production (Luce and Bolton, 1976), and people lost their creative capacity (Dunn, 2002).

A tsunami, likely associated with the eruption, impacted the coastal areas of Crete. It is estimated that waves from Thera battering northern Crete could have been up to 12m high in places (Molloy et al., 2014; Bruins et al., 2008; Novikova, et al., 2011). Such waves would have destroyed boats and coastal villages, even travelling up rivers to flood farmland (Dominey-Howes, 1997; Gray and Monaghan, 2003; Monaghan et al., 1994; Antonopoulos, 1992). However, the number of vulnerable Minoan settlements located in the coastal areas was limited.

There is a possibility that the eruption caused significant climatic changes in the eastern Mediterranean region and especially in the Aegean Sea (Pyle, 1997; LaMoreaux, 1995; Panagiotaki, 2007). The potential effect of Thera volcano eruption is the possibility of injecting Sulphur dioxide into the stratosphere, as huge amounts of this gas can alter the climate through solar reflection (Rampino, 1984; Rampino, 1988).

However, the Minoan Civilization in Crete was destroyed much later than the estimated time of eruption—a puzzle that has haunted historians and scientists for decades. A strong possibility is that the ash from Santorini (Thera) overshadowed Crete for a few days but in no way destroyed the Minoan civilization (Luce and Bolton, 1976). The final collapse came at least three centuries later, most probably from other endogenous causes. In addition, archaeological and other evidences suggest that after the Thera volcano eruption in the neopalatial period, a cultural explosion, unprecedented in the history of ancient civilizations, occurred in Crete. This is demonstrated by the advanced hydrotechnologies developed at that time as there were described by Angelakis (Angelakis, 2017).

In a very interesting recent research paper about how the volcanic climate impacts can act as ultimate and proximate causes of Chinese dynastic collapse, Gao et al. (Gao et al., 2021) show correlation of collapses of Chinse dynasties after volcano eruption which happened in less than 15 years after the eruption. Even they assume that

> *in cases of collapse, that some dynasties persisted for up to a decade post-eruption while others collapsed more rapidly suggests the complexity of the underlying causal contributions and the inadequacy of monocausal or environmentally deterministic interpretations.*

they show that civilization could be impacted by an eruption but in a small-time range (i.e., less than 15 years).

<u>Fires</u>

From the traces found during the excavations of the various archeological sites, the destruction at this time appears to be the result of a fire. Platon (Platon, 1968), who carried out the excavations at Minoan places in the area of Hondros, in the south eastern Crete, suggesting these major disasters were due to fires:

Judging by the strongly cohesive layers and the calcification and burglary that the stones on the wall of the buildings suffered, the destruction of the neo-palatial settlement of Kefalas and its habitation ended after fierce wildfires.

Additionally, the neo-palatial holy-sanctuary in Roussos of Hondros had become a victim of an extensive wildfire, which is testified by the abundant remains of the *πυρίκαυστον* layer found at the site (Papadakis, 2002).

There is a possibility that a fire causes deforestation in the island. This could cause several problems as the lack of wood for ship construction. However, no indication has been found or provided on issues such as: where, by whom, how big was the fire and how it was started.

<u>Pandemic</u>

A final hypothesis is that according to the archeological findings of skeletons in a chamber tomb excavated in 1975 at Stavros, east of the village Galia and north of Moires, in a recent publication (McGeorge, 2018) McGeorge assumes that:

Most households must have kept animals for subsistence, so contact with animals at a domestic level would have been inevitable. The risk of contagion within families would have been great, while denser human population clusters would have aided the spread of epidemic diseases like tuberculosis.

Norrie discuss the sixteenth reason—infectious disease epidemics which could have led to the end of the Bronze Age (Norrie, 2016). As the cluster of people increased in Minoan civilization and we are not sure about the hygienic standards for the majority of the society, we could not exclude the possibility of a pandemic which could break social structure and continuity.

Social causes

(a) Foreign enemies: The cause of the destruction of the Minoan civilization has been attributed to an invasion by foreign enemies, e.g. Achaeans from Peloponnese. This view assumes that a campaign, similar to that organized later by the Achaeans against Troy, overthrew the Minoans (Glotz, 1922; Pendlebury, 1939). However, if we accept the attack from Achaeans, the question remains: since the Achaeans invaded Crete, why did they not stay there to exert their influence as they had in other places? In addition, there are chronological gaps. Around 1200 BC, (100 years before Minoans' collapse) the Achaean civilization itself ended when the Dorians, from the northern Balkan peninsula, conquered it. According to the Greek literature, Iliad and Odyssey, the people would rather die defending their homes than escape. In addition, if is some Achaeans escaped with ships from a Dorians' attack and immigrated to Crete displacing the Minoans we should find their footprint. Until now, archeological evidences do not confirm this theory.

(b) Unrest: This hypothesis states that the Minoan destruction was caused by internal upheaval, social unrest and conflicts that had been created between the Cretans long before the Achaeans and/or Mycenaeans subjugated them, when the civilization had already deteriorated. In other words, the Cretans began to destroy themselves, allowing external invasion to be easily accomplished, *mutatis mutandis* (i.e., changing what needs to be changed) (Fame, 1990). However, Minoans learned to live with the comforts of non-primitive living. In order to do this, they had to create infrastructure and ships that could not be exchanged in local markets and colonies. Infrastructure and large-scale creations (such as ships) need capital. In the case of Minoans, we have to imagine a society without money, therefore we have to assume that all the interaction which money represented, should have been done by an elite based on an organized bureaucracy (Whittaker, 2005). Therefore, the elite would be absolute necessary in society's function and the fact of an unrest seems impossible.

7.4 The role of the elite in Minoan era

Minoans did not thrive in an isolated environment. Even if their technology was limited and the ability of storage was small, they could find resources in other places to support their civilization. Their trading skills and their colonies indicates that they had enlarged their abilities to find new resources as they were flexible "predators".

The Gini coefficient in Knossos c. 1500 BC, is estimated about 0.5 (Fochesato et al., 2019). This value, corresponds to the exponential stratification which is referred to the entropic index of inequality $\Phi_\mu[\underline{x}]$ equal to 1 (Koutsoyiannis and Sargentis, 2021) and shows a stable social structure (maximized entropy) in which, a recession phase would have minimum effect.

In this era, Minoan manage to overpass the recession phases caused by environmental causes (Thera volcano eruption and climate changes). If we consider that in antiquity the life expectancy was no more than 30 years (Preston,1995), from the stable social structure (1500 BC) to the collapse phase (1100 BC) there were at least ten generations which could transform elite's social perceptions into greediness, creating unstable social conditions.

In addition, Minoan's had an economy organized with complex interactions (in place of money) controlled by the elite. This economy based on large-scale projects (infrastructure, ships) focused on high living standards, the creation of a surplus and overall, in a positive-sum economy.

If we consider the social utility of Minoan's different classes, we see that we could not leave aside one class and imagine that their civilization could live in prosperity. This complex social structure (**Figure 7.18**a) thrived for centuries, increasing its entropy (uncertainty) and complexity. Therefore, we could assume that an accident in which Minoans could lose the ability of management of their complex structure (e.g., a plague or a sudden loss of important members of the society), would be more possible and catastrophic as it would reduce the efficiency of the society. The average income would be decreased, the social structure would be unstable and their civilization would acquire a dynamic of collapse.

7.5 The role of the elite in present days

The empirical investigation in this section provides comparison of the theoretical framework of entropy developed with real-world data. Sargentis et al. (Sargentis et al., 2021) have made similar comparisons, also intercomparing with the Lorenz curve and the Gini coefficient, which are more standard measures of income distribution and socio-economic inequality (Atkinson and Bourguignon, 2001; Morelli et al., 1970; Förster and Tóth, 2015). In their comparisons, they used data given in tenths of the share of people from the lowest to the highest income versus share of income earned. The partitioning in tenths is a standard form of income data offered in relevant databases, yet it fully hides the behaviour of the tail, which, as we have seen, is extremely important for understanding structural characteristics of the economy and for quantifying inequality. We will provide additional evidence on this importance in this section.

In this purpose, we will analyse for data given in higher resolution than tenths of people's income and we found such data for USA and Sweden. Even in this case, the information about the tail (the very rich people) is missing as the data values end at some level c with the last bunch of data given as "c and over". It is thus crucial to find a way to extrapolate the distribution function beyond c and estimate expectations based on this extrapolation (Koutsoyiannis and Sargentis, 2021).

The data from the USA are available online thanks to the United States Census Bureau[I]; of those we choose to use the most recent available, those for year 2019 and in particular

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[I] United States Census Bureau, PINC-08. Source of Income-People 15 Years Old and Over, by Income of Specified Type, Age, Race, Hispanic Origin, and Sex, Available online: https://www.census.gov/data/tables/time-series/demo/income-poverty/cps-pinc/pinc-08.2019.html (accessed on 29 July 2021).

those for the entire population irrespective of particular characteristics (sex, race, etc.). The empirical probability density and tail function (probability of exceedance), estimated from the data are shown in **Figure 7.19**, also in comparison with the entropy maximizing exponential distribution.

Here it is useful to remark that the detailed data cover only a small portion of the range of incomes, up to less than double the mean income. Thus, they provide little information on the distribution tail (the richest people). As a result, the extrapolation becomes very important. Without the extrapolation the mean income (i.e. the quantity A_1, according to the above notation) is 30 601 $ and it becomes 53 336 $ after the extrapolation (i.e. after adding B_1). Note that the actual mean value, according to the source data[I] is 54 129 $, i.e., close to the extrapolated estimate, which suggests that the extrapolation model is not bad. Even more drastic is the change in the second moment: before extrapolation, it is 1.62×10^9 and after it 4.74×10^9, i.e. almost 3 times higher. The final (with extrapolation) estimate of the coefficient of variation is $\sigma/\mu = 1.11$, slightly higher than 1. The final estimate of entropy (for λ = 1 $) is $\Phi = 11.82$, and that of the standardized entropy $\Phi_\mu = 0.94$, slightly lower than 1.

Overall, the picture in **Figure 7.19** suggests that the principle of maximum entropy with Lebesgue background measure seems to explain the income distribution. It is interesting that the frequency of mid-rich people, from the mean income to more than twice the mean, is somewhat overpredicted by the exponential distributions, and that of the very rich (with income more than thrice the mean) is underpredicted. The incomes of the poor and middle class do not differ from what is predicted by the principle of maximum entropy. Remarkably, the condition $\mu_{x\geq c}/\mu = 80\%$ is satisfied when $\overline{F}(c) = 42\%$, close to the value 43.9% of the exponential distribution and substantially higher than 20%, thus suggesting the inappropriateness of the "80/20 rule".

Somewhat different is the picture of Sweden shown in **Figure 7.20**, again for the year 2019. The data, provided by Statistics Sweden[II], are more detailed than the USA data, covering a range of income about nine times the mean income[III]. The estimated statistics are also shown in the figure. The standardized entropy ($\Phi_\mu = 0.79$) and the coefficient of variation ($\sigma/\mu = 0.72$) are lower than in the USA, suggesting lower inequality. Strikingly however, there is an opposite effect on the very rich, whose frequency is considerably higher than that predicted by the exponential distribution. A possible explanation would

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[I] Income Distribution, Redefining Capitalism in Global Economic Development, 2017, Available online: http://www.sciencedirect.com/topics/economics-econometrics-and-finance/income-distribution (accessed on 5 October 2020).

[II] SCB – Statistics Sweden, Income and tax statistics, Available online: https://www.scb.se/en/finding-statistics/statistics-by-subject-area/household-finances/income-and-income-distribution/income-and-tax-statistics/ (accessed on 29 July 2021).

[III] SCB – Statistics Sweden, Number of persons in brackets of total earned income by age 2019, Available online: https://www.scb.se/en/finding-statistics/statistics-by-subject-area/household-finances/income-and-income-distribution/income-and-tax-statistics/pong/tables-and-graphs/income--persons-the-entire-country/total-income-from-employment-and-business-2019--by-income-brackets/ (accessed on 29 July 2021).

rely on globalization of the financial activities of the high-net-worth individuals. Again, the condition $\mu_{x\geq c}/\mu = 80\%$ is satisfied for $\overline{F}(c)$ substantially higher than 20%, namely for $\overline{F}(c) = 45\%$, close to the value 43.9% of the exponential distribution, thus suggesting again the inappropriateness of the "80/20 rule". Overall, the principle of maximum entropy again provides a good representation of the average behaviour.

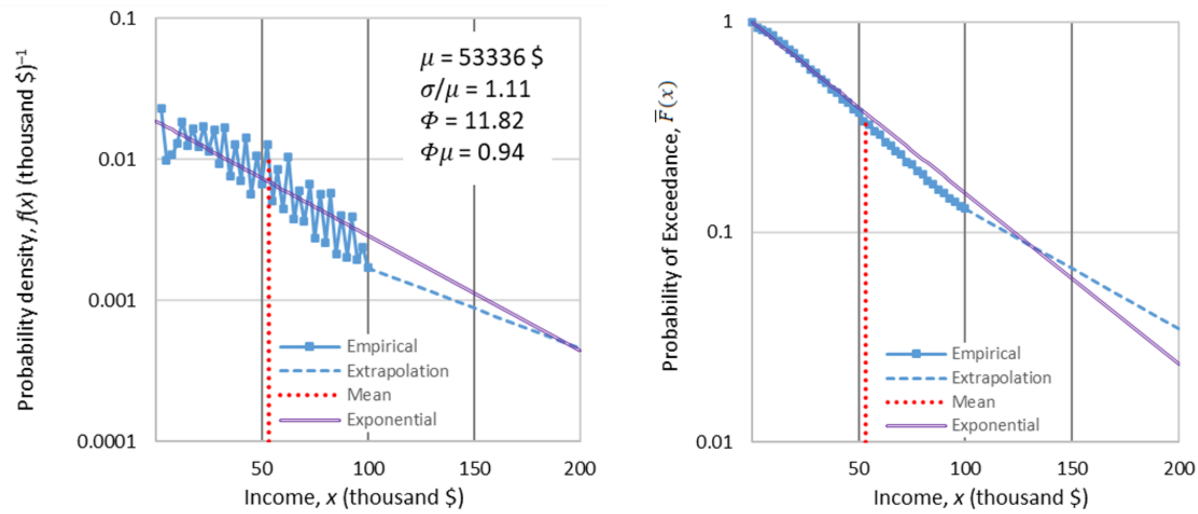

Figure 7.19 Illustration of the entropic framework using income data from the USA for year 2019; (left) probability density; (right) tail function (probability of exceedance).

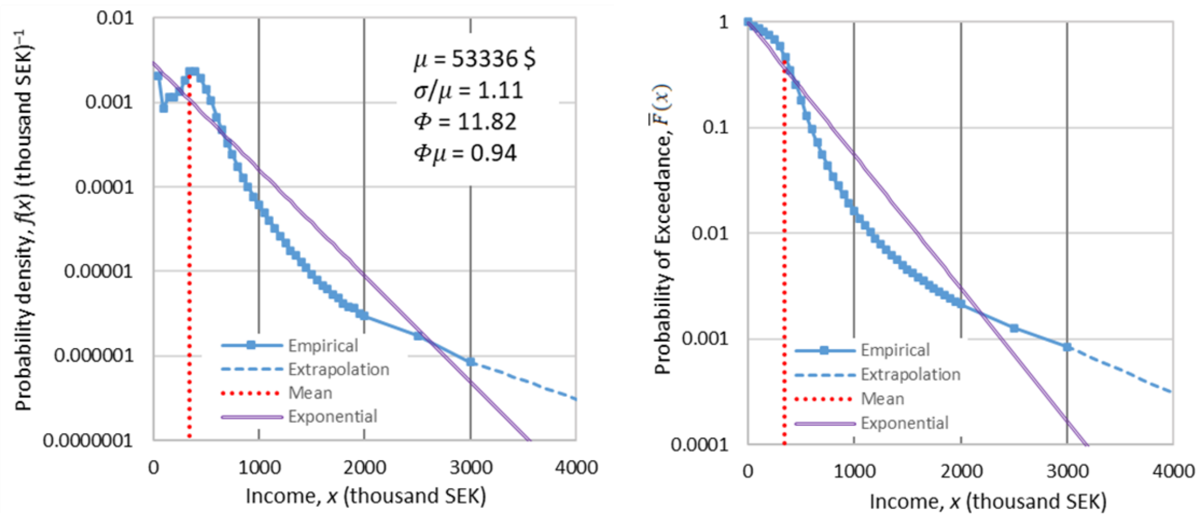

Figure 7.20 Illustration of the entropic framework using income data from the Sweden for year 2019; (left) probability density; (right) tail function (probability of exceedance).

However, the most telling evidence about the type of the distribution and, hence, the appropriate background measure, is obtained by studying the distribution tail. To study the tail, we do not need to examine the entire population, i.e., the entire range of the variable x.

In order to empirically study the tail of income distribution, we will used data for the net worth of richest people of the world (billionaires) and the evolution thereof. We located the database which is referenced in the Forbes list for the years 1996 to 2018.

For the years 2002 (lowest average income) and 2021 (highest average income) exponential and power–law trends, respectively, are also plotted with dashed lines of the same color (where in the left panel the green dashed line for 2002 is indistinguishable from the continuous line).

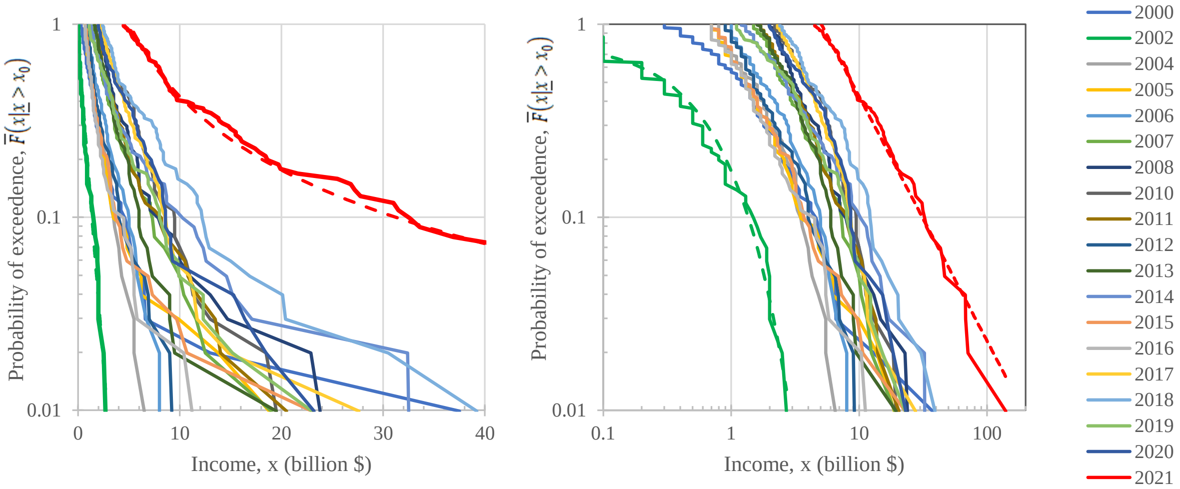

Figure 7.21 Conditional probability of exceedance of the annual income of the richest persons in the world for the indicated years. The income per person was found by subtracting the total net worth of a year from that of the previous year.

Based on real-world data, and in particular, those of the world's richest, in order to give a better idea on the distribution tail, we conclude that the exponential tail is not uncommon, while the Pareto tail appears particularly in anomalous periods. Impressively, the latest period of pandemic resulted in unprecedent profits of the richest, with a clear Pareto tail.

7.6 Discussion

Human civilizations have survived through natural disasters and in hostile environments. We see from different examples that when there was advanced social organization, the society could overpass environmental issues as Minoan did it with a volcano eruption or climatic changes around 1500 BC. We have also seen several studies which failed to predict or model society structures (past or present) based on environmental criteria alone. In addition, it is an undeniable fact that when social organization collapses, societies cannot survive.

In general, we note that environmental determinism is surprised, impressed and fascinated by the natural phenomena and connects them with societies without considering their dynamics. However, we see that creative capacities (technology, trading, storage), type of consumption (sustainable, non-sustainable), development (growth-recession), social dynamics and complexity of civilization have an important role in sustainability.

The famous archeologist Christos Doumas notes[I]:

τα φυσικά φαινόμενα δεν τερματίζουν πολιτισμούς εφόσον επιβιώνουν οι άνθρωποι (natural phenomena do not demise civilizations as long as people survive)

Therefore, it is important to understand how the evolutionary trajectory of early civilizations was disrupted.

Clearly the expected recession phases which are described by HK dynamics give in collapse theories a repeatability element in which ancient civilizations were vulnerable. However, even ancient civilizations as Maya and Minoans, were able to overpass many of these phases, probably with good social organization and the management of a wise elite.

The case of the Minoans illustrates that the key to a civilization's ability to thrive is the focus in large-scale infrastructure and technology that improves the living conditions. This presupposes but also enhances the society's organization. Following this simple rule, societies take the advantages of economies of scale to prey effectively water-food-energy nexus necessary for survival needs and prosperity. In order to do this, organization, division of labor (necessarily leading to social stratification) and growth (necessarily leading to complexity) is necessary. In light of this, we therefore, deem social dynamics as important, if not most important, than environmental determinism considerations with both of them nested in a complex relationship.

Regarding the present days, an overlook of the case studies of USA and Sweden, saws that the distribution of wealth follows, in general, an exponential curve.

Inspection in both panels of **Figure 7.21** shows that both exponential and power-law tails appear, with the former being more common than the latter. Characteristically, in the year with the lowest earnings, 2002, the tail is clearly exponential, while in the year with the highest earnings, 2021, the tail is clearly of power-law type. It is relevant to note that year 2021, which was the most anomalous as the COVID-19 pandemic negatively affected the economy globally, also brought the historically highest profits to the richest. This is also seen in **Figure 7.22**, where the average of the 100 highest incomes in 2021 is unprecedented and several times higher than the average of the previous years.

In recent years of it is reasonable to assume that the economic elites pursue a greater share of the community wealth (**Figure 7.21**). In this respect, their function can be twofold:

1. On the one hand, they advance both the technological limit and the average wealth.
2. On the other hand, they tend to modify the distribution of income from exponential to Pareto, thus increasing the frequency of the poor and diminishing the middle class for their own advantage.

The means to increase elites' profits certainly include political power and, more recently, an attitude to control the world. Their endeavour becomes more efficient and acceptable by the society by several means they use, such as by overstating existing or

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[I] Documentary film: Η ζωή αλλοιώς (Life in a different way). Santorini. Available online https://www.ertflix.gr/series/ser.119961-i-zoi-allios (accessed 19 February 2022).

non-existing threats, and then by presenting themselves as philanthropists (e.g., by funding nongovernmental organizations dealing with these threats) and world saviours.

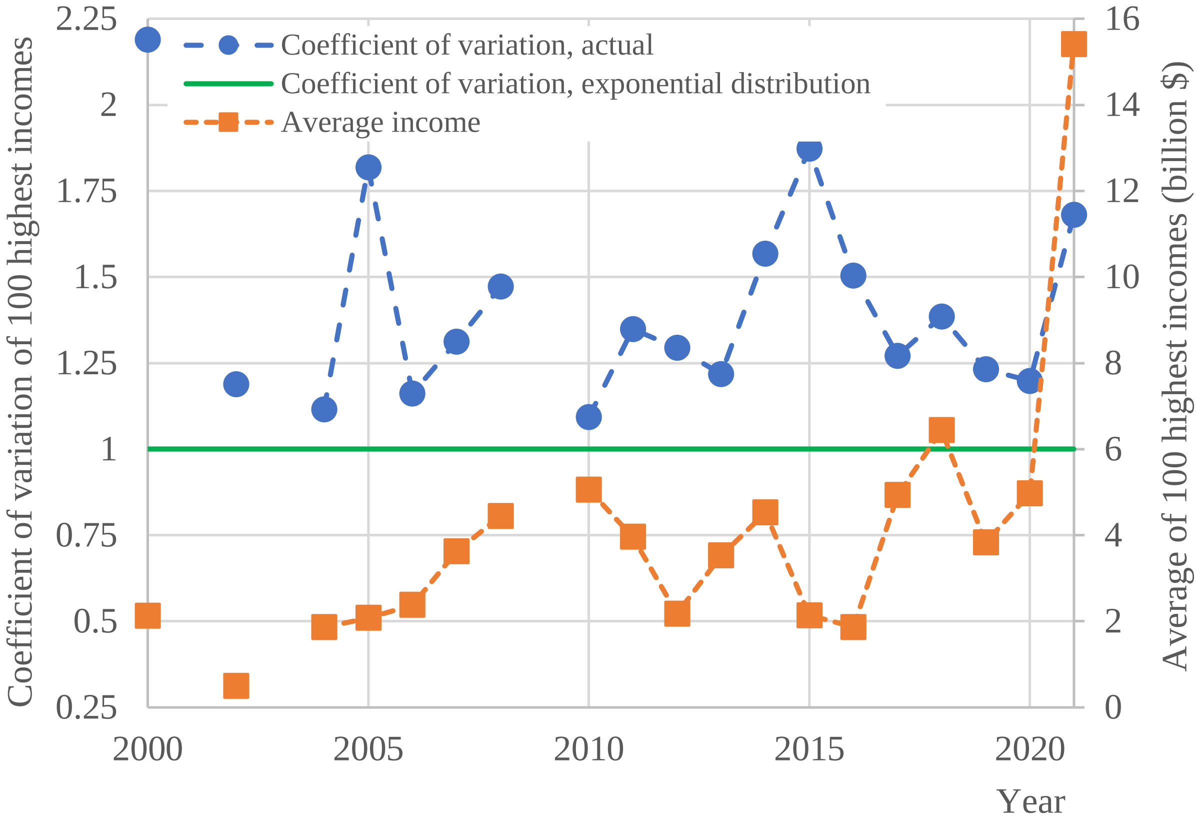


Figure 7.22 Average and coefficient of variation of the 100 highest incomes in the world per year. The coefficient of variation is calculated for the difference $\underline{x} - x_0$, where x_0 is the 100th highest income value, so that it be representative for the entire population (see explanation in text).

Apparently, if they succeed in controlling the world, this will decrease entropy and hence delimit freedom. In turn, this will lead to decadence, whose signs are already visible in the Western World.

Chapter 8. Cultural elements

Digression 8.A: Quantifying beauty

There is an eternal discussion of mathematical canons of proportion as models of beauty for the human body: ancient Egyptian civilization; ancient Greece (Lysippos , Polykleitos); ancient Rome (Vitruvius); Renaissance (Leonardo Da Vinci, Albrecht Dürer); modern times (Adolf Zeising, David Hay, John Pennethorne, Mathieu Lauweriks, Jay Hambidge, Matila Ghyka and Le Corbusier) (Figure 8.1) (Robins, 1994; Thapa, 2018).

The opinions of later philosophers on this pursuit of mathematicians for the analysis of aesthetics were more varied. Leibniz, for example, believed that there is a norm behind every aesthetic feeling which we simply do not know how to measure (Beardsley 1969). On the contrary, Descartes supports that instead of regarding the aesthetic quality as an inherent property of a physical object, the distinction of mind and nature has allowed humans to incorporate their own subjective emotional, social and cognitive background in determining their aesthetic preferences. Overall, it is evident that many artists knew and applied math and geometry in their artwork (Figure 8.2) and many philosophers tried to connect math and arts. (Bulent, 2014; Akhtaruzzaman, 2012; Omotehinwa, 2013).

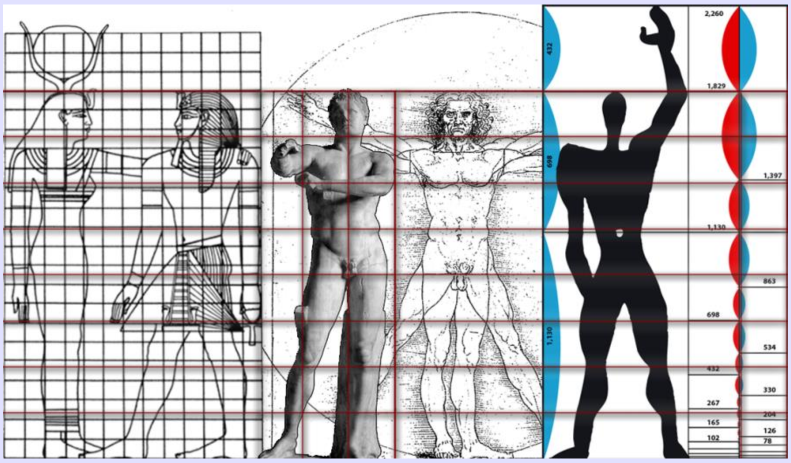


Figure 8.1 Comparison of canons of proportion: Egyptian Canon; Ancient Greece Canon; Leonardo da Vinci's Canon; Le Corbusier's Canon (Modulor).

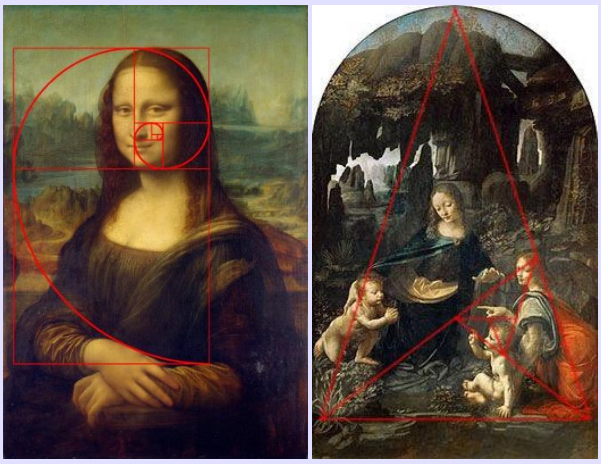


Figure 8.2 Golden ratio in Da Vinci's artworks.

Although art is a mix of determinism (e.g., certain rules have to be followed) and stochasticity (e.g., creativity and inspiration), we treat artistic works as a natural process and test whether art paintings share a similar structure of dependence as do various natural processes.

8.1 Stochastic evaluation of art portraits

In art paintings portraying human faces, the face is a focus point which condenses the feeling of the painting. In order to evaluate how nature depicts in 2D first we first examine the climacogram of photographs of human faces[I], shown in **Figure 8.3**. Then we analyse portraits from various artistic genres dating from medieval to recent times[II], i.e., of Byzantine art, Renaissance and Baroque and 20th century modern art **Figure 8.5**, **Figure 8.7**, **Figure 8.9**, **Figure 8.11**, **Figure 8.13**. We also analyse the self-portraits of Rembrandt Harmenszoon van Rijn[III] and Pablo Picasso[IV] made in different periods of their lives. Each 2D photo and painting is digitized based on a grayscale colour intensity and the climacogram is estimated based on the geometric scale rather than the average one (**Figure 8.4**, **Figure 8.6**, **Figure 8.8**, **Figure 8.10**, **Figure 8.10**, **Figure 8.12**, **Figure 8.14**).

Figure 8.3 Images of portrait photography. Photo's courtesy of Kostas Mountrichas.

[I] Portrait photographers. Available online: https://fixthephoto.com/best-portrait-photographers.html (accessed on 2 January 2021).

Top 10 Photographers. Available online: https://www.bwvision.com/top-10-photographers/ (accessed on 2 January 2021).

The 10 Most Famous Portrait Photographers in the World. Available online: https://blazepress.com/2014/12/10-famous-portrait-photographers-world/ (accessed on 2 January 2021).

[II] Data retrieved on 2021-01-2 by

Painting: https://en.wikipedia.org/wiki/Painting

Portrait painting. Available online: https://en.wikipedia.org/wiki/Portrait_painting

Speranzas Spyridon (Byzantine artist). Available online: https://paletaart.wordpress.com/

Cretan School. Available online: https://en.wikipedia.org/wiki/Cretan_School

Italian Renaissance painting. Available online: https://en.wikipedia.org/wiki/Italian_Renaissance_painting

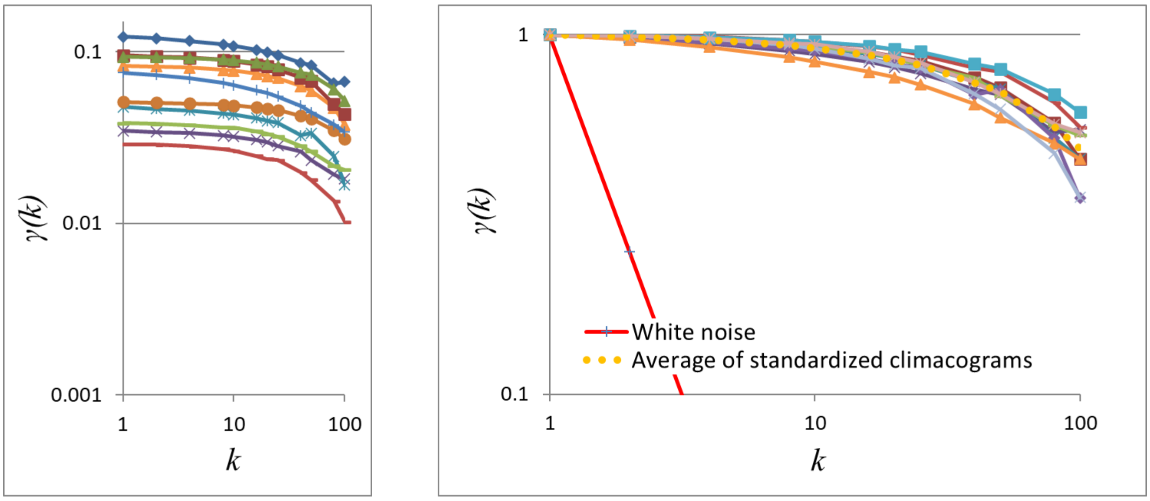
Albrecht Dürer. Available online: https://en.wikipedia.org/wiki/Albrecht_D%C3%BCrer

Titian. Available online: https://en.wikipedia.org/wiki/Titian (accessed on 2 January 2021). Impressionism. Available online: https://en.wikipedia.org/wiki/Impressionism

20th-century art. Available online: https://en.wikipedia.org/wiki/20th-century_art

[III] Rembrandt. Available online: https://en.wikipedia.org/wiki/Rembrandt (accessed on 2 January 2021)

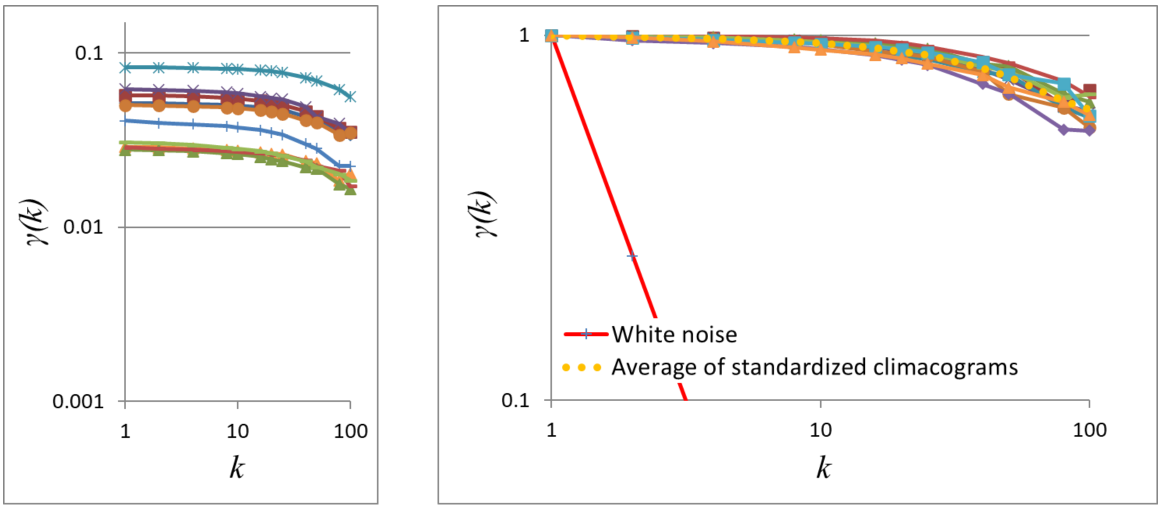
[IV] Pablo Picasso self-portraits. Available online: https://mymodernmet.com/pablo-picasso-self-portraits/ (accessed on 2 January 2021).



(a) (b)

Figure 8.4 (a) Climacograms and; (b) standardized climacograms of the images in **Figure 8.3** (Hurst parameters ranging from 0.76 for the lower left image to 0.91 for the upper right, averaging to 0.87).

Figure 8.5 (a) Images of portrait paintings from the Renaissance and Baroque periods.



(a) (b)

Figure 8.6 (a) Climacograms and; (b) standardized climacograms of the paintings in **Figure 8.5** (Hurst parameters ranging from 0.90 for the lower left image to 0.94 for the lower right, averaging to 0.92).

Figure 8.7 Self-portraits of Rembrandt in chronological order.

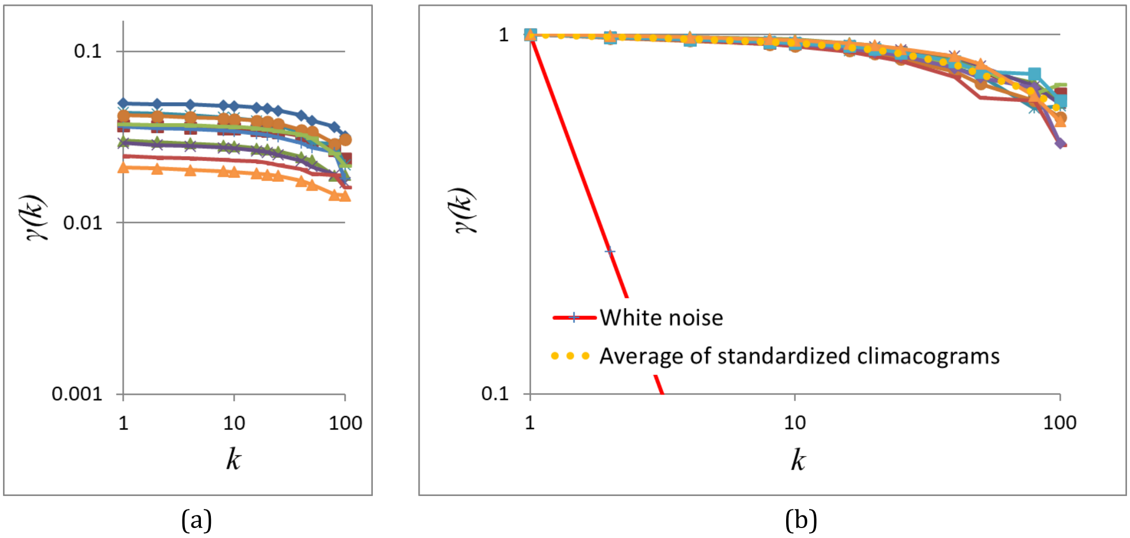


Figure 8.8 (a) Climacograms and; (b) standardized climacograms of the paintings in **Figure 8.7** (Hurst parameters ranging from 0.87 for the lower right image to 0.95 for the upper left, averaging to 0.92).

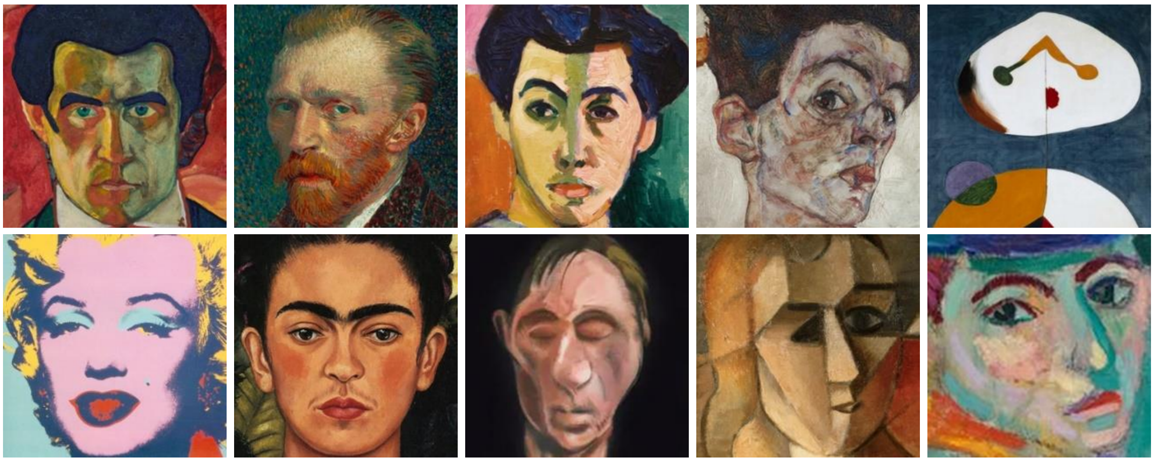
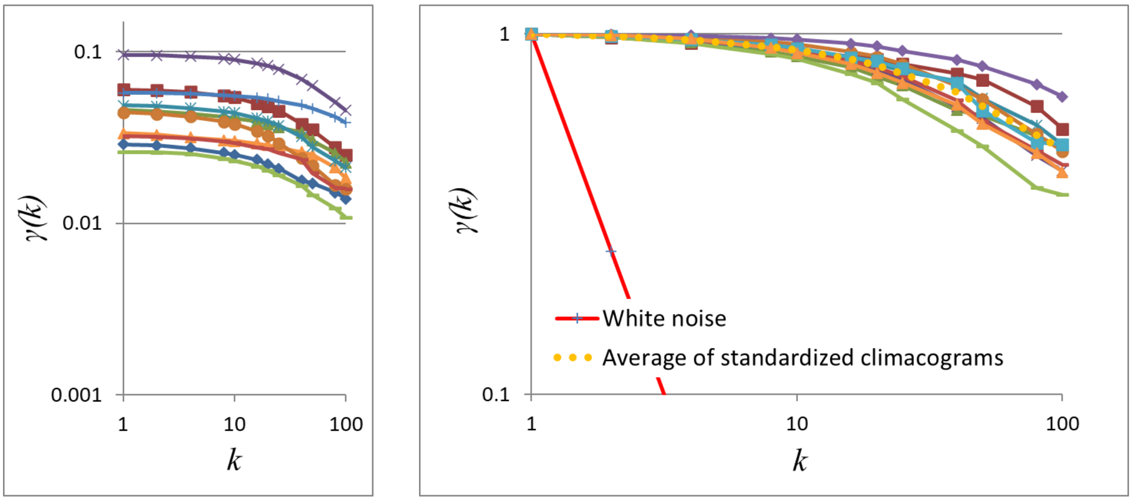


Figure 8.9 Images of portrait paintings of 20th century art.



(a) (b)

Figure 8.10 (a) Climacograms and; (b) standardized climacograms of the paintings in **Figure 8.9** (Hurst parameters ranging from 0.88 for the lower left image to 0.93 for the upper left, averaging to 0.90).

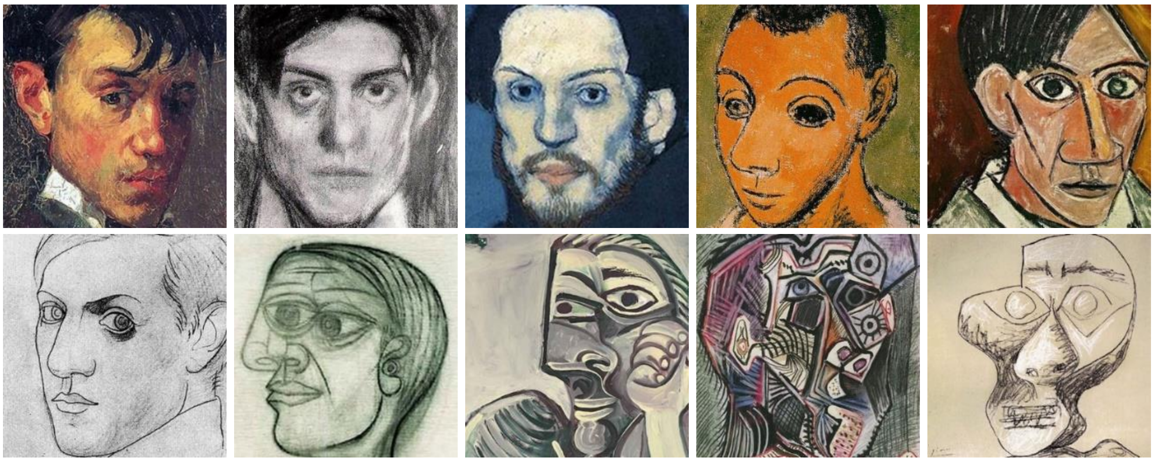
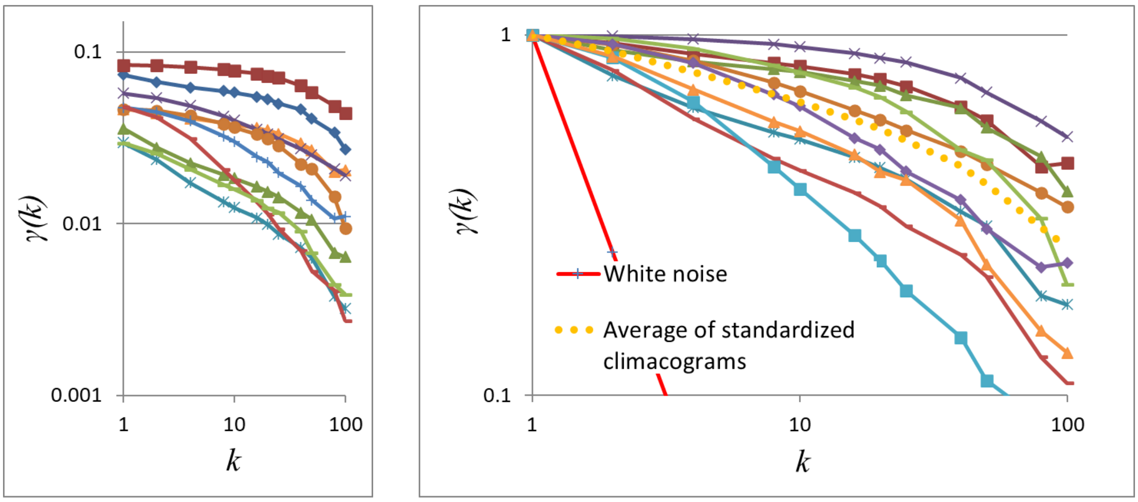


Figure 8.11 Self-portraits of Pablo Picasso in chronological order.



(a) (b)

Figure 8.12 (a) Climacograms and; (b) standardized climacograms of the paintings in **Figure 8.11** (Hurst parameters ranging from 0.73 lower second from the left image to 0.91 lower in the middle, averaging to 0.83).

Figure 8.13 Images of portrait paintings of Byzantine art, fresco.

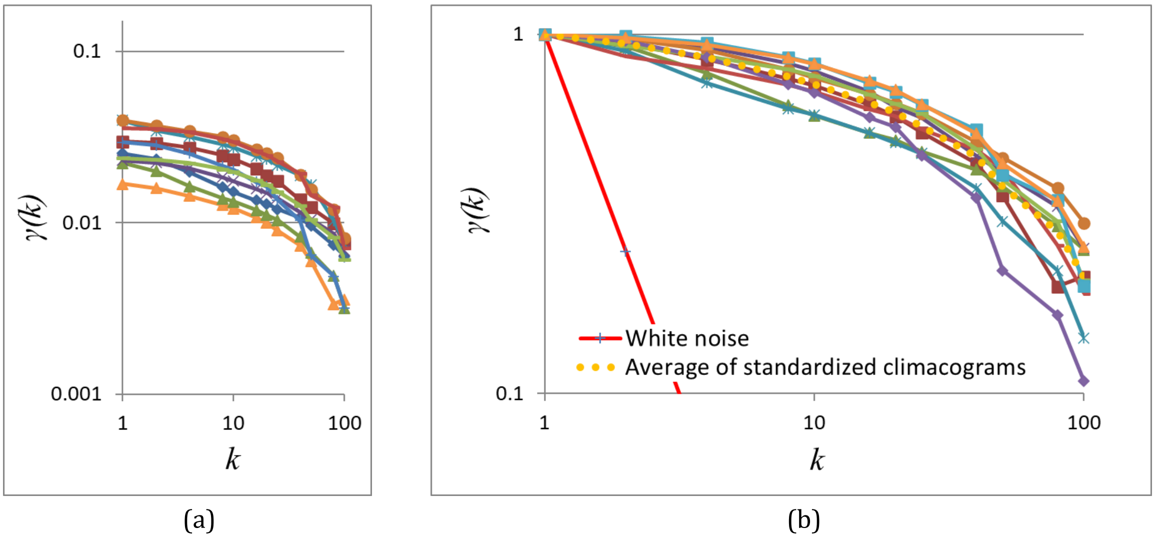
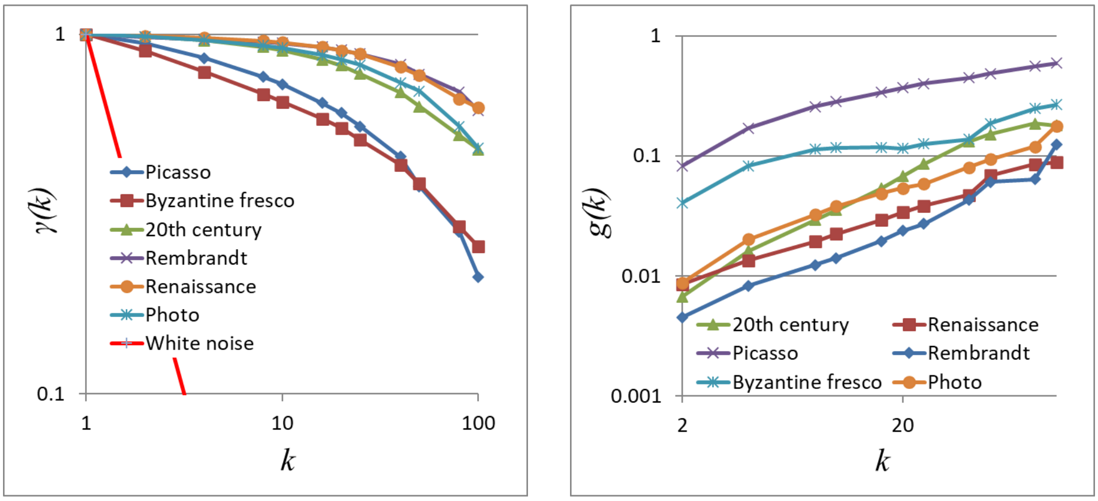


Figure 8.14 (a) Climacograms and; (b) standardized climacograms of the paintings in **Figure 8.13** (Hurst parameters ranging from 0.72 for the lower left image to 0.86 for the upper right, averaging to 0.79).

The Hurst parameter is estimated for each image set and shown in **Table 8.1**.

For each painting, we calculated the coefficient of variation of the original image at scale 1, which, by definition, is the standard deviation of brightness divided by the average. We then calculated the average of all the images of each set. A high value of the coefficient of variation shows that, in each set there is a broad range of brightness in paintings for the same average brightness. The average coefficient of variation of each set is presented in Table 1.

Results show an interesting insight. Renaissance/Baroque and Rembrandt's self-portraits which follow the most naturalistic aesthetic approach, have a strong dependence structure similar to photos and of various hydrometeorological processes (estimated H≈0.9). A strong dependence structure is also observed in the portraits of 20th century (estimated H≈0.9) and Picasso's self-portraits (estimated H≈0.85), yet with a bigger range of fluctuations, indicative of the artistically freer and nonrepresentational approach of modern art. The most interesting insight however is that the portraits belonging to the Byzantine art period show a weaker dependence structure (estimated H≈0.8), which is closer to white noise. This attribute seems consistent to the theology of Christian's Orthodox dogma dictating a specific type of representation of saints and religious figures.



(a) (b)

Figure 8.15 Average of standardized climacograms of different sets (b) Coefficient of variation of the climacograms of the different image sets.

Table 8.1 Average Hurst parameter H and coefficient of variation of the climacograms g(k) of the exanimated sets.

	Portrait photography	**Renaissance and Baroque periods**	**Self-portraits of Rembrandt**	**Portrait paintings of 20th century art**	**Self-portraits of Pablo Picasso**	**Byzantine art, fresco**
Hurst parameter	0.87	0.92	0.92	0.90	0.83	0.79
Coefficient of variation	0.726	0.609	0.647	0.524	0.445	0.379

In order to evaluate the different sets, averages of climacograms thereof are plotted (**Figure 8.15**a). To quantify the range of fluctuations of the climacograms, for each scale k we calculated the coefficient of variation of all standardized climacograms, $g(k)$. **Figure 8.15**b shows the graphs of $g(k)$ vs. k for all examined cases, indicating the range of fluctuations from the average climacogram of each set.

Since prehistoric art creations, art was related to, and inspired by natural forms. Aristotle said[I] that "art takes nature as its model", and "...not only imitates nature, but also completes its deficiencies". Furthermore, Plato connected arts with ideas, the soul and the idealistic expression (Beardsley, 1976; Sargentis, 2005).

[I] Aristoteles, Poetics, Αριστοτέλης, Ποιητική 1447a, 19-23. Translated and with a Commentary by George Whalley, Edt. John Baxter and Patrick Atherton, McGill-Queen's University Press, London 1997.

Around 20th century, artists embraced an alternative way of expression by focusing more on modern society habits and deviating from naturalistic themes and related representation. Even more, artists then found Nature's complexity obsolete. Paul Klee noted that "Nature is garrulous to the point of confusion, let the artist be truly taciturn." (Klee, 1968). One may argue however that the uncertainty within ourselves that drives all forms of art, is the same inherent uncertainty of nature that was used subconsciously as inspiration. If this is true, then we should be able to find stochastic similarities between art projects and natural processes imprinted in the estimated variability vs. scale.

The results of this study provide grounds to this hypothesis as patterns can be observed in the dependence structure in photographs and portraits of Renaissance/Baroque which represents the most naturalistic approach, having similar moderate structure (photo, average $H≈0.87$; Renaissance/Baroque, average $H≈0.92$). A similar Hurst parameter was estimated by Hurst in his pioneering work on the stage of the river Nile (Hurst, 1956; Cohn, 2005; Koutsoyiannis et al., 2008) and, additionally, in global-scale analyses of the long annual records of key hydrometeorological processes such as temperature and wind speed as well as of small-scale processes recorded in the laboratory such as grid-turbulence and turbulent jets. An overall Hurst parameter (H) equal to 0.9 is observed in all hydrometeorological processes (after adjusting for bias; a task that is often neglected in stochastic analysis (Dimitriadis and Koutsoyiannis, 2019; Koutsoyiannis, 2016, Ioannidis et al., 2019).

Patterns can also be observed in the art portraits of 20th century yet with a bigger range of fluctuation as modern artists wanted to express their 'own' view of nature away from what they perceived as "nature's monotony" (Apollinaire, 1913; Sargentis, 1998). Interestingly, though, although the aesthetic means employed are indeed markedly different from older naturalistic paintings, the stochastic variability of modern art portraits is still on average close to the one found both in the most naturalistic paintings and in natural processes itself, revealing an overall Hurst parameter (H) equal to 0.9.

Another related validation is the evaluation of self-portraits during the lifetime of Rembrandt's and Picasso. Rembrandt's works exhibit stochastic similarities and a strong dependence structure (average $H=0.92$) whereas Picasso's self-portraits show a wider range of fluctuation (Figure 17b).

Sant Gregory of Nyssa (*Άγιος Γρηγόριος Νύσσης*) (died c. 395 AD) describes how the creation of Byzantine art is connected with the spirituality of the artist "man is the painter of his life, creator of paintings is artists' motive"«*της ιδίας έκαστος ζωής εστί ζωγράφος, τεχνίτης δε της [ζωγραφικής] δημιουργίας ταύτης εστίν η προαίρεσις*» (Sant Gregory of Nyssa, 1980). The portraits of Byzantine art, a religious art serving the purposes of the Christian's Orthodox dogma. An interesting note is that Byzantine art portraits correspond to a weaker dependence structure ($0.7 < H < 0.85$) than that of the other genres, with wide range of fluctuation at small scales and small range of fluctuation at large scales, closer to white noise. This might be explained considering that these paintings depict religious figures being in divine states of mine[I], often praying (Gerontos Paisiou Agioritou, 2012). The meaning of pray in Orthodox dogma is described in one of the most important theological books of Orthodox, Philokalia (*Φιλοκαλία*)[II], which contains the writings of the Eastern Fathers from the fourth to the fifteenth centuries. In this work, Saint Nilus of Sinai (*Άγιος Νείλος ο Σιναΐτης*) (died c. 430 AD), teaches that the mind must be "deaf and mute during prayer" *«Αγωνίσου να κρατάς το νού σου την ώρα της προσευχής κουφό και άλαλο.»* and "when you pray, do not accept any form or shape…" *«Μην επιδιώκεις να δεχτείς την ώρα της προσευχής με κανένα τρόπο μορφή ή σχήμα».* The identified stochastic structure corresponds to this theology as this ideal of religious figures experiencing a divine humbling experience is better delivered with weaker dependence structures.

Stochastic Analysis of Da Vinci's Virgin of the Rocks)

One more example of the stochastic methodology is the evaluation of Da Vinci's painting Virgin of the Rocks (Italian: Vergine delle rocce; sometimes the Madonna of the Rocks) by the relations of climacogram's curves.

Virgin of the Rocks is the common name of two paintings by Leonardo da Vinci, on the same subject. The compositions are very similar but present several significant details. The version generally regarded as the prime version, the earlier of the two, is in the Louvre in Paris and has not been not restored (**Figure 8.16**a). The other, is in the National Gallery London, and was restored between 2008-2010 (**Figure 8.16**b).

Both paintings are ascribed to Leonardo da Vinci. Originally, they were thought to have been partially painted by Leonardo's assistants. A closer look at the painting during the recent restoration has led the conservators of the National Gallery to conclude that the greater part of the work is by the hand of Leonardo, but the debate continues[III]. Parts of the painting, the flowers, in particular, indicate the collaboration and have led to speculation that the work is entirely by other hands, possibly Leonardo's assistant Giovanni Ambrogio de Predis and perhaps Evangelista[IV].

[I] Holy Bible, New Testament, Mathew (Κατά Ματθαίον) 22,37; Mark (Κατά Μάρκον) 12,30; Luke (Κατά Λουκά) 10,27,Available online: http://www.apostoliki-diakonia.gr/bible/bible.asp?contents=new_testament/contents.asp&main= (accessed on 4 February 2021).

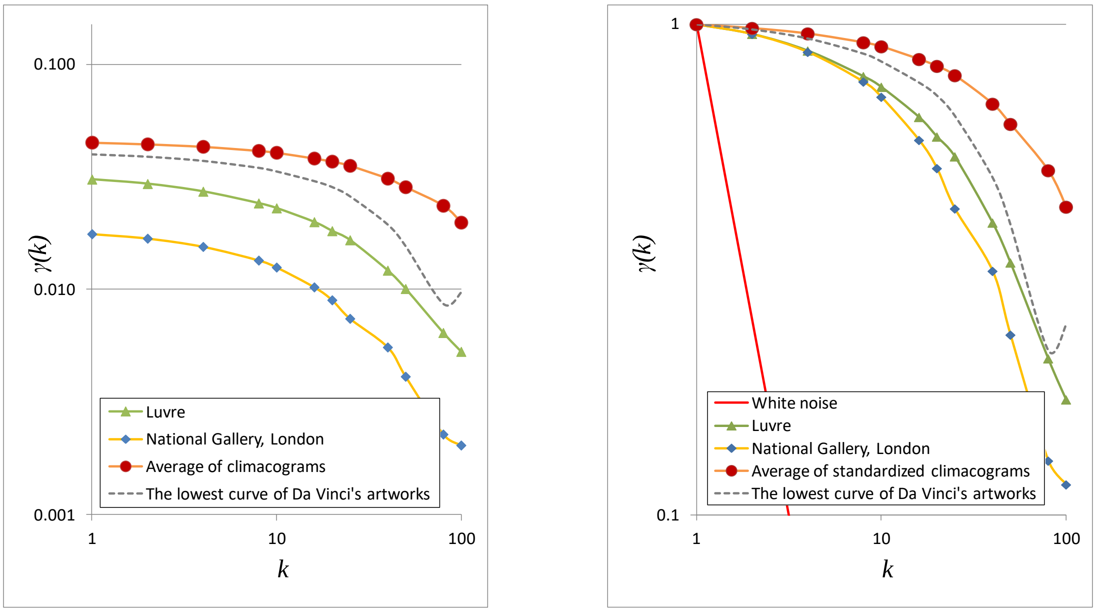
[II] Philocalia (Φιλοκαλία), edt. Ioannou Mavrogordatou (Ιωάννου Μαυρογορδάτου), Venice 1782, Greek translation, available online: https://greekdownloads.wordpress.com/φιλοκαλία/ (accessed on 2 January 2021).

[III] "The Virgin of the Rocks: Da Vinci decoded", Jonathan Jones, The Guardian, 13 July 2010. Available online: https://www.theguardian.com/artanddesign/2010/jul/13/the-virgin-of-the-rocks-leonardo-restoration (accessed on 2 January 2021).

[IV]"The daffodil code: doubts revived over Leonardo's Virgin of the Rocks in London", Dalya Alberge, The Guardian, 9 December 2014. Available online: https://www.theguardian.com/artanddesign/2014/dec/09/leonardo-da-vinci-virgin-rocks-louvre-national-gallery (accessed on 2 January 2021).

(a) (b)

Figure 8.16 Leonardo da Vinci's Virgin of the Rocks: Areas of analysis; (a) Louvre version, 1483–1486; (b) National Gallery, London, before 1508[I].



(a) (b)

Figure 8.17 Standardized climacograms of Leonardo da Vinci's Virgin of the Rocks and averages thereof. Notice that the curve of the Louvre version is closer to the average of standardized climacograms of the National Gallery of London version.

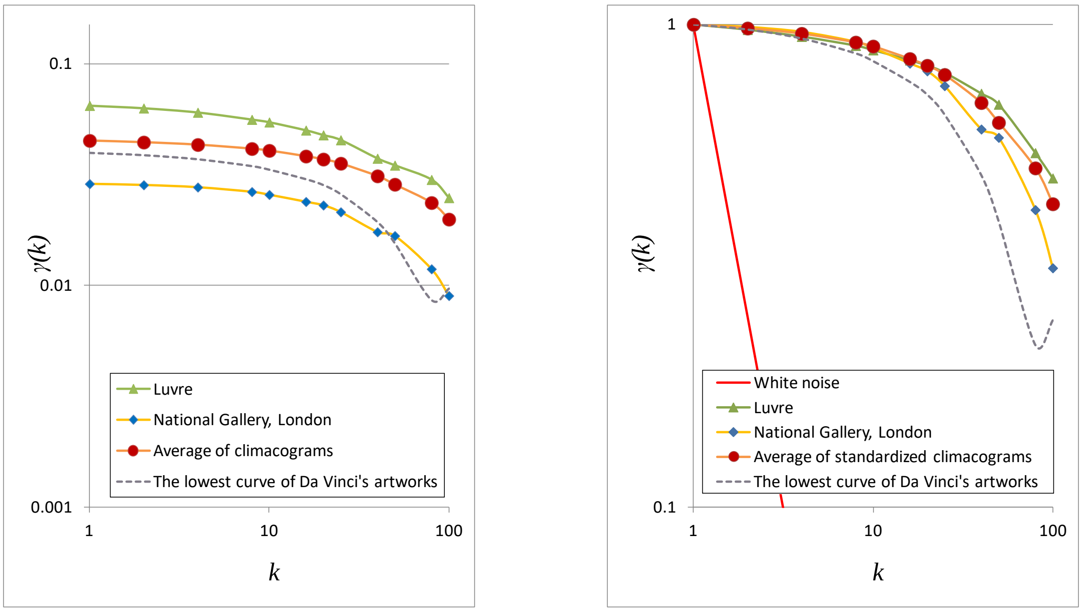
The review of Da Vinci's Virgin of the Rocks paintings with the utilization of stochastic analysis shows that both paintings differentiate from Da Vinci's stochastic forms.

I Leonardo da Vinci's Virgin of the Rocks. Available online: https://en.wikipedia.org/wiki/Virgin_of_the_Rocks (accessed 5 March 2022)

However, the Louvre version is closer to what Sargentis et al. have define as Da Vinci's stochastic Golden Climacogram (Sargentis et al., 2020) (**Figure 8.17**). A closer view in the frames of Madonna (**Figure 8.18**) and Angel (**Figure 8.20**) shows that, in stochastic terms, both of them are very close to Da Vinci's Golden Climacogram but again the Louvre version is closer to Da Vinci's stochastic Golden Climacogram (**Figure 8.17**, **Figure 8.19**). Thus, we could make the conjecture that the wider drawing of the painting might have been done by someone else and these details by Da Vinci.

(a) (b) (c)

Figure 8.18 Leonardo da Vinci's Virgin of the Rocks, Madonna. Areas of analysis; (a) Louvre version, 1483–1486; (b) National Gallery of London, before 1508; (c) Preparation of analysing (one image on top of the other).

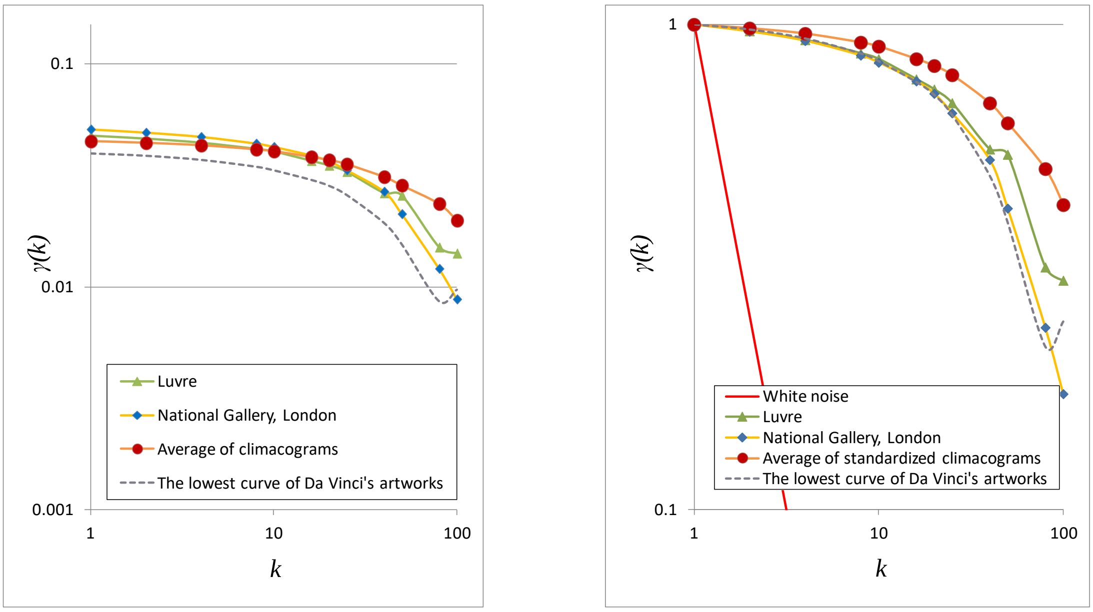


(a) (b)

Figure 8.19 (**a**) Climacograms; (**b**) standardized climacograms of Leonardo da Vinci's Virgin of the Rocks (Madonna), and averages thereof. Notice that curve of Louvre version is closer to the average of standardized climacograms of Da Vinci's artworks than the curve of National Gallery of London.

(a) (b) (c)

Figure 8.20 Leonardo da Vinci's Virgin of the Rocks, Angel. Areas of analysis; (a) Louvre version, 1483–1486; (b) National Gallery of London, before 1508; (c) Preparation of analysing (one image above the other).



(a) (b)

Figure 8.21 (**a**) Climacograms; (**b**) standardized climacograms of Leonardo da Vinci's Virgin of the Rocks (Angel), and averages thereof. Notice that curve of Louvre version is closer to the average of standardized climacograms of Da Vinci's artworks than the curve of National Gallery of London.

8.2 Stochastic evaluation of the transformation of the landscape

Works of technological and civil infrastructure support the needs of human society but generate important transformations in multiple scales to urban and natural landscapes. These transformations become even more perceivable when they are made in landscapes, either urban or natural, of historical and cultural significance. Landscapes (castles, traditional settlements, sacred places, etc.) bear the spirit of the place (Latin: *genius loci*) (Pope, 1731) and their transformation with modern infrastructures can impact both the sensual experience of the visitor, as well as his mental understanding of the place.

In urban environments, transformations are generated by installation of small-scale technological infrastructure (air conditioning units, solar water heaters, plastic water tanks), while in natural landscapes transformations are mostly caused by civil infrastructure such as renewable energy projects (Ioannidis and Koutsoyiannis, 2020), roads and electricity transmission networks.

Various methods have been developed for the management and mitigation of these landscape impacts from civil works. These methods are used to quantify and evaluate visibility and generated visual impacts and overall, to assess the significance of aesthetic transformations to landscapes. Such methods range from photo-montage and digital representation to Geographic Information Systems (GIS) viewshed analyses (Sargentis et al., 2005a).

The preservation of landscape as a part of natural and cultural heritage (Krebs, 2014) is a requested to the sustainability of human developments in a changing world (Ellison, 2014). EU define the landscape as: "part of the land, as perceived by local people or visitors, which evolves through time as a result of being acted upon by natural forces and human beings"[I]. Changes to landscapes from infrastructure projects can be considered both positive (Ioannidis et al., 2022, Ioannidis 2022), by the transformation of landscapes with respect to cultural and natural landscape elements; (b) and negative; by the transformation of landscapes with repeated use of industrial elements without landscape planning. Infrastructure's installation, recently occurs political problems related to transformation of landscape[II] (Manta et al., 2020).

The aesthetical value of the landscape is in its essence a political problem[III] (Wascher, 2000; Wascher 2005) which characterizes the socio-economic development and determines quality of life (Blaschke, 2006). The aesthetic evaluation is widely accepted as a subjective process in philosophy (Guyer, 1997) thus many researchers classify their approach as subjective (Shafer et al., 1969; Cook and Cable, 1995; Forman and Godron 1986; Stefanou, 1994; Stefanou, 1980) on the other hand, other researchers have tried to find some objective rules, indicators and proxies (Franklin and Forman, 1987; Adam, 1982) to evaluate the aesthetical value of the landscape. Using modern technological tools such as Geographic Information System (GIS) analysis methods which facilitate Decision Makers to identify for example the most valuable or the most critical areas, according to the landscape value, and help in the design of suitable policies of short-medium or long-

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[I] The European Landscape Convention of the Council of Europe, Available online https://www.coe.int/en/web/landscape (Acceded 9 October 2020)

Greek Law 3827/2010: Ratification of the European Landscape Convention, Νόμος 3827/2010 - ΦΕΚ 30/Α/25-2-2010, Κύρωση της Ευρωπαϊκής Σύμβασης του Τοπίου https://www.e-nomothesia.gr/kat-periballon/n-3827-2010.html (Acceded 22 December 2020)

[II] NO-TAV movement against High Speed Train, Val di Susa Italy. Available online: https://ejatlas.org/conflict/no-tav-movement-against-high-speed-train-val-di-susa-italy (Acceded 22 December 2020)

[III] German Federal Nature Conservation Act, 2010. Bundesnaturschutzgesetz (BNatSchG). Gesetz über Naturschutz und Landschaftspflege. First version 14.05.1967, Actualized 01.03.2010, Bundesgesetzblatt 1/2010, p. 2542.

term[I]. Through image segmentation and other more sophisticated methods, researchers in 21th century tried to minimize the subjective elements of this issue, quantifying existing or new indicators and proxies (Vukomanovic, 2014; Morris, 2009; Cureton, 2017; Evert, 2010; Cloquell-Ballester, 2012; Ioannidis, 2022)

Schönthaler et al. (2003) note that there must be a necessary reduction of complexity of environmental monitoring and a specific selection of a few and relevant variables in order to answer related questions. Therefore, we will define the clustering of infrastructures as a simple proxy of Focus Points (FPs) in the impact of the aesthetic value of the landscape.

FPs are elements that attract our vision, which affect the perspective we have on a landscape. A FP is defined as the part of the landscape which it is distinguished in terms of texture, color or size and attract our vision (Appleton, 1975a). A Magnetic Focus Point (MFP) is defined as the part of the landscape which has the characteristics of a FP and is also a pleasant aesthetic element (Gobster, 1999).

We often see MFPs in our view. An MFP can be, for example, a statue, a beautiful house, or a lake (Appleton, 1975; Ioannidis and Koutsoyiannis, 2020; Sargentis, 2005). On the other hand, a common type of visually unpleasing or even repellent FPs are industrial installations or other civil infrastructures in landscapes.

It is widely accepted that the visibility of a FP impacts its environment. This so-called visual impact, is in part subjective (Frank, 2013), and can extend from few centimeters if the examined FP is a jewelry to several kilometers if the examined FP is a work of civil infrastructure (**Figure 8.22**). In terms of civil infrastructures, this visual impact of landscape is approached with methods of visibility analysis, e.g. with the mapping of Zones of Theoretical Visibility (ZTVs) (Wood, 2000; Ross, 2009; de Vries et al., 2012; de Vries et al., 2013).

[I] Environmental Impact Assessment - EIA (EU Directive 85/337/EEC). Available online: https://ec.europa.eu/environment/eia/eia-legalcontext.htm (Acceded 22 December 2020)

Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context (SEA Protocol, Kyiv 2003) (EU Directive 2001/42/EC). Available online: https://ec.europa.eu/environment/eia/sea-legalcontext.htm (Acceded 22 December 2020)

Greek Law 1225/B/5-9-2006: Environmental impact assessment, Εκτίμηση των περιβαλλοντικών επιπτώσεων, ΦΕΚ 1225/Β/5-9-2006, Available online: http://www.et.gr/idocs-nph/search/pdfViewerForm.html?args=5C7QrtC22wFGQ40gSLPFOXdtvSoClrL87iJx0JCjFxoliYHTRwL0-OJInJ48_97uHrMts-zFzeyCiBSQOpYnT00MHhcXFRTstozpnVPh-wDJB4JwgNEuTBoWXYHbbtnvArd9-3ui3jc. (Acceded 22 December 2020)

(a) (b) (c)

Figure 8.22 Focus Points (a) Signet ring; Egypt; 664–525 BC; gold; diameter: 3 × 3.4 cm; British Museum (London) with a few centimeters ZTV[I]; (b) Statue by Henry Moore, Oval with Points, height 3.32m, 1970; with a few hundred meters ZTV[II]; (c) Plastiras Lake landscape created by an artificial lake of 24 km^2[III].

<u>Comparing images</u>

A FP can be perceived in different ways. One observer can view the FP without any barrier or filter in one part of the scenery, or with barriers or filters. If an observer beholds a FP without any barrier or filter then the FP is revealed intensively (Hatzistathis and Ispikoudi 1995).

When a FP appears in the scenery, we have to examine how this FP can be discernible from different locations. This depends on the distance, the barriers, and the filters located between the FP and the observer.

Utilizing 2D-C a novel qualitative-perceptual evaluation methodology was developed. Images from landscapes of urban or natural character that are associated with cultural heritage are analysed to review their transformation by infrastructure of various scales (**Figure 8.23**). Using the 2D-C tool the degree of variability was calculated for the images of such landscapes as well as the change in variability vs. scale, among images (**Figure 8.24**).

The 2D-C analysis of civil infrastructure generates interesting insights and be used to evaluate existing or potential transformations, with 3D modelling and photo-montage. Through the generation and analysis of visual representations of different proposals for interventions in the urban or natural landscape, 2D-C can become a useful tool for minimizing visual impacts and alterations and preserving cultural heritage in both urban and natural landscapes.

[I] Jewellery. Available online: https://en.wikipedia.org/wiki/Jewellery (accessed on 2 October 2020).

Oval with Points: Available online: https://en.wikipedia.org/wiki/Oval_with_Points (accessed on 2 October 2020).

[II] Oval with Points: Available online: https://en.wikipedia.org/wiki/Oval_with_Points (accessed on 2 October 2020).

[III] Plastiras lake. Available online: https://el.wikipedia.org/wiki/Λίμνη_Πλαστήρα (accessed on 2 October 2020).

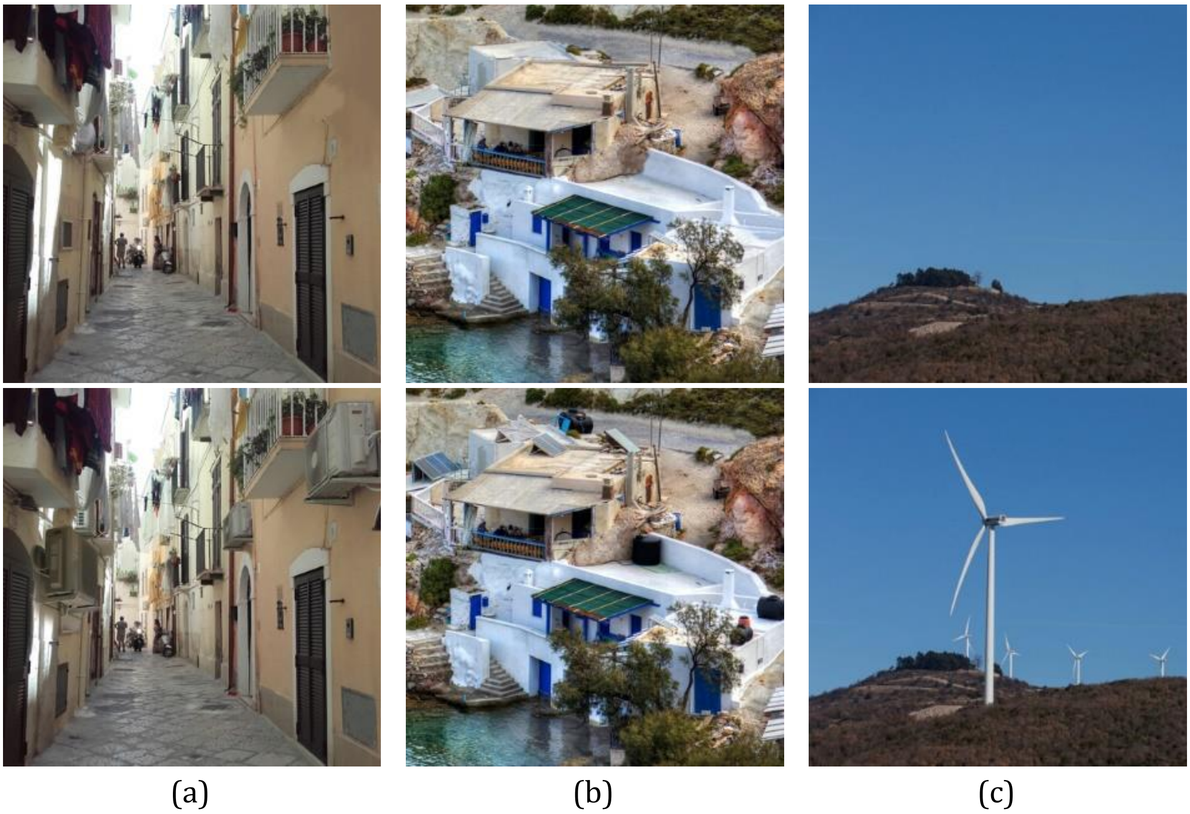


Figure 8.23 (a) Alley in the medieval settlement in Bari (Italy) - urban landscape transformed with A/C; (b) Fyriplaka, traditional settlement in Cyclades (Greece) - urban landscape transformed by solar heaters and water tanks; (c) Slope in Greek island with high attraction of tourists – positively perceived natural landscape transformed by wind turbines.

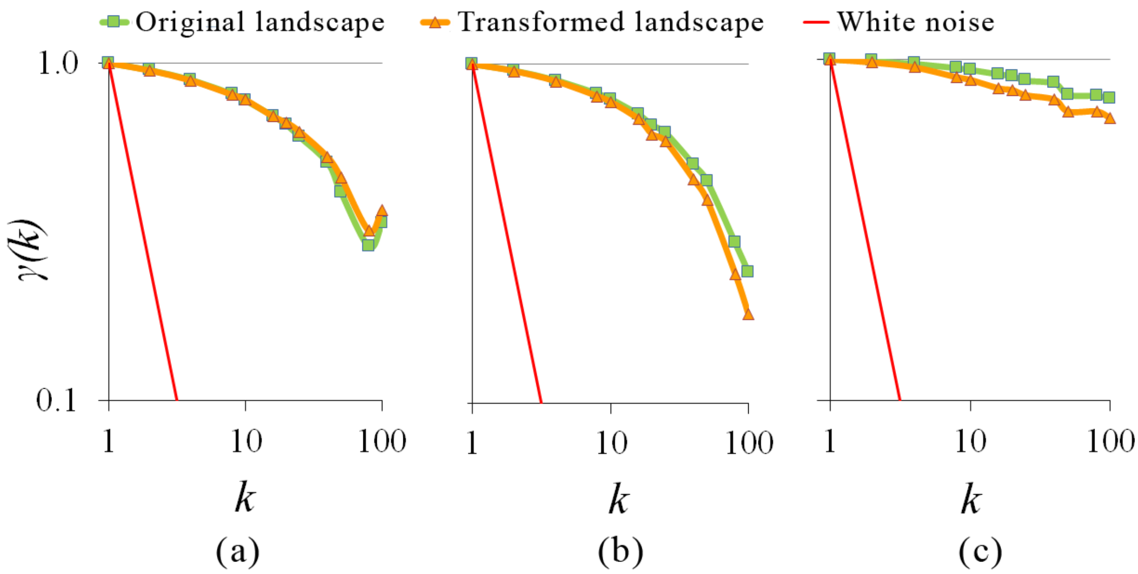


Figure 8.24 Standardized climacograms of images in Figure 8.23.

In **Figure 8.25** the method is used in a theoretical scenario of installation of two wind turbines in a landscape containing a settlement of high value for cultural heritage.

Different positions of the turbines are examined aiming to achieve the minimum visual disturbance to the examined landscape, using the minimum transformation of the original image as a metric of impact (**Figure 8.26**). It has to be noted that this analysis is investigative and no such project has actually been proposed.

(a) (b) (c)

Figure 8.25 Vathia medieval byzantine town in Mani (Greece); (a) Original landscape; (b) Transformed by wind turbines in the left; (c) Transformed by wind turbines in the centre.

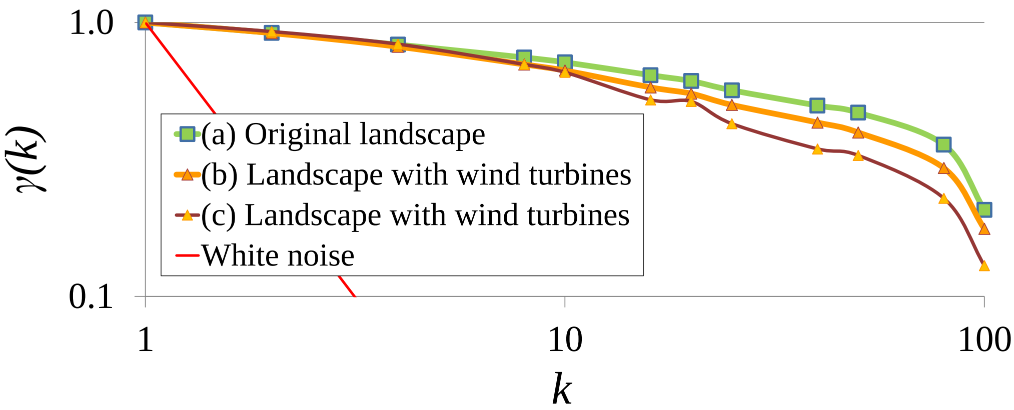


Figure 8.26 Standardized climacograms of images in Figure 8.25.

For the quantification of the difference between climacograms, we subtracted their values for each scale (**Figure 8.24**, **Figure 8.26**):

$$R(k) = \gamma(\kappa)_{\text{original image}} - \gamma(\kappa)_{\text{transformed image}} \quad (8.17)$$

where γ_l and γ_t are the climacogram estimations of the original image and the transformed image, respectively.

In example (**Figure 8.23**) transformations in three different landscapes were examined and it was concluded that the most impactful transformation was in the natural landscape of a Greek island from the installation of wind turbines.

In example (**Figure 8.25**) two different positions were examined, for the theoretical scenario of the installation of wind turbines in the proximity of a traditional settlement. The results indicate that the most visual heterogeneity, in relation to the original image, was caused with the insertion of the wind turbines in the center, rather than in the side of the image. This quantification of visual alteration can be utilized for comparative analyses, either independently, for the analysis of differences in visual heterogeneity, or in combination with other existing methodologies for visual impact assessment.

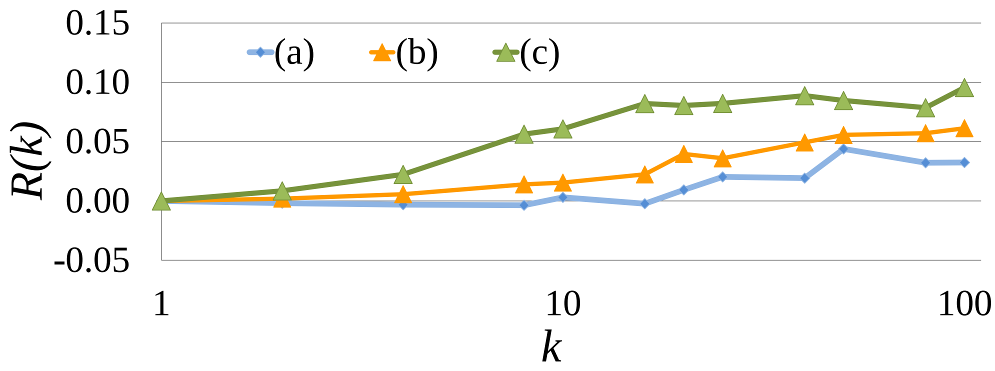


Figure 8.27 Evaluation climacograms with the alteration of original vs. transformed landscapes; curve (a) Alley in the medieval settlement in Bari; curve (b) Fyriplaka, traditional settlement in Cyclades (Greece); curve (c) Natural landscape in Greek island with attraction of tourism .

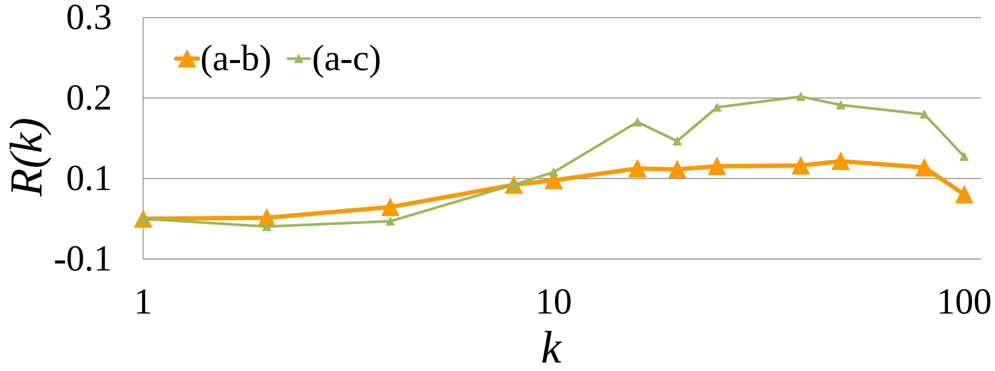


Figure 8.28 Evaluation climacograms with the alteration of original vs. transformed landscapes; curve (a-b) Transformed landscape with wind turbines in the left; (a-c) Transformed landscape with wind turbines in the center.

Aesthetical issues of Plastiras lake

Plastiras reservoir is an artificial lake in Greece, generated by the arched dam of the same name and famous for its beautiful landscape (Hadjibiros et al., 2005; Sargentis et al., 2005a; Sargentis et al., 2005b; Sargentis,1998). Plastiras lake is a unique example of how civil infrastructures can be integrated into landscape sustainably and create beautiful artificial landscapes that attract viewers and support a multi-dynamic sustainable development.

We chose this case study because previous work based on questionnaires (human judgment), theoretical analysis, and field research of landscapes have shown that water is perceived as an MFP in the landscape and also that observers perceive the south part of the Plastiras reservoir as more beautiful than the north part of the reservoir. When an expert looks at data and images, this conclusion could be also reached due to other landscape-parameters, but in this case the validation of the positive character of the landscape by public perception is correlated with quantitative visibility analysis. Based on previous research, we can validate the presented-novel methodology utilizing the past knowledge of the problem and the public's perception. Twenty years ago, when the initial analysis of the problem was carried out, we only had qualitative tools at our disposal.

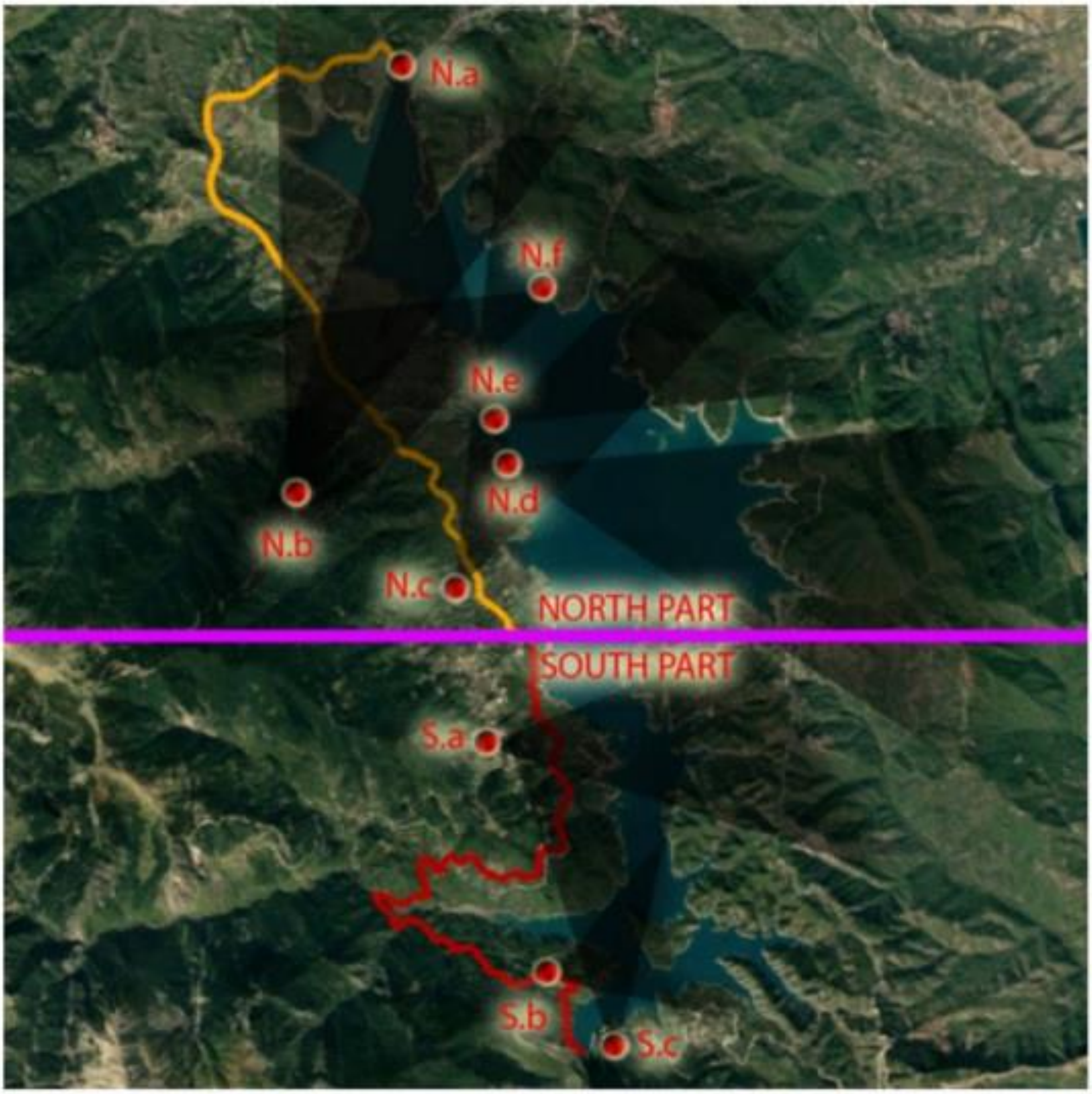


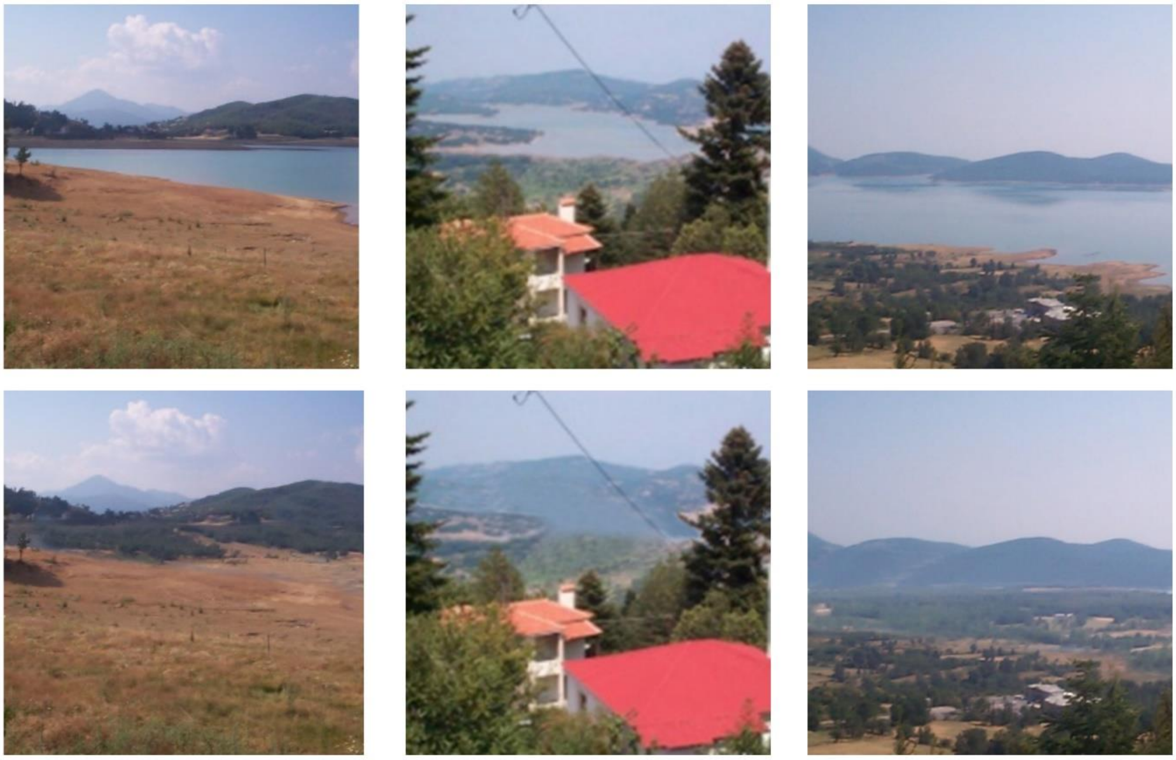
Figure 8.29 Purple line: theoretical line that separates the north and south part of the landscape; yellow and red lines: main peripheral reservoir roads; red dots and shadowed cones: positions of pictures and direction of views of the landscape (Figure 8.30, Figure 8.31, Figure 8.32).

In order to evaluate the view of the landscape we select characteristically pictures from the data base of previews landscape research project. Each picture is marked in the map and we know exactly the date and level of the lake. Obviously, an observer will see infinity views as "pictures" but in summary we present the most characteristics which were extract as results of previous research defining (aesthetically) the north and south part of the lake.

It is important to note that these pictures are selected trough questionaries and express the typical views for the majority of the observers.

(**a**) (**b**) (**c**)

Figure 8.30 Plastiras reservoir south part; Viewpoints of Figure 6 (a) S.a; (b) S.b; (c) S.c; First row, original view; Second row, transformed images without lake.



(**a**) (**b**) (**c**)

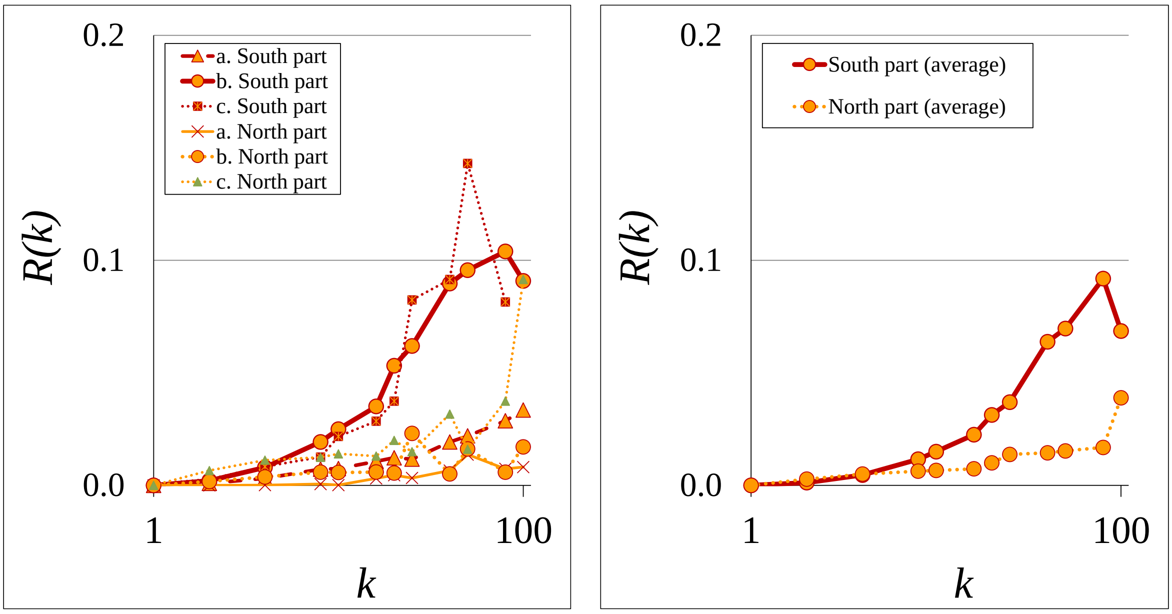
Figure 8.31 Plastiras reservoir north part; Viewpoints of Figure 6 (a) N.a; (b) N.b; (c) N.c; First row, original view; Second row, transformed images without lake.

(a) (b) (c)

Figure 8.32 Plastiras reservoir north part; Viewpoints of Figure 6 (a) N.d; (b) N.e; (c) N.f; First row, original view; Second row, transformed images without lake.

Trying to quantify why the landscape of the south part is visually more pleasing than the landscape of the north part, we transformed the scenery (removing the lake), as can be seen in the second row of **Figure 8.30**, **Figure 8.31**, **Figure 8.32**. The evaluation climacograms of the alteration of original images (with the lake) v.s. transformed images (without the lake) of the landscape, shows that the south part of the lake is transformed more intensively from the lake (**Figure 8.33**). This could explain why the observers are more impressed by the south part of the landscape and find its landscape more beautiful, as this part is transformed more intensively in relation to the (theoretical) original image (without the lake).

In order to evaluate the differences in the landscape integration of the reservoir in each case, due to the differentiation of water presence in the north and the south part of the lake (**Figure 8.34**) we evaluated the respective climacograms of presence of water in the landscape (**Figure 8.34**, **Figure 8.35**) and the corresponding ZTV maps of the reservoir. These demonstrated that clustering of the north part of the reservoir is more intense than clustering of the south part of the reservoir where the water is more dispersed in the landscape.



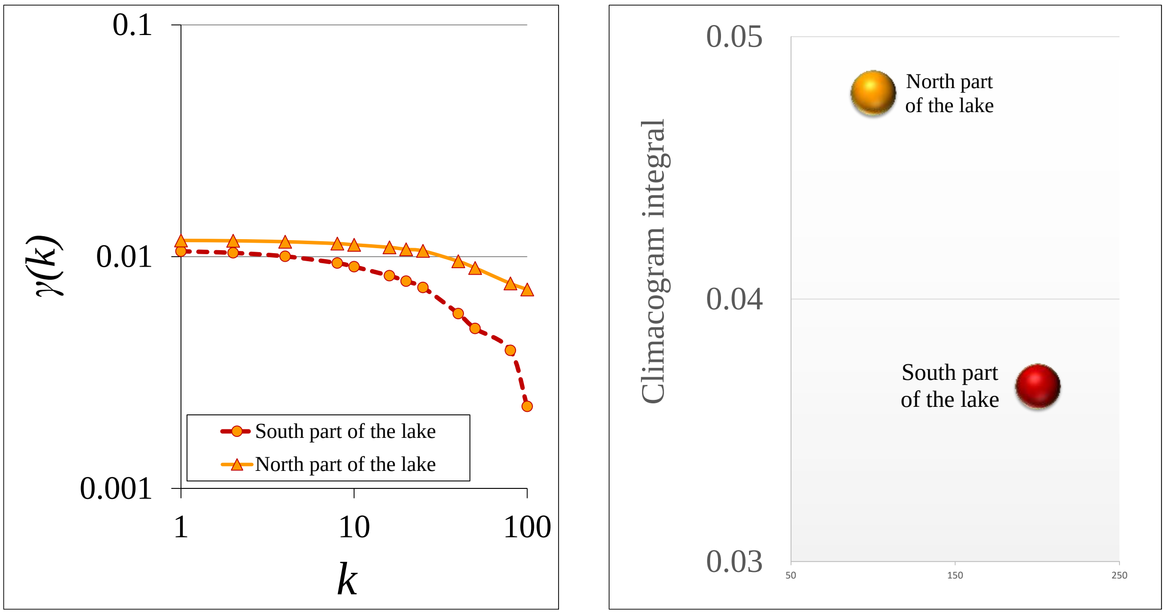
(a) (b)

Figure 8.33 (a) Evaluation climacograms with the alteration of original vs. transformed scenery (b) averages of the north and south part of the lake.

Investigating the clustering of the ZTVs we calculated the ZTVs that correspond to the same road distance (~11.5km) for the north and south part of the landscape (Figure 11). As demonstrated in Figure 12, the results show that the south part of the lake has a fainter clustering of ZTV than the north part of the lake.

(a) (b) (c)

Figure 8.34 (a) Plastiras reservoir; (b) presence of water in the north part of the lake; (c) presence of water in the south part of the lake.



(a) (b)

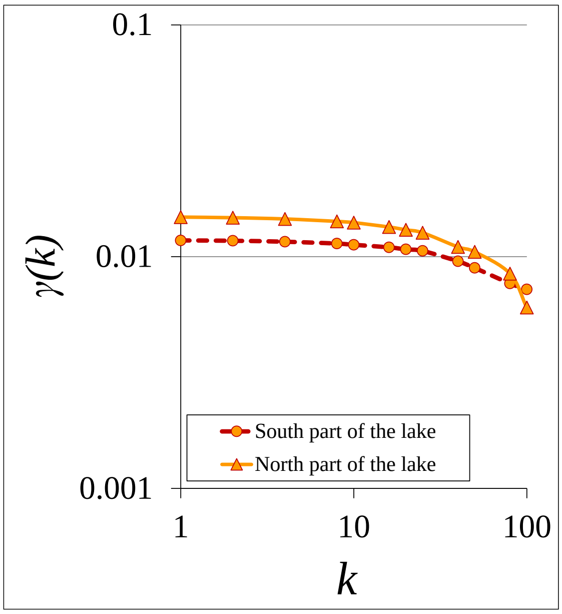
Figure 8.35 (a) Climacogram for each scale of Figure 8.34; (b) rate of alteration of clustering of Figure 8.34.

(a) (b) (c)

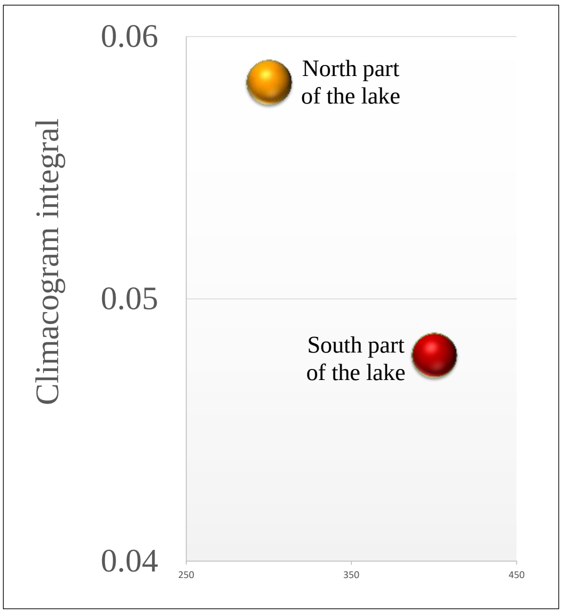
Figure 8.36 (a) Plastiras reservoir; (b) Examined sections of road; (c) ZTV of the south (red) and north (yellow) parts of the reservoir.

In the south part of the landscape, we observe faint clustering of ZTV. That means that the lake which is perceived as a MFP with positive landscape impact, has more spread dispersed visibility in the south part of the landscape than in the north part (**Figure 8.36**, **Figure 8.37**).

Therefore, minimum clustering and increased spread of a MFP in a landscape is positive to the observer, which is also intuitive and also in accordance to previous research. On the contrary, maximum clustering and limited spread of a negatively perceived FP can contribute to minimizing its landscape impact.



(a)



(b)

Figure 8.37 (a) Climacogram for each scale of Figure 8.36; (b) rate of alteration of clustering of Figure 8.36.

Chapter 9. Conclusions

"Reality is something that refuses to obey our wishes" [I]

Even if our fantasy favours the existence of an imaginary world, which is deterministic and predictable, environmental-friendly with total equality, green development, the truth is that the access to WEF nexus, social cohesion and social stability are the primary issues of prosperity.

In Chapter 2, we saw that the access to WEF nexus is the primary need for prosperity. We also saw that a big part of the humanity lives in lower standards than antiquity showing that humanity has not made great progress in the last 2000 years.

In Chapter 3 we showed that clustering/partitioning of society and the distribution of wealth are main issues of societies' shape as:

a) Clustering is related to the functioning of economies of scale which support the economy and the prosperity of the society.
b) Partitioning is related to the functioning of protection.
c) Entropic analysis of the wealth distribution identifies exponential distribution as the optimum in terms of social stability.

In Chapter 4, we introduced new stochastic tools which have been developed for the evaluation of clustering in two dimensions and the evaluation of social stability under an entropic view.

In Chapters 5-8 we performed an evaluation of case studies. The conclusions are summarized in the following paragraphs.

9.1 The water–energy–food (WEF) nexus

Real wealth is water-energy and food. Humanity hunts it with large scale infrastructure as economies of scale made this more efficient. An investigation of the range of population in Roman Athens and the estimation of the range of the water footprint of the consumption of domestic use per Athenian shows that according to the global data, there are about two billion people in present with less water footprint for consumption of domestic uses than the minimum water footprint of an Athenian in Roman era. We also found that according to global data, about 1.4 billion people live with less access to food than the average wheat-wage in Roman Athens. These examples show that humanity has not made a great progress in the last 2000 years.

The concept of a water–energy–food (WEF) nexus was manifested as a natural resource management approach, aiming at promoting sustainable development at the international, national, or local level and eliminating the negative effects that result from the use of each of the three resources against the other two. At the same time, the

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[I] Much Wants More And Loses All. Available online: https://gefira.org/en/2022/03/11/much-wants-more-and-loses-all/ (accessed 13 March 2022) transition to green energy through the application of renewable energy technologies is changing and perplexing the relationships between the constituent elements of the nexus, introducing new conflicts, particularly related to land use for energy production vs. food.

Specifically, one of the most widespread green technologies is photovoltaic (PV) solar energy, now being the third foremost renewable energy source in terms of global installed capacity. However, the growing development of PV systems results in ever expanding occupation of agricultural lands, which are most advantageous for siting PV parks. Initially, the development of PV parks requires a large investment fund, but in its life cycle, the revenue of energy production and the negligible water demand highlight this scenario as the best solution for the case study in Thessaly plain.

Nonetheless, whereas energy is essential for prosperity, it is not edible, thus food security is first priority. Moreover, we observed that, financially successful cultivation paradigms (such as kiwifruit production) and ideas which are not adjusted to the local characteristics of the area could be very harmful and very unsustainable.

9.2 External shape: clustering, partitioning

Clustering is both a natural and a human social tendency that comes with different qualitative consequences with scaling, i.e., the properties of large scales cannot be derived from the ones of small scales. In these terms, as both the scales of current societies and that of engineering projects increase, it is of paramount importance to understand both the structure of spatial clustering and its temporal evolution. To this aim, we show a stochastic method of general applicability for the quantification of the temporal evolution of spatial clustering as a tool to assess, monitor and potentially predict elements of global changes.

The tool called 2D-C (2D-Climacogram) quantifies the variability of images through the variance of the brightness intensity in grayscale. Upon a careful selection of images representing spatial information, we can derive a quantification of clustering over time that is useful for either quantitatively characterizing known spatial changes, as urbanization, and tracking their temporal evolution, or even revealing spatial patterns that are less expected, i.e., pertaining to feedback loops between anthropogenic interventions and natural variability. We present a range of applications for (a) the natural sciences, in terms of the evolution of the universe as suggested by cosmological simulations and of ecosystems, such as forests and lakes, and (b) for human sciences dealing with social structures, as revealed by the evolution of worldwide cropland data, satellite images of night lights and spatial data on urban land cover.

Our results support the concept that there is a tendency for clustering both in the natural and anthropic world, yet this tendency is scale-dependent as beyond a certain scale it may as well be dissolved or replaced by a structure of another quality. We have seen that in the evolution of the universe clustering increases and decreases depending on the scale of view, and structures that have grown and seem at a certain scale to be merging (galaxies, clusters, super clusters, etc.), in other scales are moving apart. In biological life clustering is related to saving of energy resources, as in in mammals, but it is not stable to threats; for instance, dinosaurs disappeared. The case studies on ecosystems, namely the Borneo and Amazon forests and the lakes in Greece, show that the stochastic clustering methods offers an effective characterization of the evolution of ecosystems revealing clustering and partitioning patterns. In many cases, the interplay of natural and human-driven variability is difficult to discern and proves unpredictable in terms of evolution. Such a counterintuitive case is the found increase in ecosystem variability stemming from anthropogenic interventions such as dams.

Clustering and partitioning periods are apparent in nature as also revealed by our case studies, as well as in human social structures. There are local examples of partitioning, i.e., related to wars, famines or nuclear and natural disasters, but our case studies show an overall positive clustering trend. Specifically, in our study of long-term worldwide cropland data and London's evolution, we have found that the rhythm of clustering dramatically increased since the industrial revolution, whereas urbanization followed this overall positive trend till the present time. This is in accordance with the widespread belief that larger human clustering structures enhance efficiency (e.g., through economies of scale). Yet it is becoming increasingly evident that clustered human structures come with increased risks as well. For instance, in the economy increasing clustering comes with increase in systemic risks, while centralization of infrastructure and resources increases vulnerability of the population during failure or war.

Despite the vast benefits resulting from centralized social structures during the last centuries, it is tempting to consider an alternative social distribution in space, perhaps a sparser and more decentralized one, taking example of the evolution of natural structures that are driven by uncertainty.

The large-scale infrastructures of water supply system, was a key factor for Athens' growth. If we consider that the Athenians would like to stay in Athens with the current life style but without the hydraulic infrastructures, they would certainly decide to build them. Indeed, given that before the big infrastructures they were paying for water about 400 €/m^3 (almost the same price of bottled water today), they would have made amortization of the capital for infrastructure or water supply system in less than a month! Therefore, it seems that economies of scale in hydraulic works are obviously a key for the development of the city. According to the data analysed, the question of scale, in the case of the Athenian water supply system, is highlighted from the following facts: (a) the cost of the infrastructures of hydraulic works, necessary for the development of the city, was minimized with large-scale infrastructures; (b) the price of water was significantly reduced with the construction of large-scale infrastructures; (c) the infrastructures constructed led to increased water consumption; (d) the water supply system of Athens depends on natural resources from basins far away from the city but the small number of large-scale reservoirs minimized the length of the aqueducts; (e) large concentration of population in Athens is obviously capital intensive for water management.

We can see also that partitioning of the forests is a way of protection even if it is not widely acceptable. Forests are admirable and complex natural ecosystems, and fires, albeit devastating, can be attributed to both human activity and to natural processes that contribute to their rebirth, with the latter constituting an intrinsic and perpetual process of the forest ecosystem. Other than their important ecological value, forests are, in the

21st century, also a capital resource, for many people's livelihoods depend on them. In this study, we proposed a method for taking mitigation measures against wildfires based on the partitioning of forests, considering both the protection of the ecosystem and the inhabitants and aiming to utilize their co-dependent nature for the general protection and preservation of forests. As a case study, we show that the current devastating fire in Euboea (occurred in August 2021), initially in terms of the spatio-temporal progression of the actual wildfire that lasted several days and then by examining how an implementation of the proposed method in the study area could contribute to both the recovery of the ecosystem and the enhancement of the quality of life of the inhabitants as well as their long-term protection.

9.3 Internal structure of society: distribution of wealth

Human civilizations have survived through natural disasters and in hostile environments. We see from different examples that when there was advanced social organization, the society could overpass environmental issues as Minoan did it with a volcano eruption or climatic changes around 1500 BC. We have also seen several studies which failed to predict or model society structures (past or present) based on environmental criteria alone. In addition, it is an undeniable fact that when social organization collapses, societies cannot survive.

The case of the Minoans illustrates that the key to a civilization's ability to thrive is the focus in large-scale infrastructure and technology that improves the living conditions. This presupposes but also enhances the society's organization. The Gini coefficient in Knossos c. 1500 BC, is estimated about 0.5. This value, corresponds to the exponential stratification which is referred to the entropic index of inequality $\Phi_\mu[\underline{x}]$ equal to 1 and shows a stable social structure (maximized entropy) in which, a recession phase would have minimum effect.

Following this simple rule, societies take the advantages of economies of scale to prey effectively water-food-energy nexus necessary for survival needs and prosperity. In order to do this, organization, division of labor (necessarily leading to social stratification) and growth (necessarily leading to complexity) is necessary. In light of this, we therefore, deem social dynamics as more important than environmental determinism.

9.4 Cultural elements of prosperity

In recent years, artificial intelligence processes and mathematical computational tools have been used to develop methods for classification and evaluation of aesthetics. Scale-variant methods similar to the presented stochastic analysis have also been used, but they usually include very complex processes and algorithms not easily understood by non-experts.

With the presented 2D-C methodology quantifying the brightness's variability over scales of pixels, we can observe stochastic patterns among different groups of art paintings. We identified dependence structures similar to that of natural processes, with an average H ≈ 0.9, in photographs of faces, as well as in portraits belonging to the

Renaissance/Baroque period and Rembrandt's self-portraits. Modern art portraits and Picasso's portraits also have an average H ≈ 0.9 implying underlining strong dependence structures, but showing a wider range of fluctuations indicative of the pursuit of freer artistic expression during these years. On the contrary, the stricter dogma-inspired Byzantine figures exhibit an overall weaker dependence structure (average H ≈ 0.8) and the smaller coefficient of variation (0.379) among the other sets.

These findings suggest that the presented methodology can capture the interrelation between the stochastic expression of the art paintings and the philosophical issues they want to describe (desideratum). This aspect is encouraging for the use of stochastics in the analysis of art paintings and their relation to wider philosophical and cultural issues.

From the above we saw that 2D-C methodology is a reliable tool for the aesthetic evaluation, therefore we evaluate the transformation of aesthetical value of the landscapes by works of technological and civil infrastructure. These transformations become even more perceivable when they alter landscapes, urban or natural, of historical and cultural significance.

The case study of the landscape of Plastiras Lake, in which the stochastic method for the visual evaluation clustering of FPs is applied, extends the results of our previous work in both qualitative and quantitative terms. Through the utilized stochastic method, we highlight an important quantitative parameter of the visual experience of a landscape, i.e., the impact of FP clustering. In particular, we concluded that the clustering of positively perceived FPs seems to have contributed to the positive public perception of Plastiras lake, which is widely considered as an example of a highly sustainable infrastructure project. The inclusion of ZTV mapping in the analysis allowed for this quantitative improvement and allowed for a better spatial definition of landscape's aesthetic appeal to visitors.

The proposed method can be utilized as part of environmental impact assessment studies or in the management of landscape for tourism and recreation. For the former, the methodology could be used in the effort to optimize the positioning of infrastructures and for the latter to aid in the determination of areas to be promoted. Despite its limitations, the proposed quantification of landscape aesthetics provides an intelligible way of identification and communication of landscape changes, which may be useful in infrastructural landscapes policies and decision making.

9.5 Final notes

This thesis develops the argument that there are some critical elements for human prosperity that money cannot describe. The most critical among them is the availability of natural resources and the access to the WEF nexus. Water, energy and food are not generated by money; rather money derives by the availability and the access to water, energy and food. However, money can be used as a proxy of this access. The assurance of the function of WEF nexus is dependent on a rational management of natural resources (e.g., as it is presented in the case study of Thessaly plain).

a) An exterior view of the society's structure can be achieved by inspection of the clustering or partitioning dynamics. On the other hand, the interior view of society is driven by the distribution of wealth and the stratification.
b) Clustering is a way of growth, and is supported with large scale infrastructures (e.g., the evolution of water bodies in Greece and the evolution of Athens water supply system). Partitioning is a way of protection and can be applied in many different threats as viruses (social distancing), wars and wildfires (partitioning of the forest). However, the society have to take critical decisions based on real data (and not on imaginary beliefs as is customary) in order to decide which way, it has to follow.
c) We also saw that entropy can give us interesting insights for the formulation of social stratification and social stability which are critical for the prosperity and cohesion of the society, and it is much more informative than the often-used environmental determinism. The entropic analysis of the distribution of wealth shows that an exponential stratification of wealth corresponds to a stable social structure. It is presented that many times in history, ill-considered attempts (e.g. by socioeconomic elites) to transform this distribution to Pareto (which populates more the poor and the very rich, reducing the middle class), led to unstable structure breaking the social cohesion to the point of a collapse. Especially nowadays, politico-economic elites try and succeed in increasing their profits thus pushing toward a Pareto distribution and de-stabilizing society.
d) The prevailing approach of environmental determinism, fails systematically to explain and predict the dynamics of society. Instead, social dynamics appear to be more important.
e) Prosperity also contains cultural aspects as the aesthetic value of the landscape, which is may undergo deterioration by badly designed civil infrastructures. The aesthetic of the landscape is a cultural element of prosperity which is very important and, in this thesis, we examined many related case studies.

All the above issues of prosperity have been studied with novel stochastic tools which have been developed and used in order to have a quantitative evaluation of different data seeking an objective evaluation. These issues were supported by historical paradigms, and analysed following a rationalistic approach.

Stratification is an obvious attribute of society and an exponential distribution of wealth is shown to correspond to the most stable social structure.

Focusing on human needs, in contrast to the always re-occurring Malthusian thought (at present represented by environmental activism and related elites where people are considered problematic to the Earth[I]) the author's view is to: *side with the people who love the people*.

[I] Population decline and smaller families good news for climate, says former head of FSA, Independent, 9 Okt 2021. Available online https://www.independent.co.uk/climate-change/news/fsa-population-decline-climate-change-b1934877.html (accessed 12 October 2021).

9.6 Further research

The developed stochastic tools could have a wide range of applications.

a) The quantification of 2D clustering, could be used in medicine, meteorology, mapping among other fields.
b) The entropic view of the social structure could be used in analyses of social dynamics. Furthermore, the entropic index of inequality could have a wide range of applications quantifying the range of inequality of any data series.
c) The aesthetical evaluation using stochastic tools could be used in landscape studies or even in analysis of paintings.

Finally, this thesis highlights the power and the flexibility of the stochastic calculus to study and unify the study of issues which are not easy to approach and characterize in an objective and interpretable manner, such as social dynamics, aesthetics, clustering and partitioning. This may trigger further researcher to use the presented stochastic tools in order to solve similar problems, or to develop new tools solving new problems using stochastic calculus and rationality.

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Issues of prosperity:
Stochastic evaluation of data related to environment, infrastructures, economy and society

Appendix

G.-Fivos Sargentis
Ph.D. Thesis

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3. K. Hadjibiros. Prof. Emeritus N.T.U.A.

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7. S. Mavroudeas Prof. Panteion University

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Issues of prosperity:
Stochastic evaluation of data related to environment, infrastructures, economy and society

Appendix

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Contents

Chapter 1. Conversion of past century drachma to current €

1.1 Data and examination periods

The periods under consideration are related to the phases of the development of hydraulic infrastructure, and the development and expansion of the city. Thus, socio-economic conditions are examined before and after the construction of large-scale projects.

Social, urban and technical data were extracted and used from relevant studies, and were further processed into charts from which useful conclusions are postulated/depicted.

The social, urban and technical data can be reliably measured, but we could not claim the same for the economic data. As we know, the temporal value of money changes and in order to assess reliably the available monetary data, there should be a calculation of the temporal equivalence between the past value of drachma (as the national currency of Greece until 1999. From 1999 until the end of 2001 the drachma was still in circulation, however with a locked exchange ratio to the euro) and the current value of the euro as the country's official adopted currency in circulation since 2002. In addition, we should also calculate the effect of the Consumer Price Index (CPI) as it is also a major factor determining prices.

The calculations are becoming increasingly difficult as we move back in time because it is both more difficult to find data on the price of water and hydraulic infrastructures as well as to convert them to current €.

From 1959 until now, there are official data for both the price of water and the conversion of drachmas in €. From 1922 to 1959, there are still satisfactory data but less official sources that had to be combined. Finally, from 1910 to 1922 the data are based on bibliographic sources of which the validity cannot be easily cross-referenced or verified and the conversion of drachma to € has been made using a synthesis of different approaches, as no relevant literature or relevant sources have been found to make a direct calculation.

It should be noted that the value of money depends on highly complex parameters including social conditions, gross capital formation, unemployment, wars, financial changes, devaluations, revaluations, etc. and the more we go back in time, the drachma conversion in € becomes more of an estimate than an accurate conversion.

The next paragraphs comprise a description of the bibliographic data and economic methods used at each time period based on data availability.

1.2 Conversion for the period after 1955

From 1955 until today, finding data on the price of water and the cost of works and their conversion to current € was easy as official data are available (Adamopoulou, 2017).

Prices were based on the Greek Monetary Unit Evolution Value (annual), based on the General CPI[I].

1.3 Conversion for 1930-1940

In 1923 Ulen & Co. from New York City was selected to construct the Marathon dam. This included the dam, reservoir, a conveyance pipe and a water treatment plant. After this project Ulen & Co, had the management of the water in Athens.

Ulen's invoices, can be considered a reliable indicator of the price of water for the period 1930-1940 (1940), which was converted into 2018 € with data from the Bank of Greece (Kontelis, 2018). Correspondingly, the infrastructure cost of the period (1932, Marathon Dam) was converted to current €.

1.4 Conversion for 1913

In 1913 the price of water was 80 drachmas/m^3 (Merkouris, 1913). Converting this price to current € was particularly important so that conclusions could be drawn on the fluctuation of the water price, after the inclusion of large water infrastructures in the water supply network.

Since no method was found to have already been developed for this conversion in the literature, the following four alternative approaches were adopted using available data to estimate the price of water.

1. The first approach is based on the correlation of the data of the French franc in 1913 with the Greek drachma which, at that date, fully followed the rules of parity of the Latin Monetary Union. Available French franc conversion data for that period were used from the equivalence to 2007 €[II] and then in current €.
2. Greece's currency table for the period 1959–2001 is based on the general consumer price index. For the years before 1959 with no corresponding data on the evolution of the value of the currency, a separate methodology was used to find the equivalent value of the drachma of 1913 to the drachma of 1959. This method was based on the use of historical CPI data and inflation rates for the same period. The CPI figures found are CPIs without the effect of inflation, while using the inflation data a new gross CPI was created, including inflation changes (Koutsoyiannis and Mamassis, 2018). **Figure 1.1** shows the CPI time series used.

[I] Evolution of Monetary Unit Value of Greece (per annum), based on the General CPI, excel file, Available from: www.statistics.gr (accessed Mar 19 2018).

[II] The Value of the Old French Franc in €-2007. Available online: https://en.wikipedia.org/wiki/French_franc (accessed on 19 March 2018).

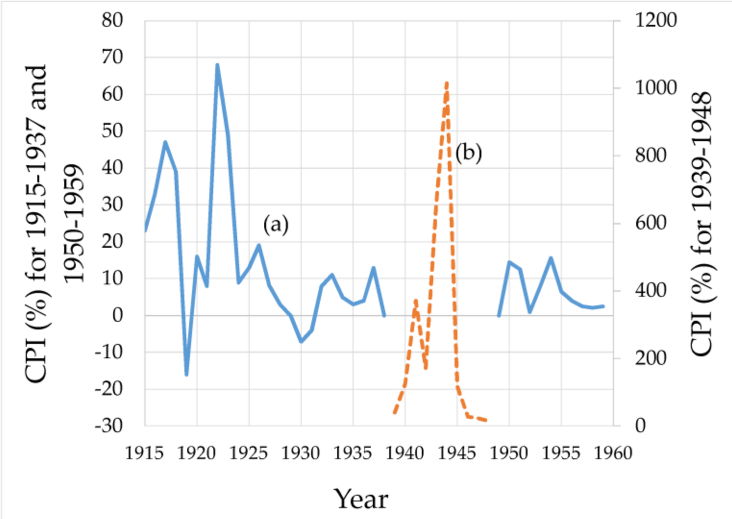


Figure 1.1 CPI of Greece (a) 1914–1938 (Lazaretou, 2005), 1949–2000 (Pagoulatos, 2003), (b) 1939–1948 (Lazaretou, 2005).

3. The closest calculation of the equivalence of drachma value to euro 2013, was a calculation made by the Bank of Greece on the drachma of 1923, which was found equivalent to 0.29 € of 2018. From 1913 to 1923, a period not covered by this calculation, we used the method also used in approach 2 i.e., the evolution of the value of drachma for the period 1913 to 1959 combining net CPI and inflation.
4. In the "Memorandum of the Athens Trade Union", which was submitted to the Parliament of Greece in 1911, it is mentioned that "The wage of the press workers in Athens ranges from drachmas 3.50 to 5.25, reaching up to 6 drachmas only for night workers". Therefore, we can assume that an indicative average wage was approximately 4.25 drachmas. Today, Greek Laws 4046/2012, 6/28-2-2012 and the interpretative circular 4601/304/12-3-2012[I] determine the worker's daily wage between 22.83 € and 26.18 €, so an indicative average wage is 24.50 €. Corresponding to the wages with any political-social errors that can be included, the correspondence of the drachma of 1911 to € 2012 is approached.

The results of these different approaches for the price of m^3 of water are shown in **Figure 1.2** and their average value, which is an indicator for the water price in 1913, is equal to 408 €/m3. Interestingly, if someone wanted to buy 1 m^3 of bottled water in Athens at the year 2018 assuming that no infrastructure was built since 1913, the price would be circa 300 €, which is close to the price of water before large infrastructure projects were implemented.

The closest of the 1913 drachma value calculation in euro from the Bank of Greece, refers to the drachma of 1923, which is equivalent to 0.29 € of 2018. From 1913 to 1923, a period not covered by the above calculation, we used the method developed in approach

[I] Greek Law 4046/2012, 6/28-2-2012 and Interpretative Circular 4601/304/12-3-2012. Available online: http://epixeirisi.gr/download.php?filepath=files/2012/pdf/egkyeka/&filename=egkyeka_4601_304_12_3_2012&filetype=pdf (accessed on 25 April 2019).

2 i.e., the evolution of the drachma value for the period 1913 to 1959 combining net CPI and inflation.

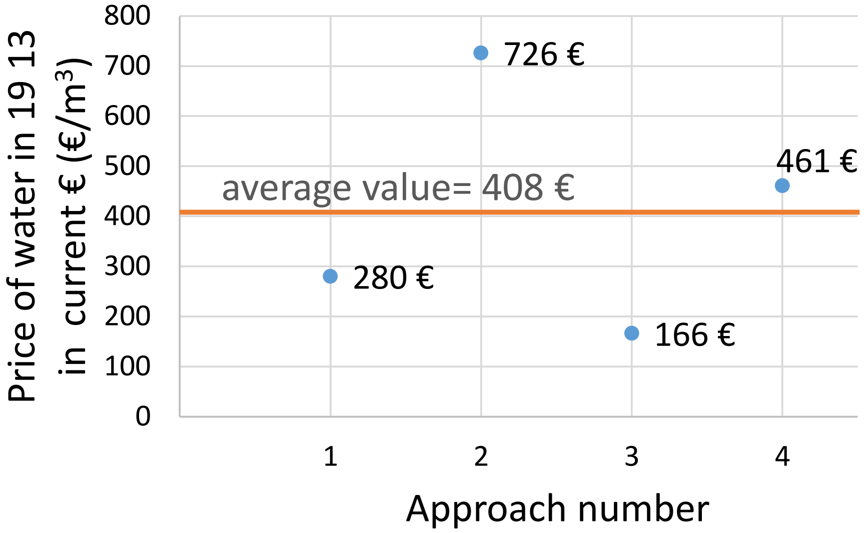


Figure 1.2 Cost of water in 1913 in Athens, based on different financial methodologies for estimating the equivalence of drachma of 1913 to euro of 2018.

Chapter 2. Evolution of clustering quantified by a stochastic method

2.1 Ecosystems

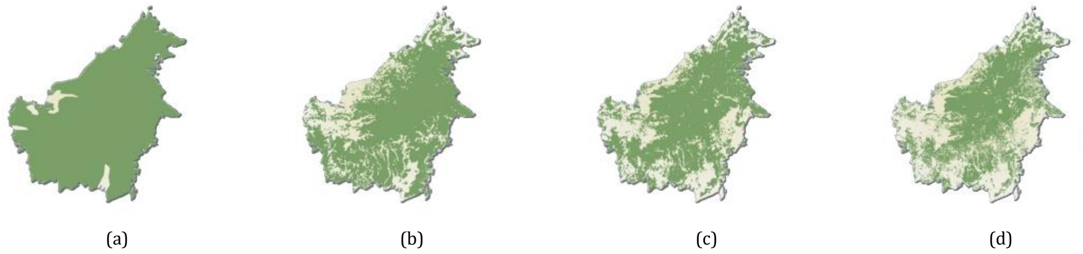


Figure 2.1 Deforestation in Borneo 1950-2005 (a) 1950; (b) 1985; (c) 2000 (d) 2005[I].

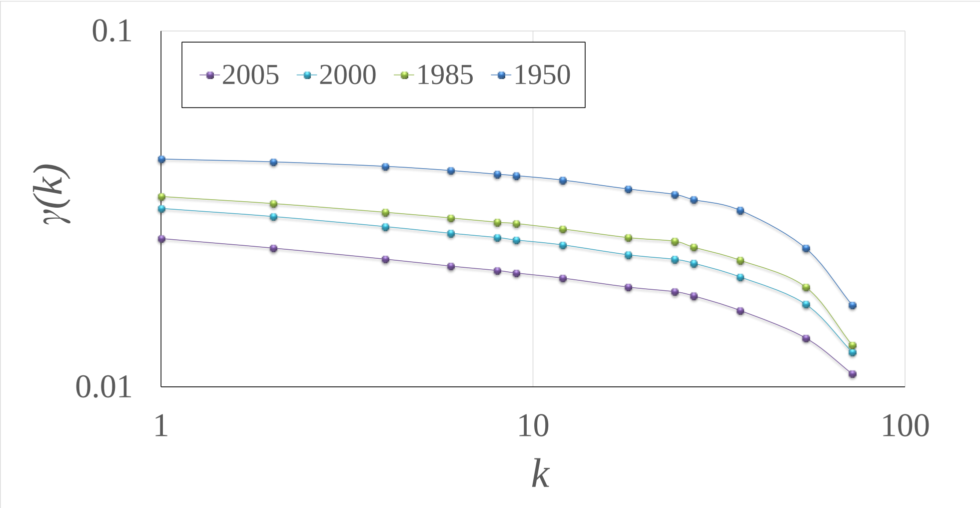


Figure 2.2 Climacograms of the deforestation in Borneo (**Figure 2.1**).

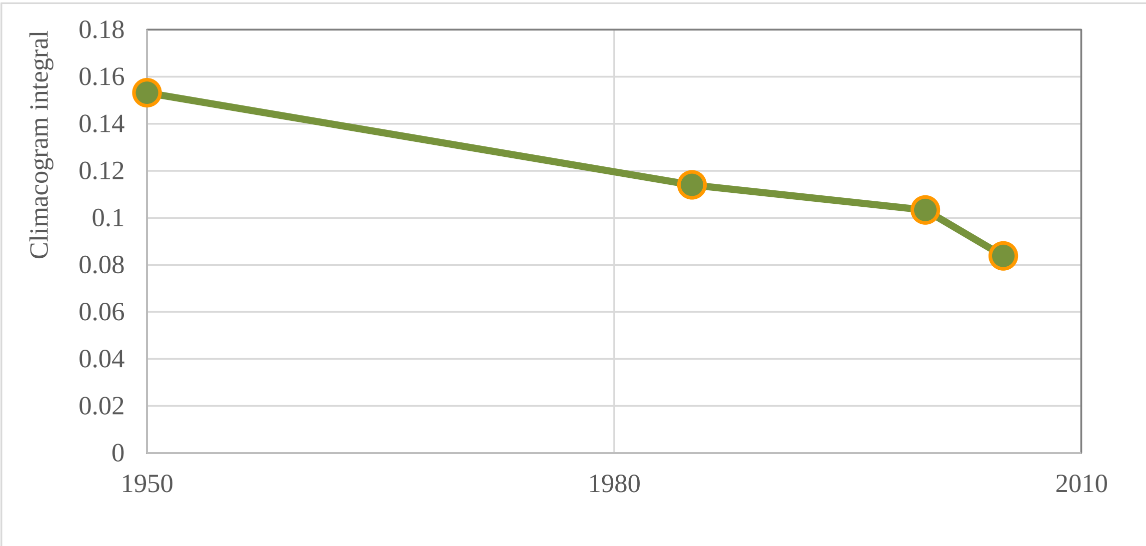


Figure 2.3 Evaluation of climacograms and rhythm of clustering in demolition of fosters' clustering in Borneo **(Figure 2.2).**

[I] Creator Credit Hugo Ahlenius. Available online: https://www.grida.no/resources/8324 (accessed on 15 September 2020).

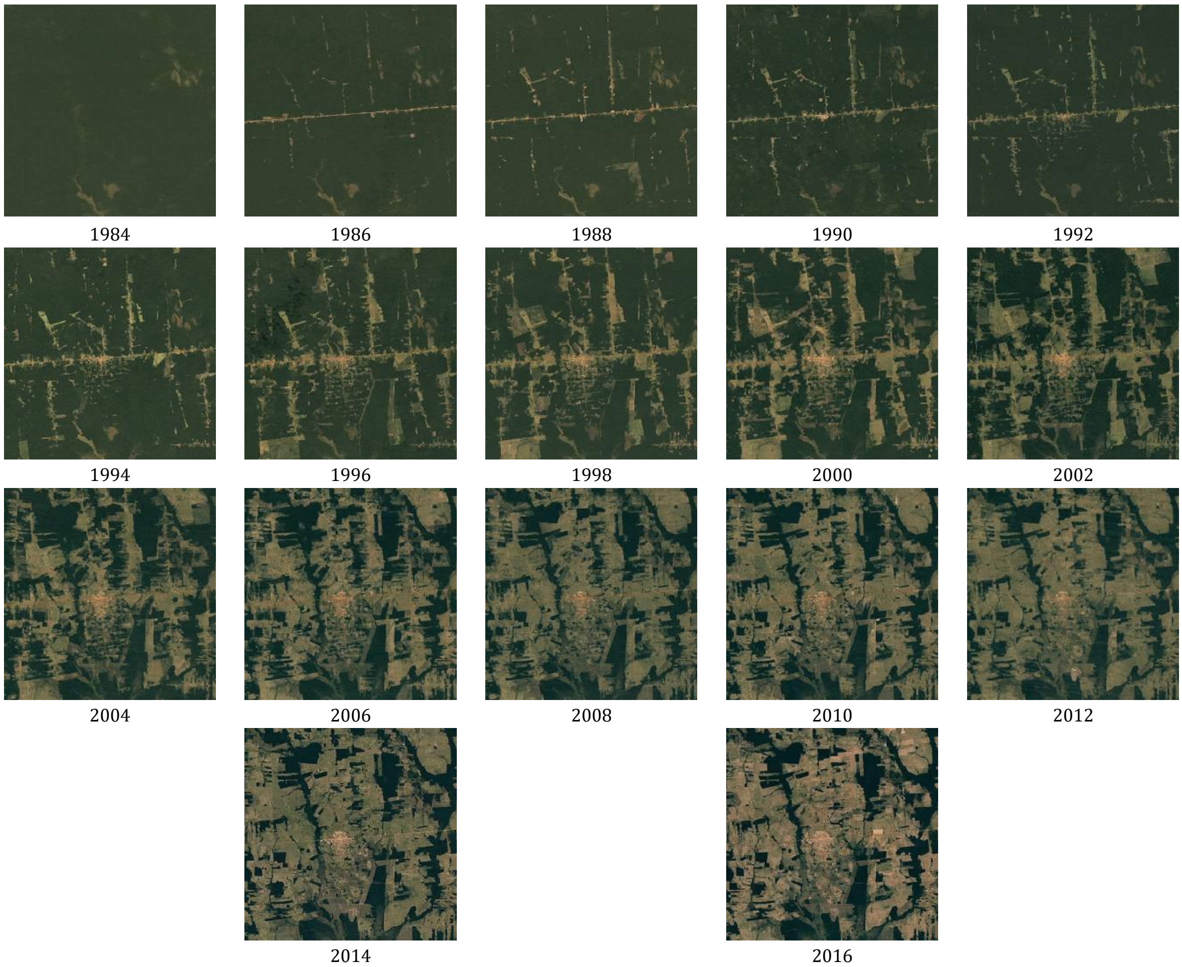


Figure 2.4 Deforestation of Amazon[I], creation of clustering of dry land and urban areas inside forest.

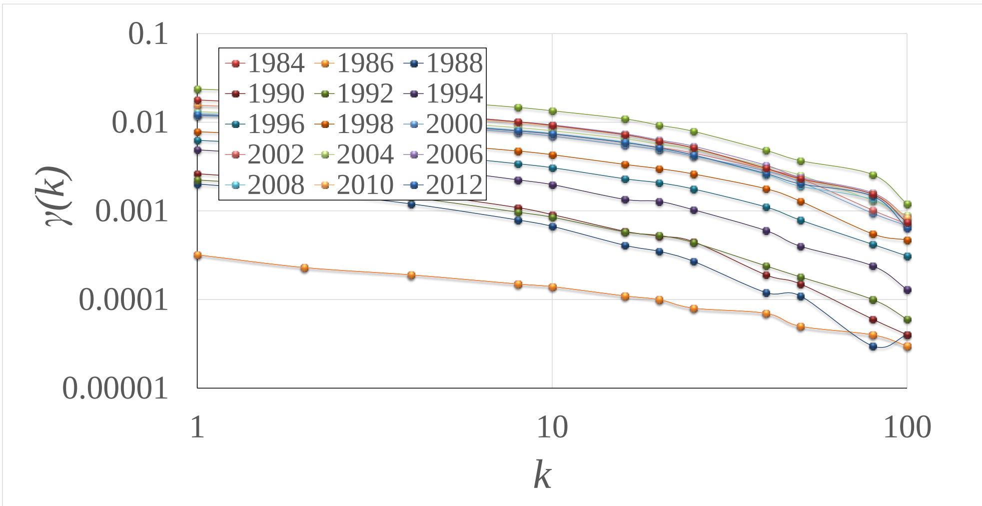


Figure 2.5 Climacograms of the deforestation in Amazon (**Figure 2.4**).

[I] The Human Impact on the World's Forest. Available online: https://www.visualcapitalist.com/human-impact-on-forests/ (accessed on 15 September 2020).

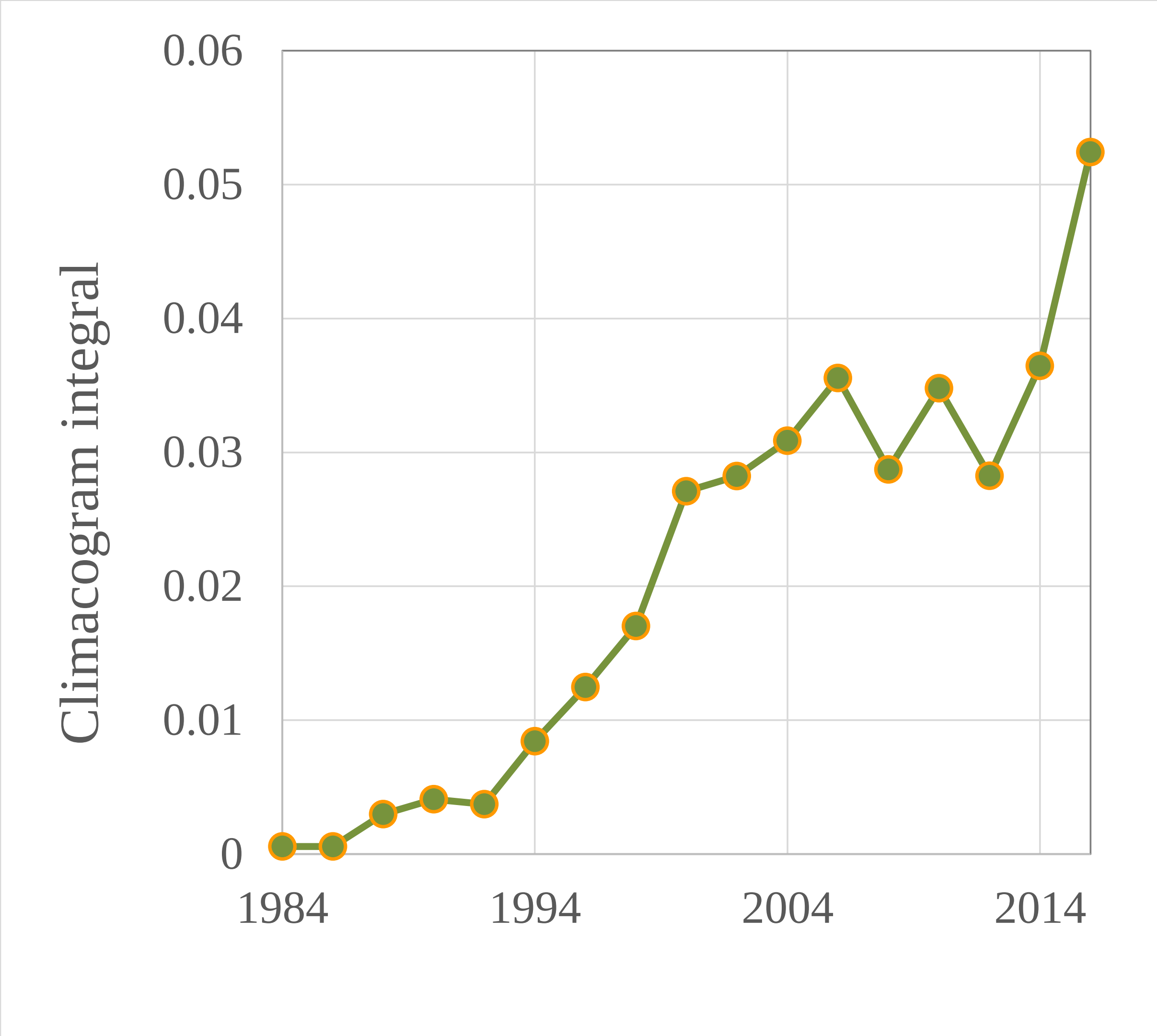
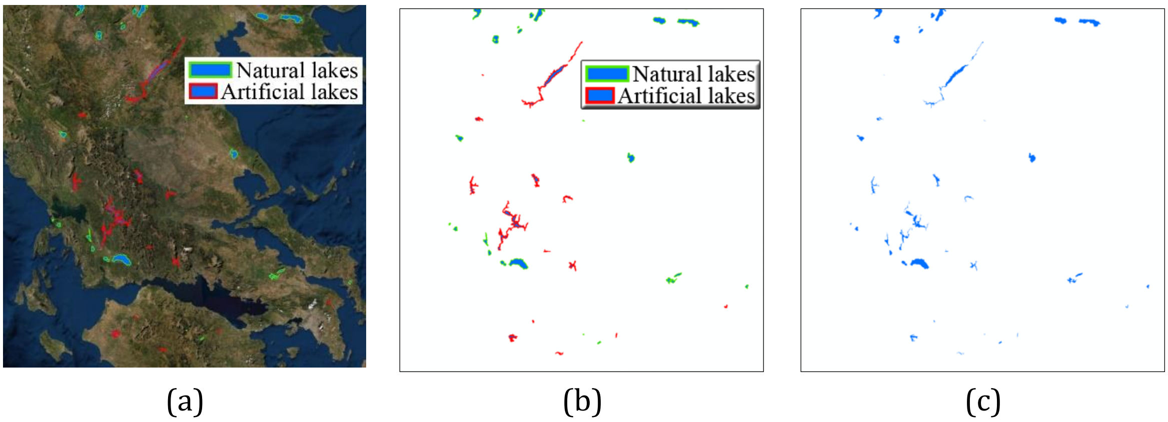


Figure 2.6 Evaluation of climacograms and rhythm of clustering evolution of dry-lands' clustering in Amazon **(Figure 2.5).**



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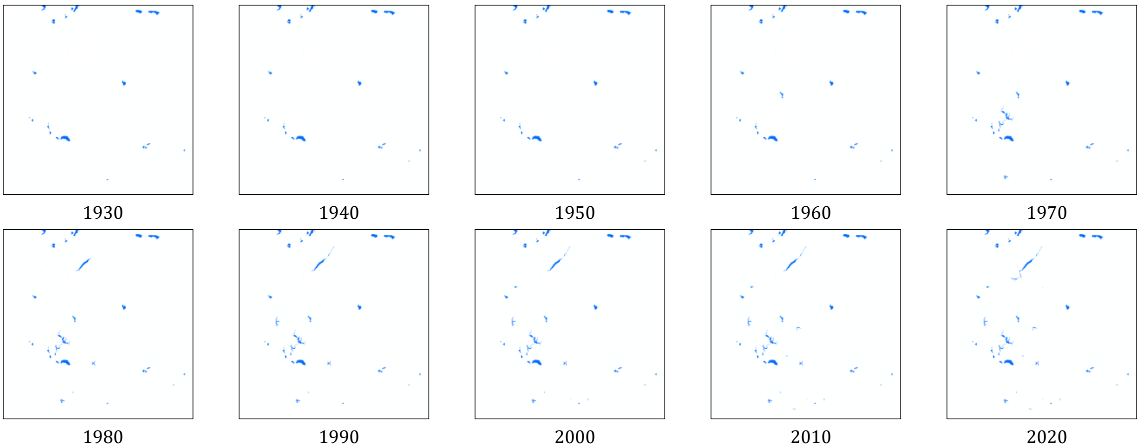


Figure 2.8 Evolution of water bodies in Greece as new big dams are constructed and new artificial lakes are created.

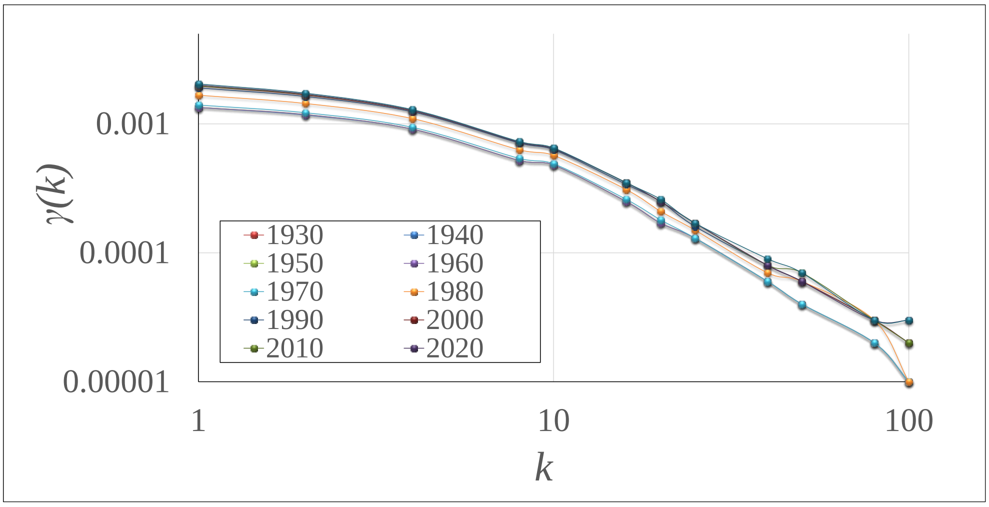


Figure 2.9 Climacograms of the evolution of water bodies in Greece (**Figure 2.8**).

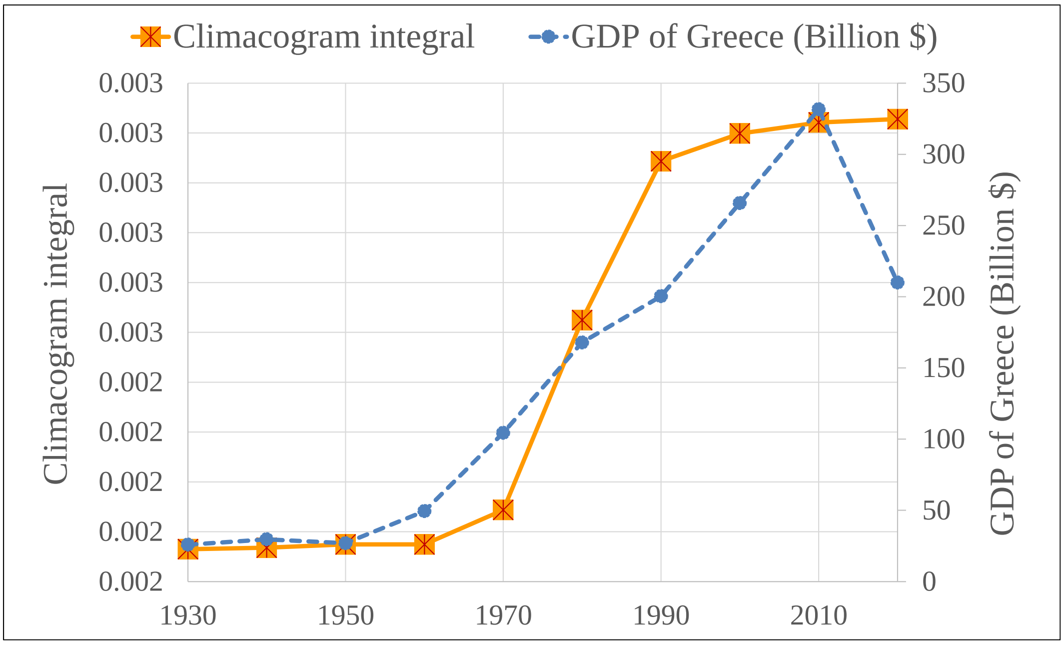


Figure 2.10 Rate of alteration of clustering through time of water bodies in Greece through the construction of large dams, related to GPD of Greece (**Figure 2.9**).

2.2 Human society clustering

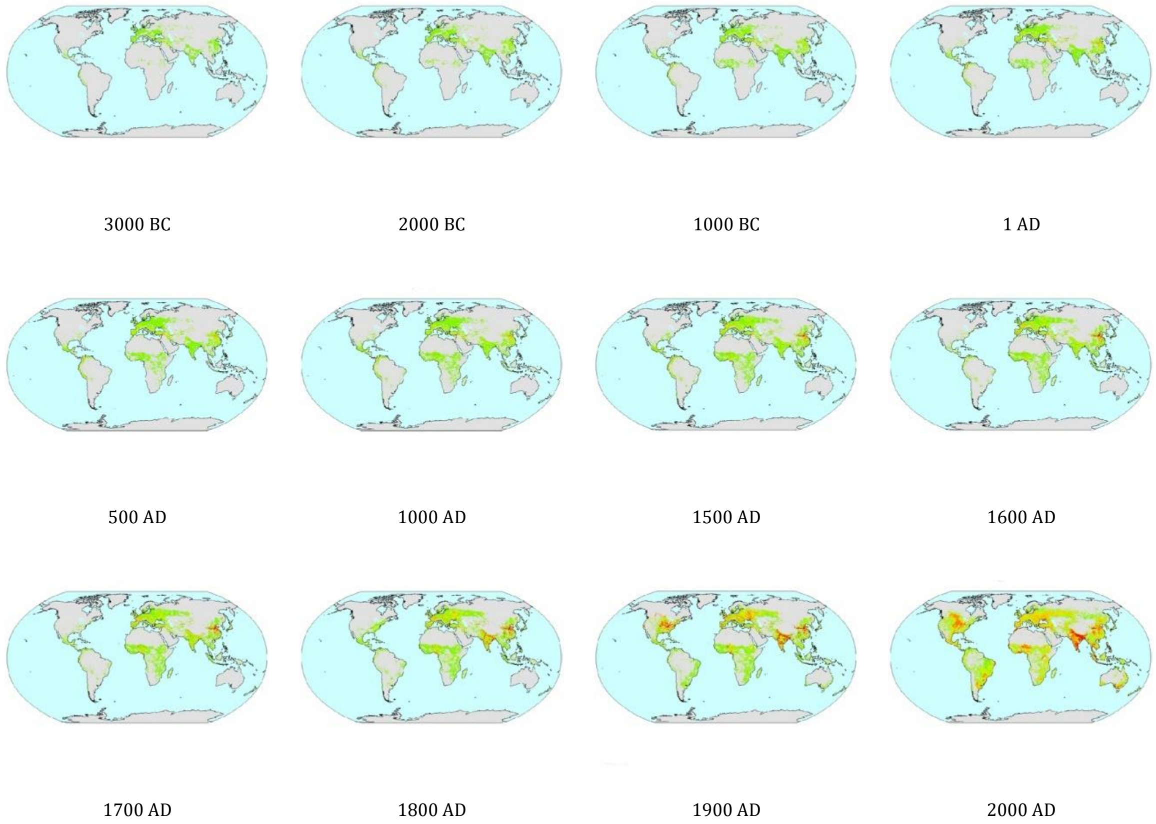


Figure 2.11 Evolution of cropland area; historical data from 3000 BC to AD 2000 (Klein Goldewijk et al., 2011).

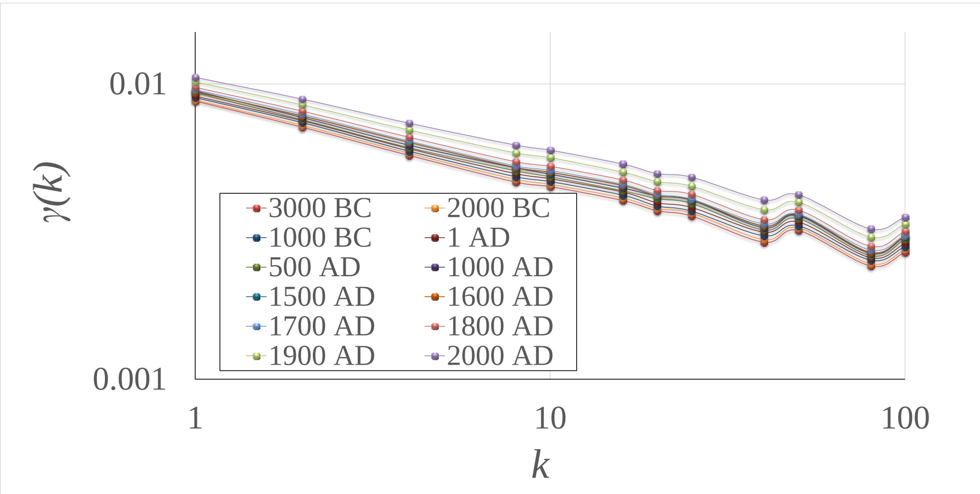


Figure 2.12 Climacograms of cropland areas (**Figure 2.11**).

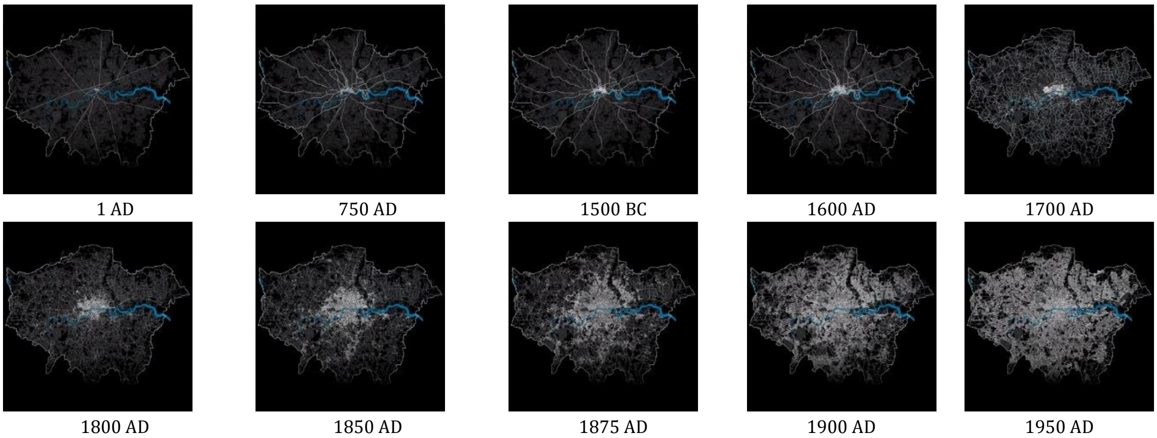
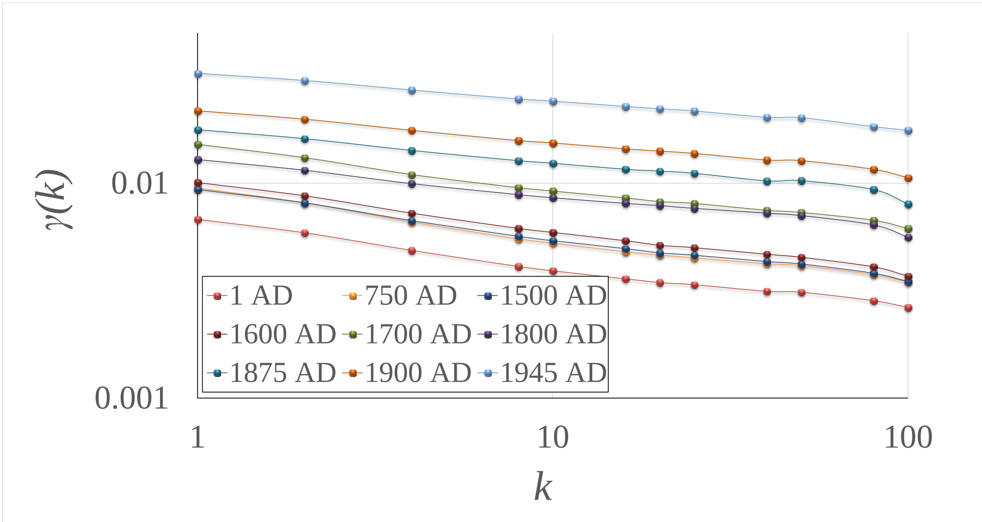


Figure 2.13 Evolution of London; historical data from 1 AD to 1950 AD[I]..



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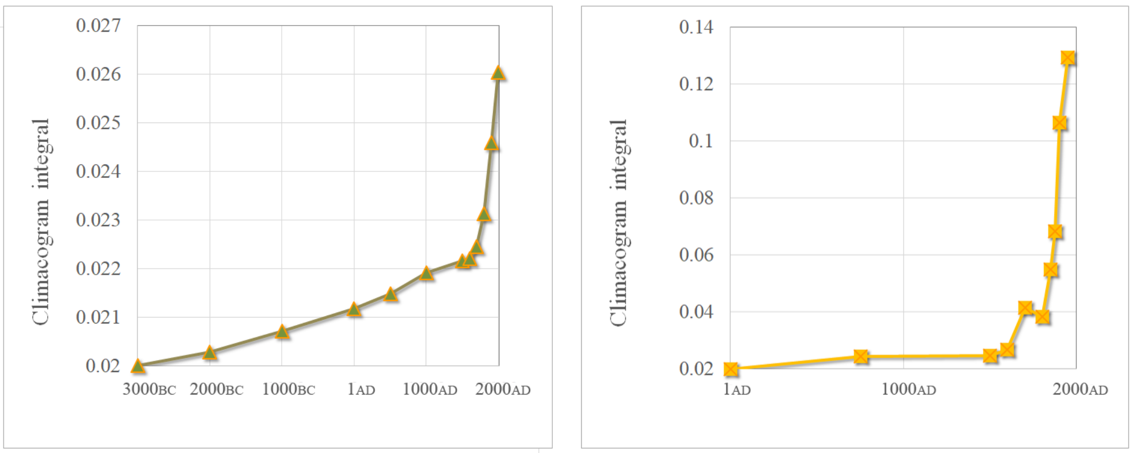
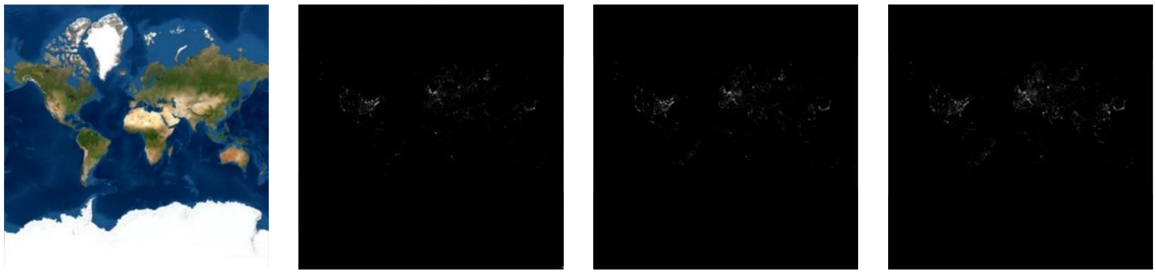


(a) (b)

Figure 2.15 Evaluation of climacograms and rhythm of clustering (a) cropland land historical data (**Figure 2.12**); (b) evolution of urbanization in London area (**Figure 2.14**).

[I] Source: https://www.theguardian.com/cities/2014/may/15/the-evolution-of-london-the-citys-near-2000-year-history-mapped (accessed 17.2.2022)



(a) (b) (c) (d)

Figure 2.16 (a) Mercator projection of earth and its night lights in (b) 1992; (c) 2002; (d) 2012.

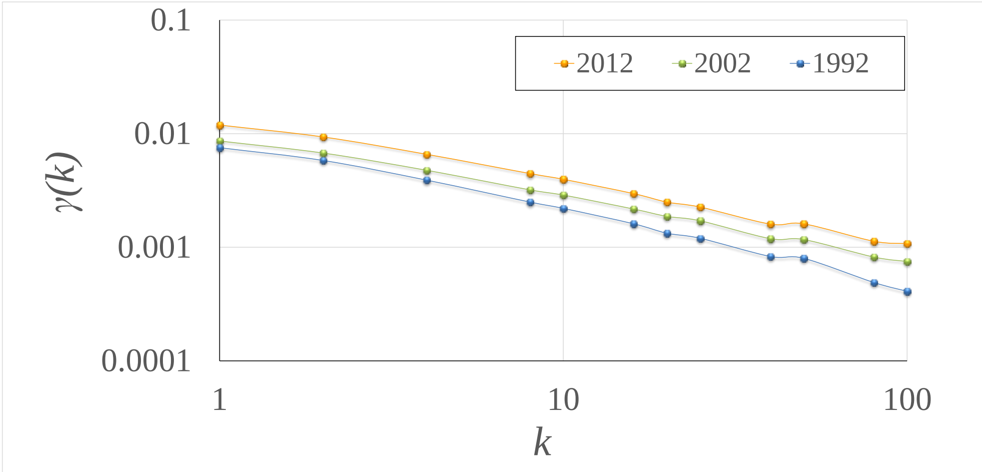


Figure 2.17 Climacograms of the images of night lights of the earth **(Figure 2.16).**

(a) (b) (c) (d)

Figure 2.18 Earth in Mercator projection of urbanization in (a) 1900; (b) 1930; (c) 1960; (d) 1990; (e) 2010.

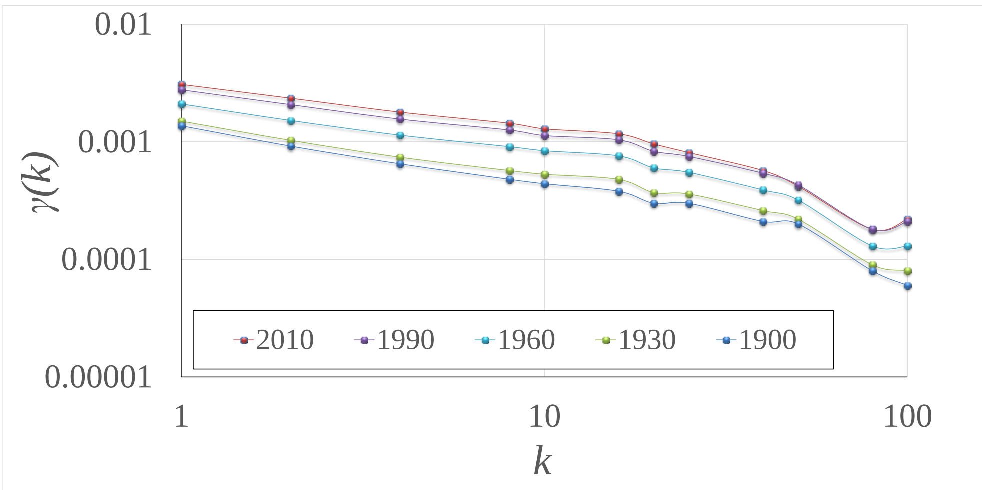
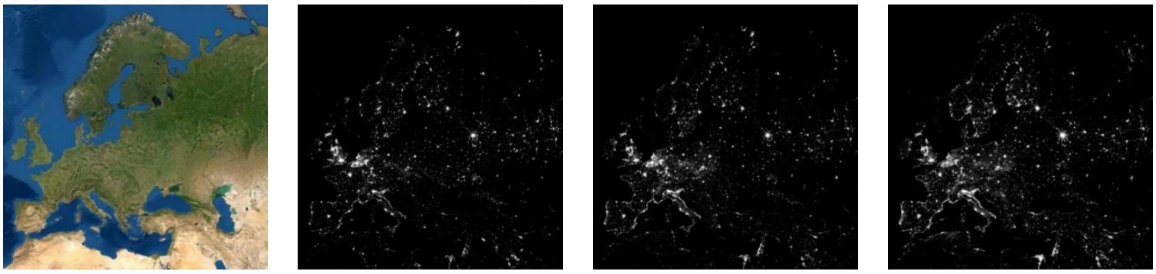


Figure 2.19 Climacograms of urbanization's clustering in worldwide (**Figure 2.19**).



(a) (b) (c) (d)

Figure 2.20 (a) Mercator projection of Europe and its night lights in (b) 1992; (c) 2002; (d) 2012.

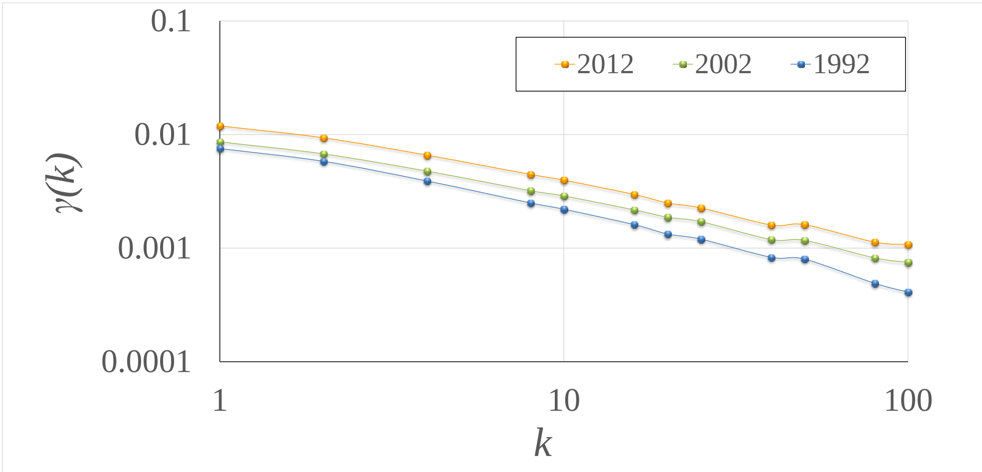
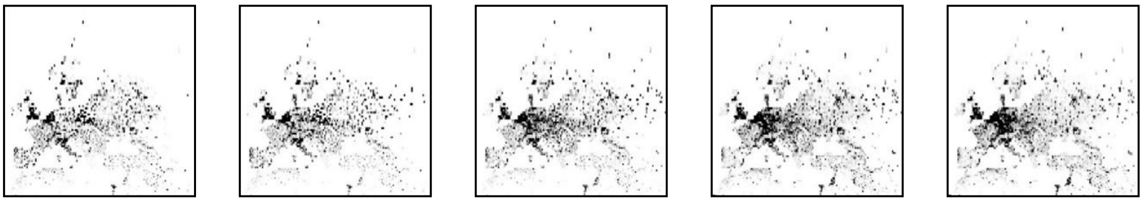


Figure 2.21 Climacograms of the images of city lights of Europe (**Figure 2.20**).



(a) (b) (c) (d)

Figure 2.22 Europe in Mercator projection of urbanization in (a) 1900; (b) 1930; (c) 1960; (d) 1990; (e) 2010.

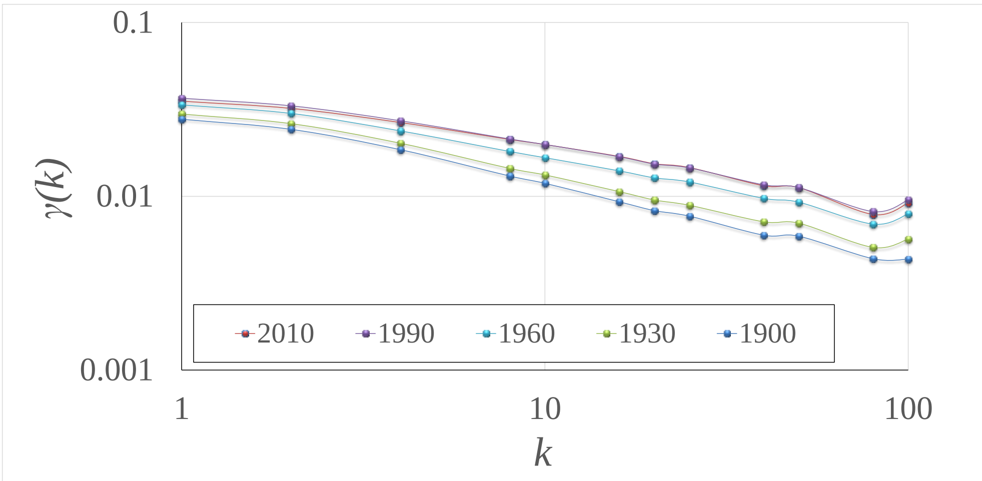
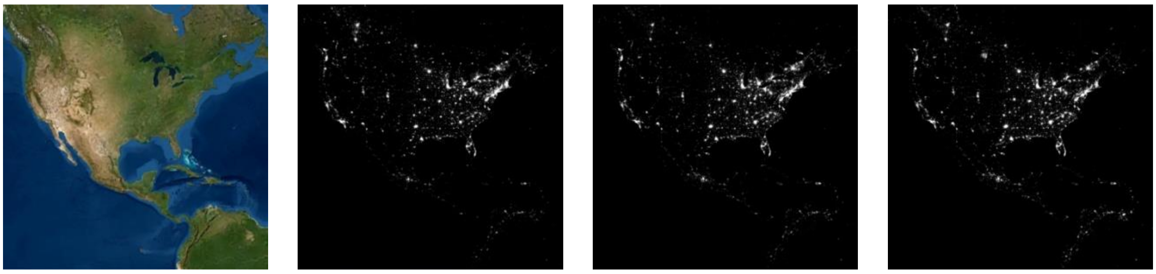


Figure 2.23 Climacograms of urbanization's clustering in Europe (**Figure 2.22**).



(a) (b) (c) (d)

Figure 2.24 (a) Mercator projection of North America and its night lights in (b) 1992; (c) 2002; (d) 2012.

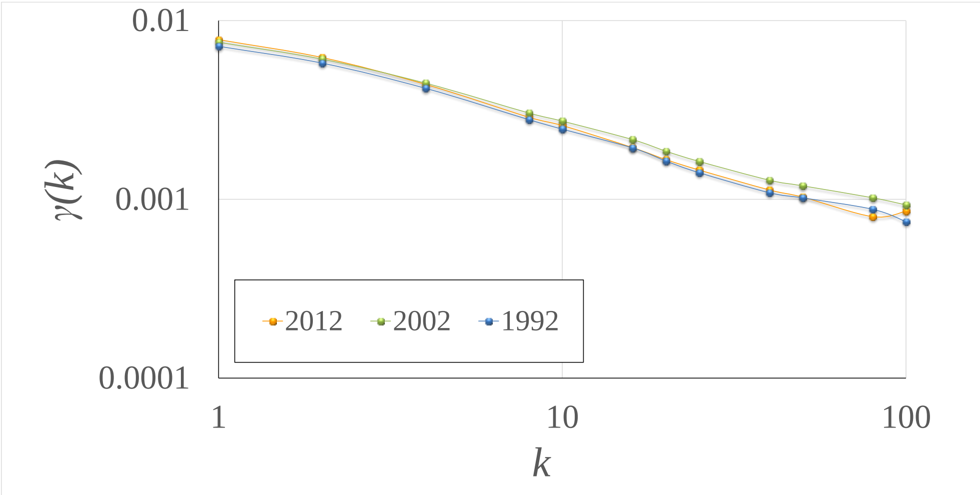


Figure 2.25 Climacograms of the images of city lights of North America (**Figure 2.24**).

(a) (b) (c) (d)

Figure 2.26 North America in Mercator projection of urbanization in (a) 1900; (b) 1930; (c) 1960; (d) 1990; (e) 2010**.**

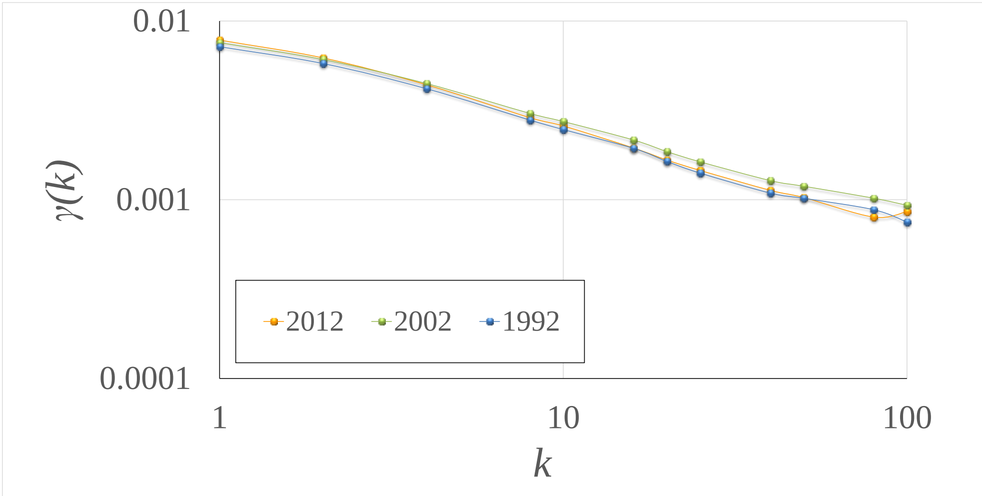


Figure 2.27 Climacograms of urbanization's clustering in North America (**Figure 2.26**).

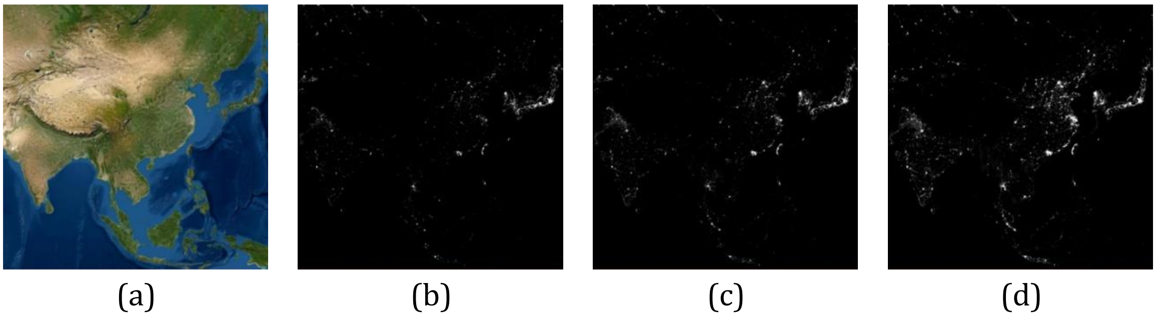


Figure 2.28 (a) Mercator projection of Asia and its night lights in (b) 1992; (c) 2002; (d) 2012.

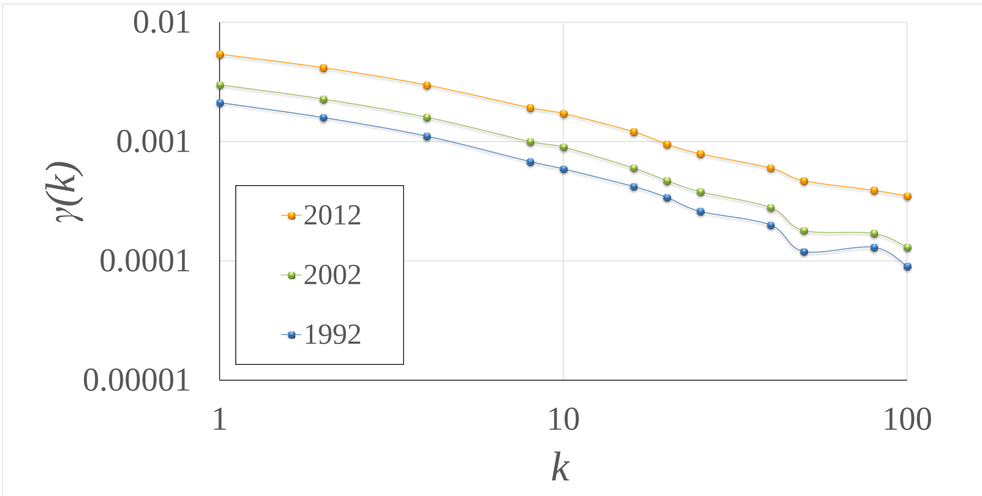


Figure 2.29 Climacograms of the images of city lights of Asia (**Figure 2.28**).

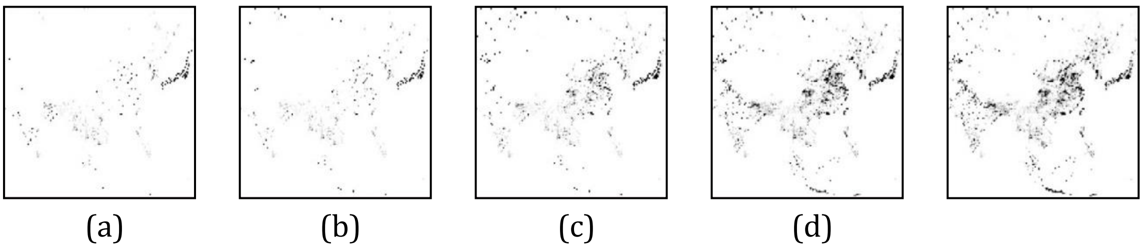


Figure 2.30 Asia in Mercator projection of urbanization in (a) 1900; (b) 1930; (c) 1960; (d) 1990; (e) 2010.

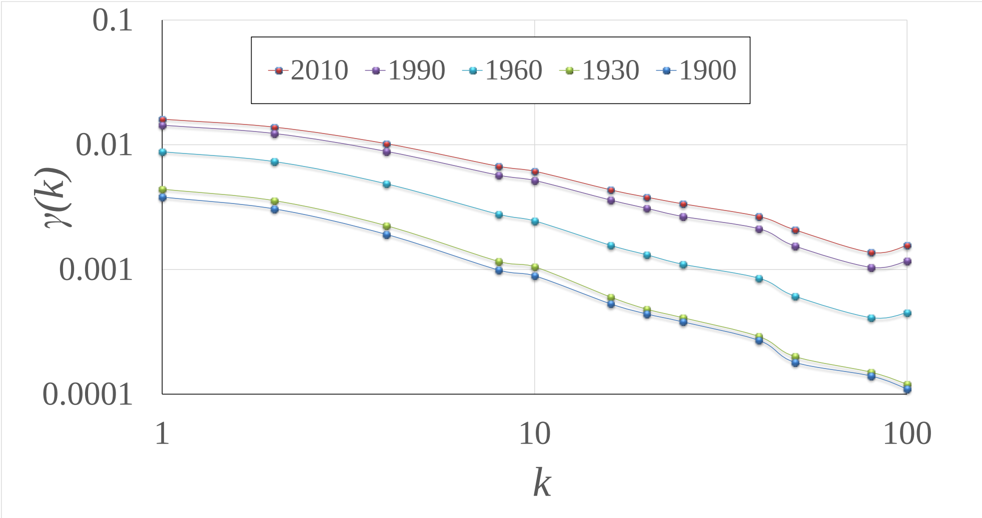
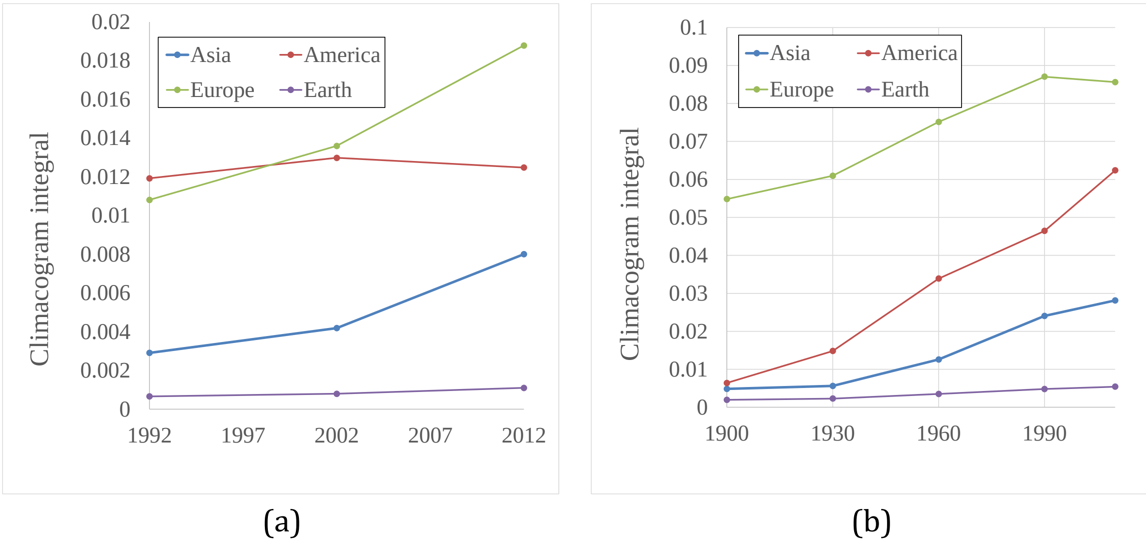


Figure 2.31 Climacograms of urbanization's clustering in Asia (**Figure 2.30**).



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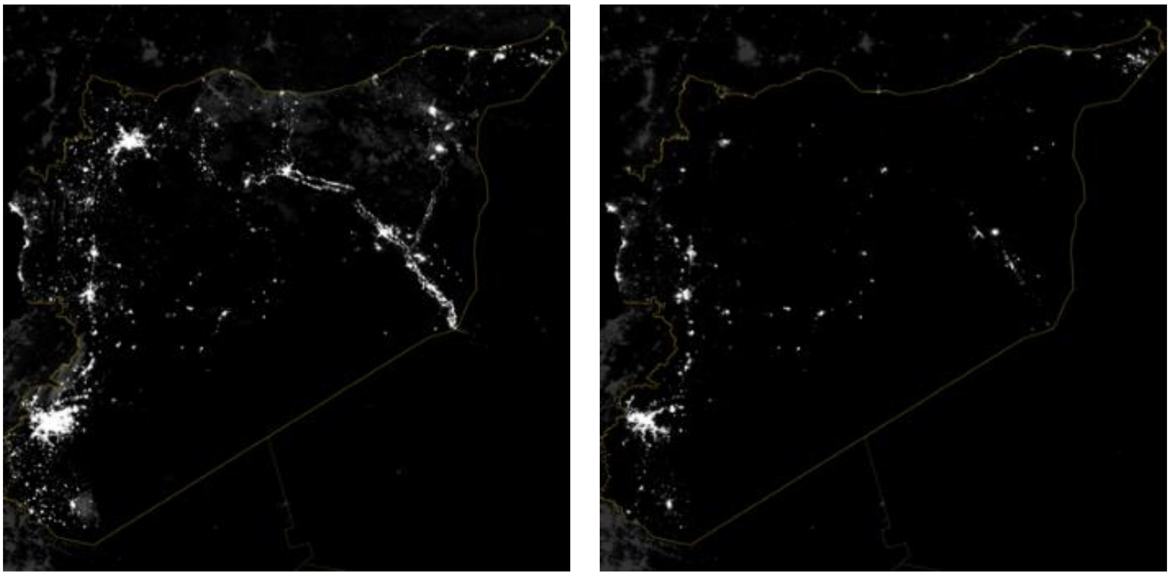
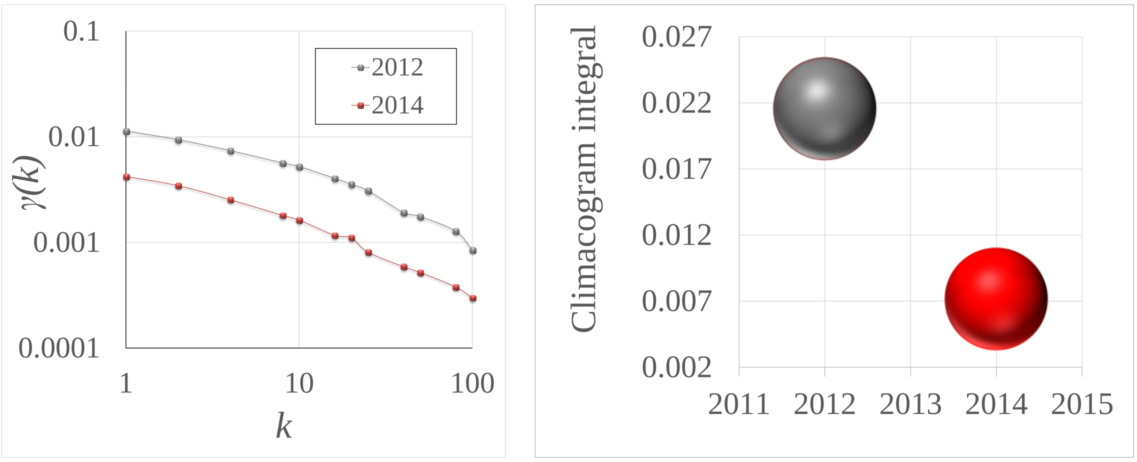


(a) (b)

Figure 2.33 Satellite night lights of Syria [8] (a) 2012; (b) 2014.



(a) (b)

Figure 2.34 (a) Climacograms, declustering of urbanization in Syria[I] (**Figure 2.33**) (b) Rate of alteration of clustering before and after war (**Figure 2.34**a).

[I] Data retrieved on 2022-02-17 by https://www.nytimes.com/interactive/2015/03/12/world/middleeast/syria-civil-war-after-four-years-map.html?mc_cid=bbef5eadb7&mc_eid=236cd449ae&_r=0

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