Realistic Maximisation of Environmental Sustainability at the Country Level Using Evolutionary Strategies

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Abstract— An assortment of evolutionary strategies (EvS's) is put forward for guiding interested countries towards the maximisation of their environmental sustainability (ES); a demonstration on the Environmental Sustainability Index (ESI) 2005 is used here as proof of concept. The proposed EvS's employ: (a) as inputs, the sets of (indicator/component) construct values of the ESI 2005 hierarchy which have been established by ES experts as both significant and sufficient in determining country ES; (b) as output, a singleton score reported in the relevant primary literature expressing the level of ES attained by the country of interest; (c) as fitness function, the quantitative expression of ES (country scores) calculated from the country-specific construct values of (a) and reproduced here via the most accurate approximation linking (a) and (b); (d) quasi-monotonic ES improvements, implemented via the application of exclusively positive mutations whose magnitude is proportional to the correlation between each (to-be-mutated) parameter and the remaining parameters. A number of EvS's are implemented from the possible combinations of direct and step-wise approximations between ESI 2005 constructs and scores of the participating countries. Each EvS has been found capable of guiding any country (either participating in the creation of the index or with data that is compatible to that of the ESI 2005) towards maximal ES via the generation of improvement paths that implement the (i) realistic and (ii) gradual, yet effective, maximisation of country ES. Given that the created paths are largely construct-dependent, it is possible to select the representation (construct) that effectuates the most efficient and/or feasible ES improvement path for each country of interest. A further extension would be to also select the most appropriate representation (construct) at each step of the EvS-guided process for achieving maximally versatile as well as efficient step-wise decision-making towards ES maximisation at the country level; the latter is put forward as a subject of future research.

Keywords—environmental sustainability, environmental sustainability index, evolutionary strategy, mutation, selection, indicator/component construct, improvement paths, optimization, maximal sustainability

I. INTRODUCTION

The early 1990s constitute a milestone in terms of the rising awareness of governments as well as of the citizens in issues relating to environmental sustainability (ES). Among other initiatives, the ensuing pro-ES "motion" has resulted in a concerted effort to understand and improve ES at the global level via the undertaking of pertinent actions at the country level [1]. For ease of comprehension as well as of the implementation of straightforward inter-country comparisons, the level of ES is conveyed in the form of a scalar "index"/score (customarily in the [0 100] range) which expresses the "quality" of life attained by each participating country, as this is aggregated in a hierarchical manner over air, land and water. The interested reader is referred to [2] for more details on ES issues and ES-related indices.

Extensive data needs to be amassed for the creation of any ES-related index, with collection being (A) focused upon salient parameters which span the three pillars of ES, namely environment, society and economy [3] and (B) performed in a uniform manner over all the countries which participate in the creation of the index. As is customary for such indices of global interest, the collected data is (a) processed in a hierarchical manner for constructing progressively more comprehensive notions of ES (namely principles that highlight the relationships between ES-related parameters at increasing levels of abstraction) and (b) ultimately combined into a singleton expression of ES which provides a quantitative, straightforward indication of where the ES level of a given participating[1] country stands relative to that of the other participating countries as well as to absolute ES. Complementary to the scalar representation of ES, the expression of ES via construct values at any given (other than the lowest, the "variable"|) level of the hierarchy promotes focused inter-country comparisons in terms of more specific ES strategies and attainment which canbe used, consequently, for facilitating pertinent decision-making concerning the maximal attainable ES improvement that best suits the current ES-related characteristics and/or needs as well as priorities of the country of interest.

One of the most well-known and universally accepted extant ES-related indices is the environmental sustainability index (ESI) [4]. This index constitutes the end-result of the

[1] or non-participating, but with data that is compatible to that of the participating countries

Environmental Performance Measurement Project (EPM) [5], a collaboration between international, European and U.S.A. organisations, countries and states, with the first four versions of the ESI published in 2000, 2001, 2002 and 2005, and with its next versions appearing every other year from 2006 to this day under the name of Environmental Performance Index (EPI) [6]. The final (2005) version of the ESI is used here [2] for demonstrating the concept of implementing the gradual, viable improvement and the ultimate maximisation of ES of any participating country - as well as of any non-participating country with data that is compatible to that of the participating countries - via an evolutionary strategy (EvS)-based approach [7-9].

The remainder of this scientific contribution is organised as follows: Section II introduces the ESI 2005 in terms of constructs and their aggregation, as well as index/score evaluation and validation; Section III puts forward the EvS-based process of maximising ES at the country level while observing the constraints that promote/preclude the simultaneous improvement of pairs (as well as sets) of indicators or of components, based on their pairwise cross-correlation (CC) coefficients; Section IV critically discusses the obtained results, with – finally - Section V summarising the results obtained and concluding this scientific contribution with future extensions to the performed investigation.

II. The ESI 2005

A. Background – Index Construction

The ESI constitutes the end-product of the EPM project [5], a collaboration between international, European and U.S.A. organisations, the results of which were published in 2000, 2001, 2002 and 2005.

The ultimate ESI 2005 version of this index has been constructed on data collected from 146 countries spanning the globe [3] via a four-level hierarchy (depicted in greater detail in [4,2]) which comprises:

- The (only partly available) variable level, composed of seventy-six (76) variables which have been derived from the raw (original) data and integrated via a sequence of standardisation and unification processes.

- The indicator level, consisting of 21 indicators, the "fundamental building blocks of ES" [4], resulting from a thematic partitioning of the variables of the previous level.

- The component level, encompassing five components, with each indicator of the previous level used for the construction of exactly one component; derived from the aggregation of between three to six thematically related indicators, each component expresses a distinct salient aspect/axis of ES.

- The ESI score, expressing the ES status/level of the participating countries via a single-decimal scalar in the interval [0 100] (representing the "no" to "total" ES continuum, respectively).

B. Index Validation

Previous research [2] has shown that the numerical procedure reported in [4] for deriving the ESI 2005 scores of the 146 participating countries cannot be fully verified. The most accurate methodology for recreating the ESI 2005 scores of the 146 participating countries has been determined as the first-degree optimal-coefficient polynomial based on the 21 indicators [2]. In order to observe the hierarchy reported in the ESI 2005 literature (and further to the aforementioned optimal approximation), the ESI 2002 scores have also been derived [2] in an exhaustive manner from the various relationships between (a) the indicator and (b) the component construct(s) as well as the ESI scores, thus providing both the direct and the step-wise expressions of ES. These expressions are, subsequently, used as complementary/alternative avenues towards the improvement and eventual (near-)maximisation of ES at the country level.

Concerning ES optimisation per se, a step-wise genetic algorithm (GA) [10] methodology was developed in [11] for deriving the characteristics of the country of maximal ES from the ESI 2005 dataset as well as for implementing a uniform procedure for guiding any interested country (either participating or with compatible data to that of the countries that participate in the construction of the ESI 2005) towards maximal ES via a sequence of gradual and realistic ES-improvement transitions. The ESI score of the theoretically ideal country[4] exceeds 100, thus confirming the findings of [11] when using direct search [12] as well as simulated annealing [13], and (perhaps) suggesting the application of additional - yet unreported - constraints which prohibit the concurrent optimisation of specific sets of construct values.

III. The EvS-Based Optimisation of ES Using the ESI 2005 Dataset

A. Evolutionary Strategies (EvS)

The EvS class of EC methodologies is put forward here for improving and eventually optimising ES at the country level. The lack of the crossover operator is a key-characteristic of the EvS and one that is especially suited to the present problem: by only allowing local changes in the chromosomes, the targeted improvement of specific aspects of ES is implemented, with the to-be-improved aspects being selected independent of their order in the corresponding gene-chromosome EvS encoding. By ensuring that (a) the chromosomes of the next generation

[2] both the verification and stability of this index have been demonstrated in [2]

[3] the interested reader is referred to [2,4] for or a list of, as well as references, to such indices

[4] namely the country demonstrating maximal ES, which is represented by the maximum values of the 21 indicator constructs, as evaluated over the 146 participating countries

bear a marked similarity to their "parent" chromosomes and (b) the mutations are focused upon positively modified individual constructs, a pronounced continuity is imposed between the selected chromosomes of successive generations [5], thus guaranteeing the feasibility of the proposed improvements in construct values and, consequently, in ESI 2005 scores.

B. Expressions of EvS-Based ESI Maximisation

Complementary representations/expressions of the ESI 2005 score maximisation process are investigated, namely using

(a) as chromosomes the sets of (a.1) indicators, (a.2) components, totalling 21 and five, respectively, real-coded genes and

(b) as fitness function the direct relationships between (b.1) indicators and ESI, (b.2) components and ESI, as well as the composite relationship (b.3) from indicators through to components to ESI.

The EvS scheme selected for implementing the aforementioned score maximisation process is identical for (i) the two direct ESI 2005 derivations (formulae) from the indicator and the component construct, respectively, as well as (b) the two-step expression from the indicator through the component construct to the ESI. The EvS chromosomes represent the characteristics of the indicators or the components, totalling 21 or five real-coded genes, respectively. The population size has been set to 40 chromosomes for both constructs in order for an adequate level of diversity to be maintained at no compromise to (delay in) EvS convergence. The termination criterion has been set to 100 iterations (generations), which is translated - in practice - into concluding the ES improvement process after 100 actions have been undertaken by the country of interest for improving its ES.

As far as the indicator construct is concerned, the genes selected by the EvS to be subjected to mutation correspond to half the indicators of each component, thus implementing the most computationally complex selection procedure which, however, accomplishes maximal ES improvement; the same procedure is applied to the component construct, where three out of five components are selected and, subsequently, mutated. The inaugural mutation-derived increase in the value of the genes of either construct does not exceed 6% of the difference between the theoretical maximum and the current value of the gene (if the current value is considered capable of providing the necessary span for big improvements) and is set to 2% if such improvements are considered hard to achieve (either due to an already high value of the gene, to the increasing ESI score of the country of interest, or to other ESI-related criteria). Each change to the value of a gene also triggers limited changes to the values of the other genes, with the amount and sign of each change evaluated using the correlation matrix of the construct used for ES optimization.

The resulting population is submitted to roulette-wheel-based selection of a single chromosome and the new population is created from the repeated (40 times) application of mutation to the selected chromosome. The EvS utilises the three polynomial expressions as independent fitness functions, expressing the most accurate polynomial relations/approximations between (a) the 21 indicators and the ESI scores, (b) the five components and the ESI scores, and (c) the five sets of indicators (with each set comprising the indicators that are related to the same component) and the ESI scores, thus exhaustively implementing the entire ESI 2005 hierarchy for deriving the ESI scores.

C. EvS Performance on ES Maximisation at the Country Level

Derived from the ESI 2005 data per se and the formulae described above, the theoretical maximal values (TMVs) of the fitness functions (a) to (c) of Section II.B. amount to 165.6, 103.0 and 165.8, respectively, with the mean distance (calculated over 30 trials for each participating country, over all countries) of the EvS-derived ESI 2005 scores from the aforementioned maximal values equalling 16.2, 3.9 and 16.0, respectively. These findings highlight the significatly higher contribution of the indicator (relative to the component) construct to the observed error; this is despite the fact that the indicator-to-ESI 2005 polynomial has been found significantly more accurate than the component-to-ESI 2005 polynomial, thereby further supporting (as already mentioned at the end of Section 2) additional constraints in the concurrent improvement of both the indicator and of the component constructs.

It is important (as well as interesting) that neither of the TMVs is reached, which is unlike what has been accomplished in the past [2,11]. However, the observed inability to reach the theoretically maximal ESI scores is fully justifiable, caused by the enforcement of constraints in the concurrent improvement of a number of pairs of indicators as well as of components, as these are expressed via their negative CC coefficients: since improving one construct triggers the deterioration of the (negatively cor)related constructs, the concurrent improvement of all constructs is not possible.

In the following, comparisons in terms of evolving (increasing) ES and ESI scores are made between participating countries and improvement methodologies/ representations; Finland and North Korea (with ESI scores

[5] yet still allowing drops in the values of negatively correlated constructs

of 75.1 and 29.2, respectively) have been used for illustration purposes. The rise in ES is quite uniform over the two - as well as over all - countries (Figs. 3, 6 and 9 for the indicators/indicators-to-components/components to ESI improvement), with the distance of the maximal EvS-derived ESI 2005 score from the theoretical absolute maxima values mentioned above of 100. The ESI plots of the three EvS representations are quite uniform over the participating countries in terms of maximum ESI 2005 attained as well as shape of improvement, though not necessarily of construct improvement, as this depends on the reported [4] (and used as initial for the EvS) construct values of each country. Priority is given to the constructs that have initial low values relative to the respective maxima, since – according to the EvS fitness function – prioroty is given to improving low construt values. The non-monotonic nature of the construct-curves is due to the CC values between constructs, which implies that some construct values may decrease owing to the EvS-initiated increase of constructs which are negatively correlated to those constructs. It is important to mention that this is a realistic situation, and the present endeavour moves a step closer to reality than existing approaches which only acknowledge the uni-directional evolution of the various constructc. Still, these fluctuations appear to be quite uniform over participating countries, between the tests on each participating country, as well as among the tests implemented using indicator, component as well as indicator-to-component based chromosomes. This is shown in Fig. 10, where the evolution curves of the three countrie used for demosntration purposes are quite similar per indicator, per component, as well as per indicator-to-component in terms of improvement of the values per se as well as of the ESI 2005 score. Countries of lower initial ESI score tend to reach comparable ESI 2005 final scores as those of higher initial ESI scores, however tey require more iterations. ? If so, what is the relationship between initial and final score?

The scores as well as trajectories over countries with different initial ESI 2005 construct profiles tend to become increasingly similar as the EvS progresses, with more time (steps) required for initially more dissimilar country ES profiles (especially when the ES indicator/component profiles are negative or low (near zero).

The curves are consistent for both constructs, all three EvS implementations, with the constructs of low initial values tending to approximate the upper limit in value of all constructs. It takes far too many iterations, however, to achieve the upper limit , convergence is approximate (no problem in practice). This is shown in Table III.

Need To Show How Consistent (In Terms Of (a) Score; (b) Indicator/Component/Indicator-To-Component Trajectory) The Curves Are Over Countries With Different Esi's And/Or Initial Values. i Think That There Is Ageneral Theme With Small Variations Depending On The Initial Construct Values, Which (Differences) Become Smaller Among Countries As Es(i) Increases.

How Well Does Esi Improvement Via Indicators Correspond To Esi Impovement Via Components (Not Necessarily Having The Same Constructs Changing).

From Which Point Onwards Is Convergence The Same For All Countries?

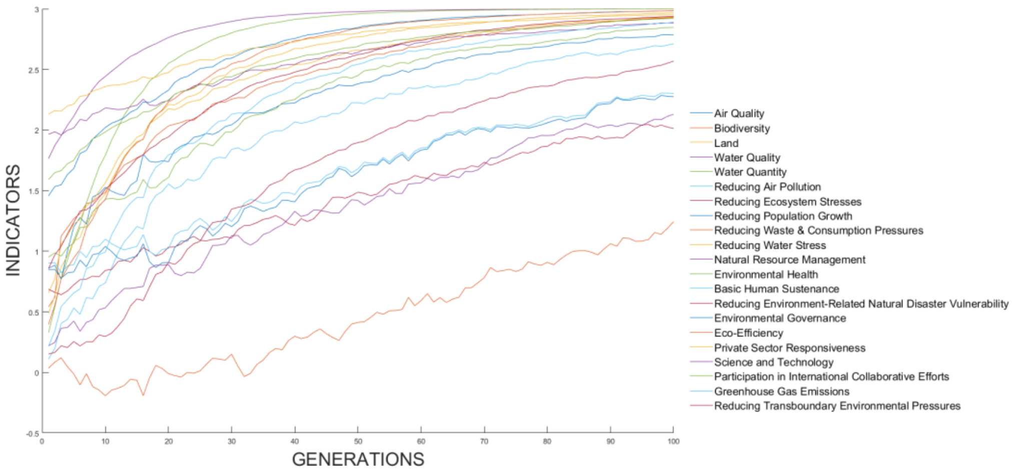


Fig 1 EVS-DERIVED EVOLUTION OF THE ESI 2005 INDICATORS TO ESI: FINLAND

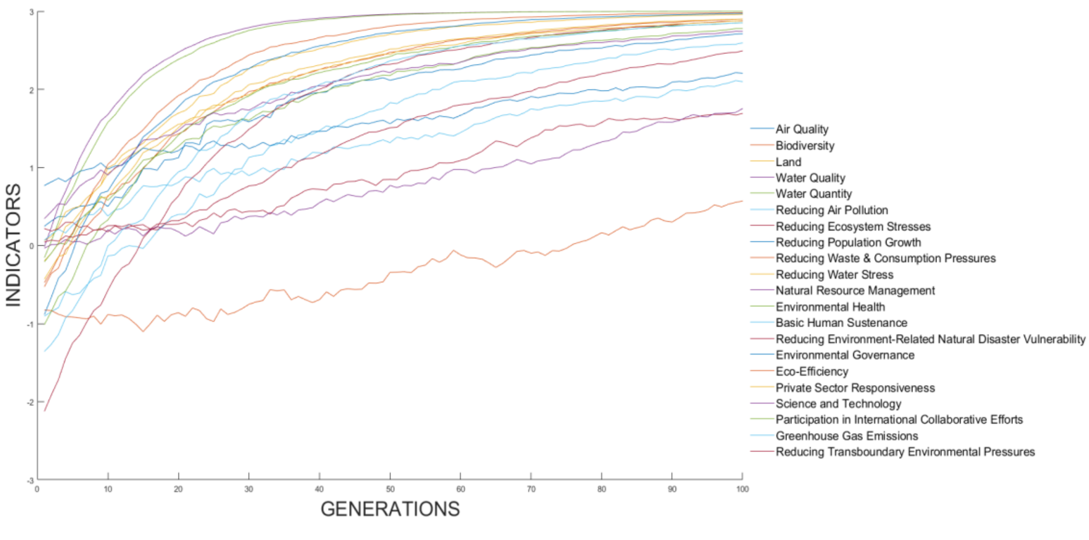


Fig 2 EVS-DERIVED EVOLUTION OF THE ESI 2005 INDICATORS TO ESI: NORTH KOREA

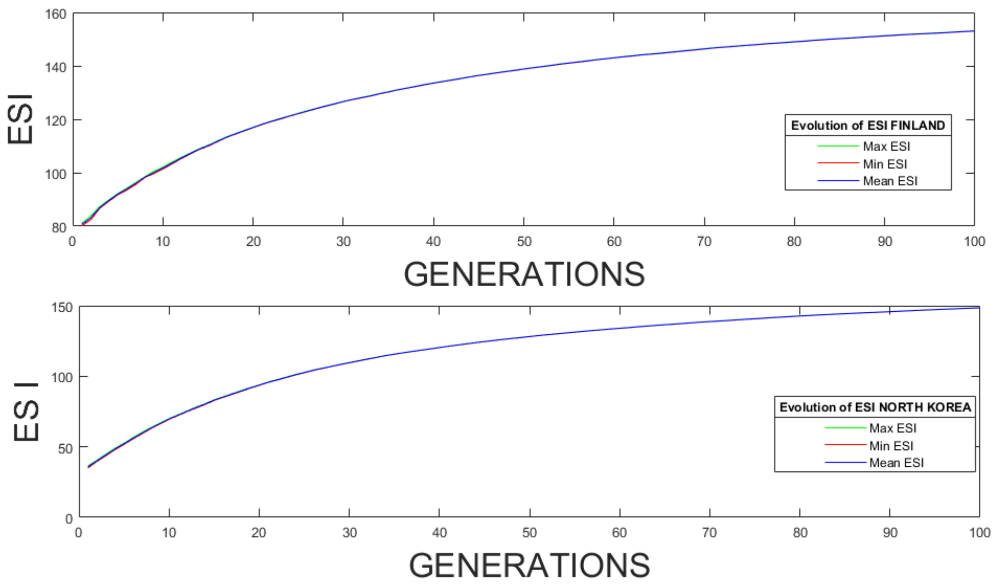
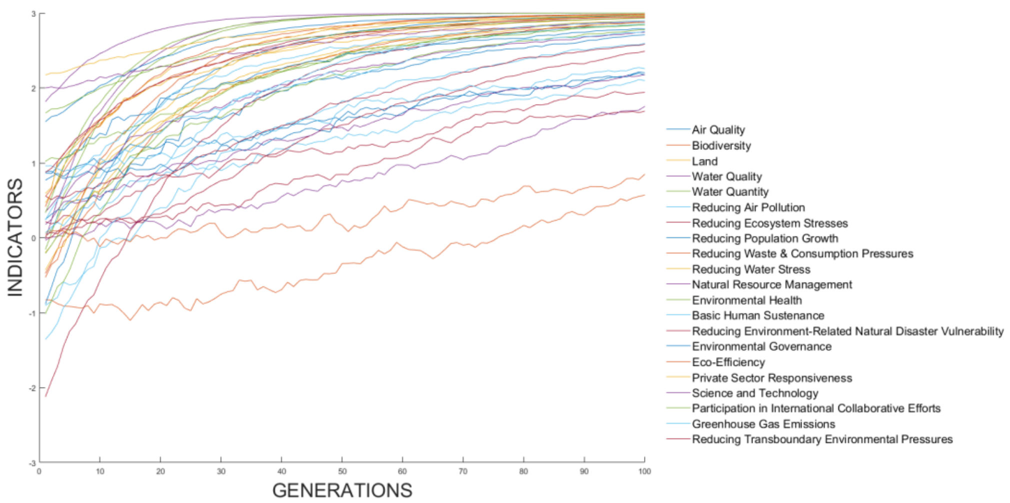
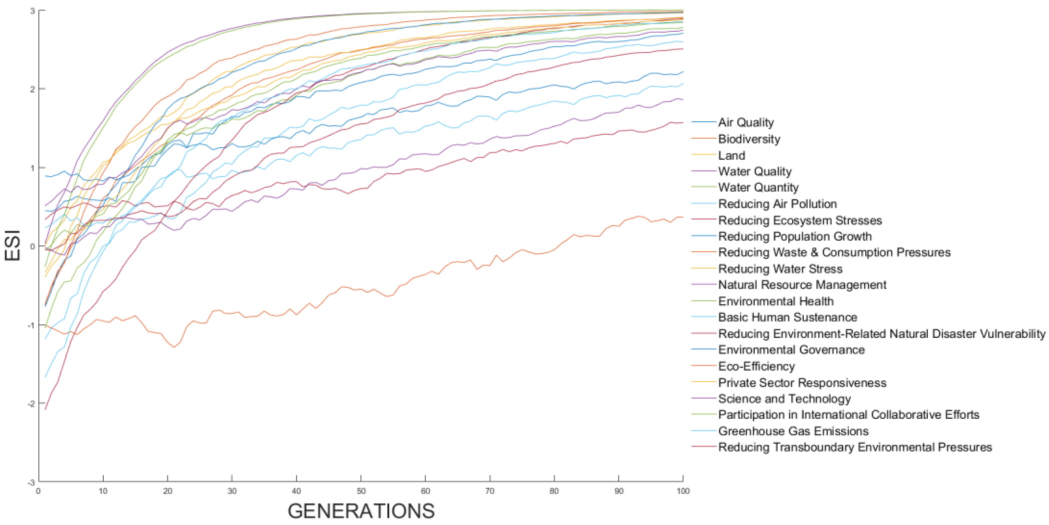


Fig 3 EVS-DERIVED EVOLUTION OF THE ESI 2005 SCORE FOR FINLAND AND NORTH KOREA (BASED ON THE ESI 2005 INDICATORS)





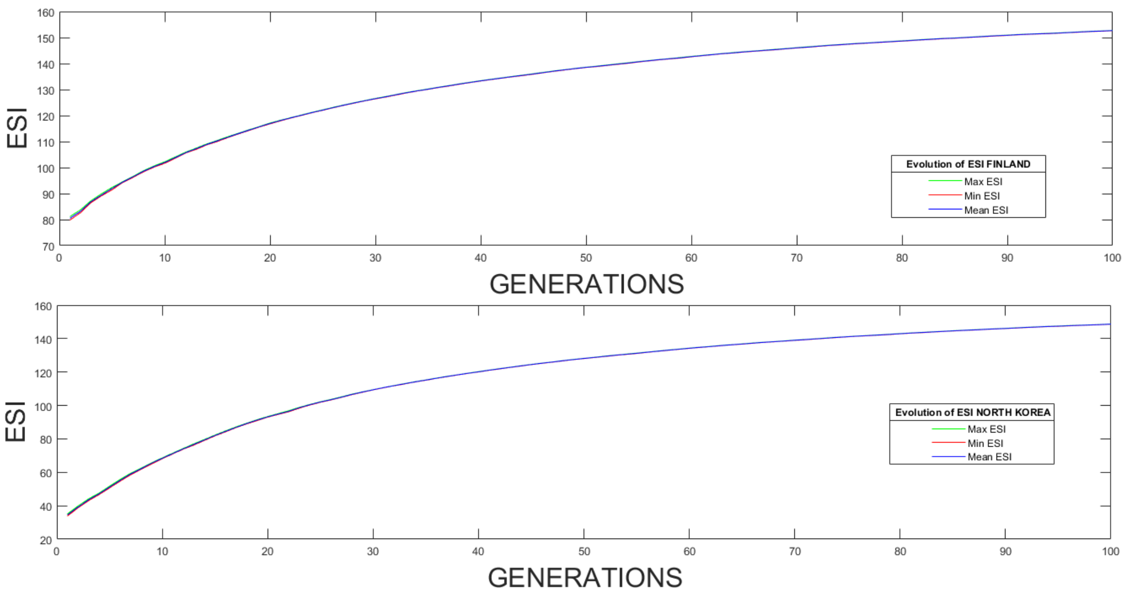
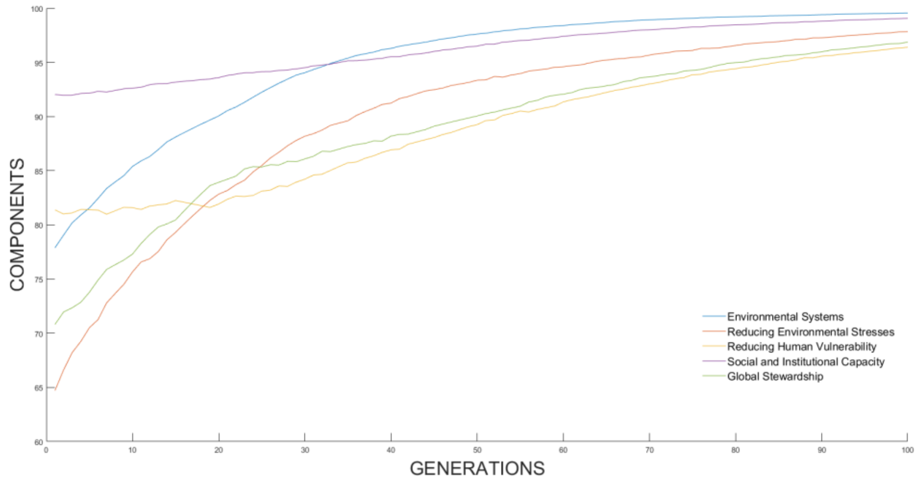
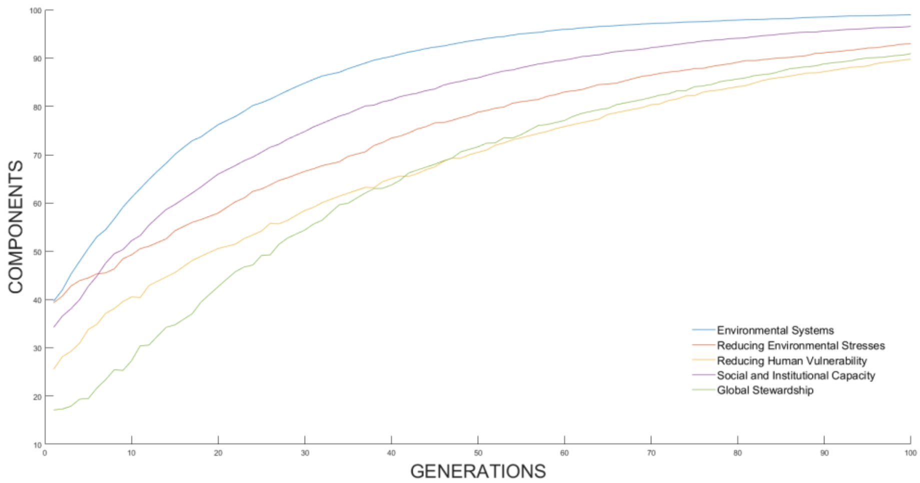
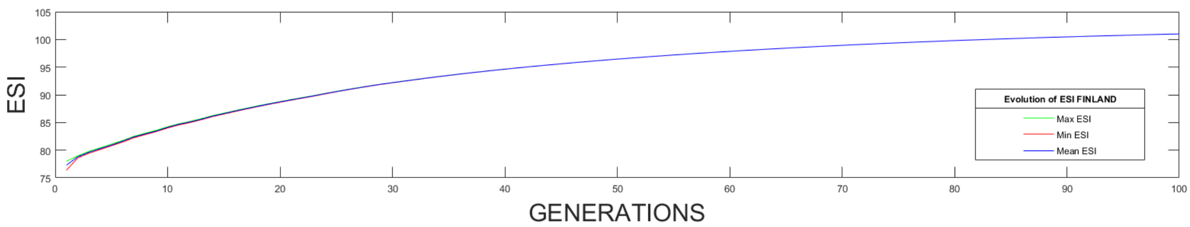
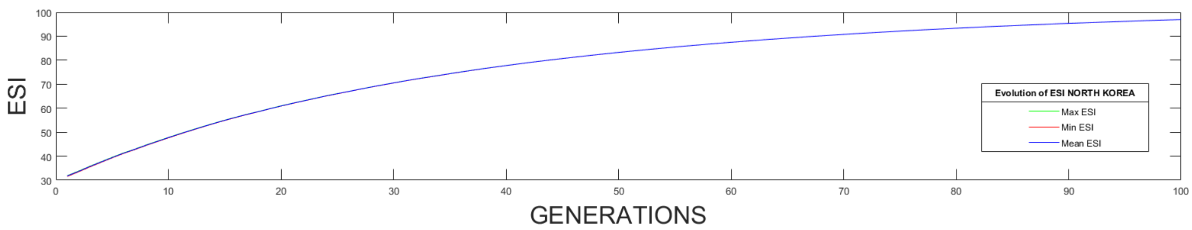


Fig 6 EVS-DERIVED EVOLUTION OF THE ESI 2005 SCORE FOR FINLAND AND NORTH KOREA (BASED ON THE ESI 2005 INDICATORS TO COMPONENTS)


COMPONENTS
GENERATIONS
Environmental Systems
Reducing Environmental Stresses
Reducing Human Vulnerability
Social and Institutional Capacity
Global Stewardship


COMPONENTS
GENERATIONS
Environmental Systems
Reducing Environmental Stresses
Reducing Human Vulnerability
Social and Institutional Capacity
Global Stewardship


ESI
GENERATIONS
Evolution of ESI FINLAND
Max ESI
Min ESI
Mean ESI


ESI
GENERATIONS
Evolution of ESI NORTH KOREA
Max ESI
Min ESI
Mean ESI

Finland		North Korea	
initial indicators	EvS-derived indicators	initial indicators	EvS-derived indicators
0.89	2.79	0.23	2.70
0.37	2.94	-0.76	2.90
0.43	2.93	-0.13	2.89
1.61	3.00	-0.46	2.99
-0.14	2.99	-0.59	2.99
-0.17	2.76	-1.03	2.59
0.64	1.94	0.20	1.56
0.91	2.17	0.70	2.21
-0.02	0.85	-0.76	0.36
0.15	2.97	-0.40	2.96
0.09	2.17	0.03	1.86
0.94	2.83	-0.41	2.77
0.97	2.25	-0.05	2.06
0.77	2.95	-2.41	2.89
1.40	2.98	-1.29	2.96
0.03	2.98	-0.83	2.98
2.12	2.95	-0.73	2.87
1.98	2.87	0.19	2.74
1.55	2.93	-1.46	2.84
-0.09	2.89	-1.59	2.84
-0.05	2.58	0.02	2.50

Table III

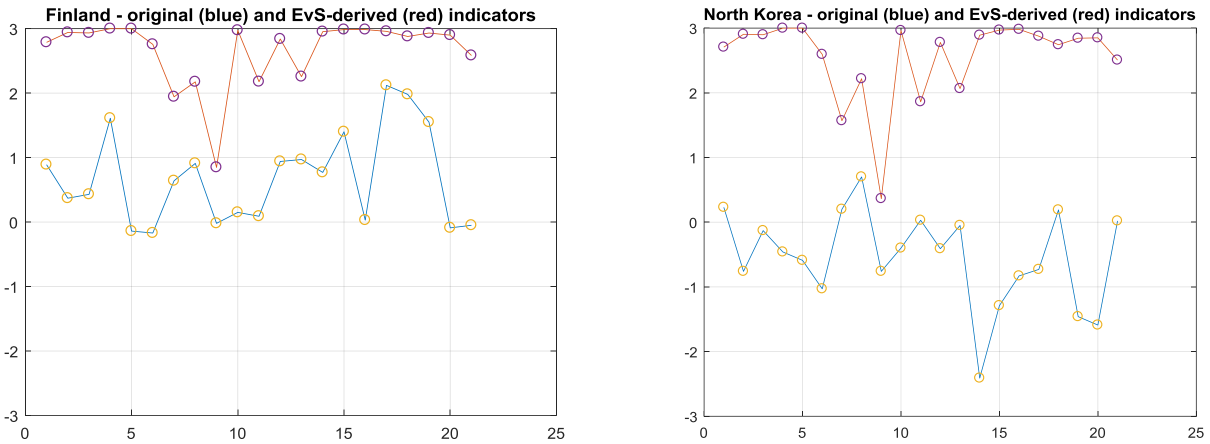


Fig 10 ORIGINAL AND FINAL (EVS-DERIVED) INDICATORS FOR FINLAND AND NORTH KOREA; MARKED SIMILARITY OF THE INDICATOR VALUES FOR THE TWO COUNRIES AT THE END OF THE EVS IMPROVEMENT PROCESS

Country	Initial ESI	Ind→ ESI	Comp→ ESI	Ind→ Comp→ ESI
Albania	58.8	151.4	99.9	151.9
Algeria	46.0	151.6	98.9	151.9
Angola	42.9	149.7	98.1	150.1
Argentina	62.7	150.5	99.9	150.9
Armenia	53.2	150.8	99.3	151.2
Australia	61.0	150.5	99.6	151.0
Austria	62.7	150.7	100.4	151.1
Azerbaijan	45.4	150.6	98.5	151.0
Bangladesh	44.1	150.6	99.1	151.1
Belarus	52.8	151.6	99.5	151.8
Belgium	44.4	149.5	100.0	150.0
Benin	47.5	149.1	99.6	149.6
Bhutan	53.5	150.0	99.2	150.4
Bolivia	59.5	150.1	99.2	150.6
Bosnia & Her	51.0	150.7	99.2	151.1
Botswana	55.9	150.0	99.0	150.5
Brazil	62.2	150.7	99.8	151.3
Bulgaria	50.0	150.5	99.2	150.9
Burkina Faso	45.7	149.4	99.1	149.9
Burundi	40.0	148.0	98.6	148.5
Cambodia	50.1	149.3	99.2	149.8
Cameroon	52.5	149.6	98.9	149.5
Canada	64.4	150.0	99.9	150.6
Cent Afr Rep	58.7	150.1	99.7	150.5
Chad	45.0	148.9	98.9	149.3
Chile	53.6	150.0	99.2	150.5
China	38.6	148.7	98.3	149.1
Colombia	58.9	150.5	99.3	150.8
Congo	53.8	149.6	98.6	150.0
Costa Rica	59.6	151.0	100.1	151.4
Côte d'Ivoire	47.3	149.0	99.0	149.5
Croatia	59.5	151.7	99.9	152.1
Cuba	52.3	150.7	99.6	151.2

Czech Rep.	46.6	149.6	99.6	150.0
D. R. Congo	44.1	148.6	98.5	149.1
Denmark	58.2	150.2	100.8	150.8
Domin. Rep.	43.7	150.5	98.6	150.9
Ecuador	52.4	150.2	98.7	150.7
Egypt	44	150.5	98.6	151.0
El Salvador	43.8	148.7	99.2	149.3
Estonia	58.2	150.5	99.6	150.9
Ethiopia	37.8	148.2	98.2	148.7
Finland	75.1	152.6	101.0	153.1
France	55.2	149.7	100.1	150.2
Gabon	61.7	150.3	99.3	150.8
Gambia	50.0	150.0	99.3	150.3
Georgia	51.5	151.6	99.4	152.0
Germany	57.0	150.4	100.6	150.8
Ghana	52.8	149.3	99.9	150.0
Greece	50.1	150.5	99.8	151.1
Guatemala	44.0	149.1	98.4	149.7
Guinea	48.1	149.1	99.1	149.5
Guin-Bissau	48.6	149.8	98.6	150.2
Guyana	62.9	151.0	99.2	151.4
Haiti	34.8	149.4	98.2	149.9
Honduras	47.4	150.4	98.8	150.9
Hungary	52.0	150.5	99.9	151.0
Iceland	70.8	150.8	100.4	151.3
India	45.2	150.3	99.5	150.7
Indonesia	48.8	150.7	99.3	151.3
Iran	39.8	150.3	98.5	150.7
Iraq	33.6	148.5	97.5	149.1
Ireland	59.2	150.6	100.2	151.0
Israel	50.9	151.6	100.3	152.0
Italy	50.1	149.8	99.9	150.3
Jamaica	44.7	150.1	98.9	150.6
Japan	57.3	151.5	101.0	152.0
Jordan	47.8	150.1	98.9	150.6
Kazakhstan	48.6	150.2	98.8	150.8

Kenya	45.3	148.8	98.5	149.1
Kuwait	36.6	148.8	98.3	149.4
Kyrgyzstan	48.4	150.3	98.8	150.8
Laos	52.4	149.8	99.0	150.2
Latvia	60.4	151.4	99.9	151.7
Lebanon	40.5	149.9	98.8	151.7
Liberia	43.4	148.5	98.3	150.4
Libya	42.3	149.7	98.2	149.0
Lithuania	58.9	151.7	100.1	150.1
Macedonia	47.2	150.0	98.8	152.1
Madagascar	50.2	150.2	99.6	150.5
Malawi	49.3	148.8	98.9	149.3
Malaysia	54.0	149.9	99.4	150.4
Mali	53.7	149.1	99.5	149.6
Mauritania	42.6	147.9	97.9	148.5
Mexico	46.2	149.3	98.9	149.8
Moldova	51.2	152.2	99.3	152.6
Mongolia	50.0	148.4	98.4	148.9
Morocco	44.8	150.0	99.3	150.5
Mozambique	44.8	148.9	98.8	149.3
Myanmar	52.8	150.4	99.3	150.8
Namibia	56.8	149.4	99.2	149.9
Nepal	47.7	150.3	99.1	150.7
Netherlands	53.7	150.5	100.9	150.9
New Zealand	61.0	150.5	99.7	151.0
Nicaragua	50.2	149.9	98.6	150.2
Niger	45.0	149.4	98.9	149.8
Nigeria	45.4	150.4	99.0	150.8
North Korea	29.2	148.2	96.9	148.6
Norway	73.4	151.3	100.6	151.7
Oman	47.9	150.7	98.7	151.2
P. N. Guinea	55.2	150.3	99.0	150.9
Pakistan	39.9	149.2	98.8	149.7
Panama	57.7	148.9	99.5	150.3
Paraguay	59.7	149.8	99.5	150.3
Peru	60.4	150.4	99.7	150.9

Philippines	42.3	149.1	98.9	149.6
Poland	45.0	149.5	99.4	149.9
Portugal	54.2	150.8	100.0	151.3
Romania	46.2	150.0	98.9	150.2
Russia	56.1	150.6	99.3	151.1
Rwanda	44.8	148.5	98.9	149.1
Saudi Arabia	37.8	149.1	98.2	149.4
Senegal	51.1	149.3	100.0	149.9
Serb & Mont	47.3	150.2	99.0	150.6
Sierra Leone	43.4	149.4	98.4	149.8
Slovakia	52.8	150.3	99.6	150.7
Slovenia	57.5	150.3	99.7	150.6
South	46.2	149.5	98.6	150.0
South	43.0	149.6	99.3	150.1
Spain	48.8	150.2	99.9	150.7
Sri Lanka	48.5	150.3	99.7	150.7
Sudan	35.9	149.0	97.6	149.5
Sweden	71.7	151.4	100.9	151.8
Switzerland	63.7	151.0	100.7	151.3
Syria	43.8	150.1	98.6	150.4
Taiwan	32.7	149.3	98.5	149.8
Tajikistan	38.6	149.7	97.8	150.2
Tanzania	50.3	149.9	99.14	150.4
Thailand	49.8	149.9	99.6	150.4
Togo	44.5	148.4	98.7	148.9
Trinidad	36.3	149.7	98.3	150.3
Tunisia	51.8	150.7	99.5	151.2
Turkey	46.6	150.0	99.0	150.4
Turkmenistan	33.1	148.9	97.3	149.3
Uganda	51.3	149.3	99.6	149.8
Ukraine	44.7	150.3	98.9	150.8
Un Arab Em	44.6	149.9	98.7	150.4
Un Kingdom	50.2	149.4	99.7	149.8
United States	53.0	148.8	99.3	149.3
Uruguay	71.8	152.7	100.8	153.2
Uzbekistan	34.4	148.0	97.6	148.4

Venezuela	48.1	149.7	98.3	150.3
Vietnam	42.3	148.6	98.5	149.1
Yemen	37.3	148.5	97.7	148.9
Zambia	51.1	149.4	98.7	149.9
Zimbabwe	41.2	149.1	98.0	149.6

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