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LATVIJAS UNIVERSITATE
ANNO 1919
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SYSTEM-DYNAMIC LOOK
ON FUNCTIONALITY OF COMPLEX SYSTEM:
ENVIRONMENT-GOVERNANCE-ECONOMY-SOCIAL SPHERE

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BONUS
SCIENCE FOR A BETTER FUTURE OF THE BALTIC SEA REGION

Why system dynamic modelling?

- Understanding functionality of coastal ecosystem and even wider of coastal socio-ecological system (SES) and its governance from environmental, social and economic point of view at existing state is challenging and complex, while analysing of future scenarios under various stressors could be solved only at site per site level or by using complex mathematical systems.
- Coastal ecosystems are very sensitive to various factors such as environmental changes and anthropogenic impacts as well.
- Even minor changes in temperature, salinity and nutrient availability can lead to substantial changes in life cycle, e.g. the runoff can result in higher nutrient and/or pollutant levels in coastal waters, algae blooms that can be dangerous to both humans and marine life.

Benefits

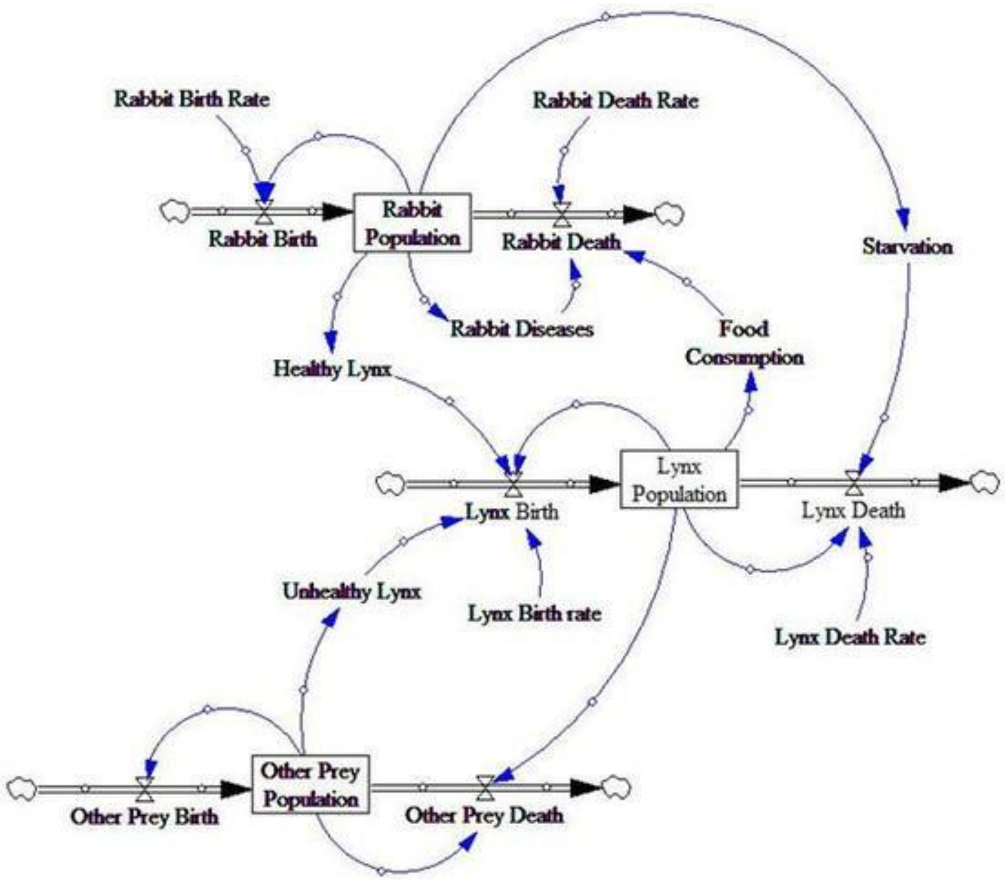
Adaptation to the climate change include evaluation of the risks for coastal ecosystems through direct impacts what could result in various ways:

(1) loss or changes to habitats and their associated organisms;

(2) warming could force species to move to higher latitudes or elevations to maintain the same environmental temperatures;

(3) sea level rise will be accompanied by saltwater intrusion into freshwater habitats, resulting that some could be forced to relocate or die, thus removing predators or prey that are critical in the existing food chain.

... systemdynamic approach can be applied from very simple to complex systems



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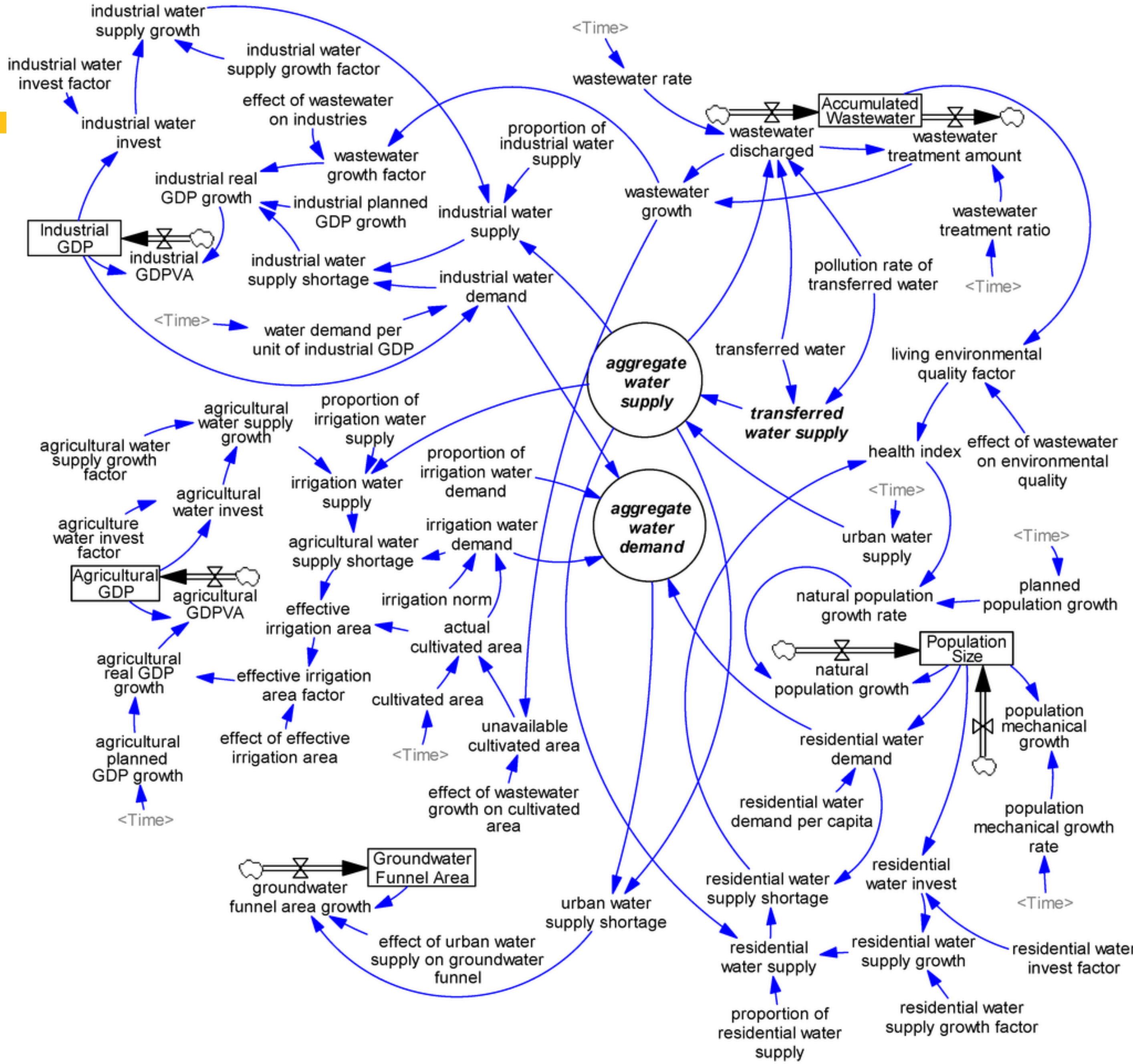
industrial water supply growth
industrial water supply growth factor
industrial water invest factor
industrial water invest
effect of wastewater on industries
wastewater growth factor
industrial real GDP growth
industrial planned GDP growth
Industrial GDP
industrial GDPVA
industrial water supply shortage
industrial water demand
industrial water supply
proportion of industrial water supply
<Time>
water demand per unit of industrial GDP
wastewater rate
Accumulated Wastewater
wastewater discharged
wastewater treatment amount
wastewater growth
wastewater treatment ratio
pollution rate of transferred water
transferred water
transferred water supply
aggregate water supply
aggregate water demand
living environmental quality factor
health index
effect of wastewater on environmental quality
urban water supply
natural population growth rate
planned population growth
Population Size
natural population growth
population mechanical growth
population mechanical growth rate
residential water demand
residential water demand per capita
residential water supply shortage
residential water invest
residential water invest factor
residential water supply growth
residential water supply
residential water supply growth factor
proportion of residential water supply
urban water supply shortage
effect of urban water supply on groundwater funnel
Groundwater Funnel Area
groundwater funnel area growth
agricultural water supply growth
agricultural water supply growth factor
proportion of irrigation water supply
irrigation water supply
proportion of irrigation water demand
irrigation water demand
agricultural water invest
agriculture water invest factor
agricultural water supply shortage
Agricultural GDP
agricultural GDPVA
effective irrigation area
irrigation norm
actual cultivated area
agricultural real GDP growth
effective irrigation area factor
cultivated area
unavailable cultivated area
agricultural planned GDP growth
effect of effective irrigation area
effect of wastewater growth on cultivated area

Main tasks

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1. Elaboration of coastal model (Salacgriva case), based on SAF methodology
2. Data collection, analysis of substantiality
3. Base scenario or „as it is“ scenario
4. Results analysis of base scenario
5. Modelling and analysis of hypothetical scenario

Methodology

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- Systems Analysis Framework (SAF) methodology:
  - definition of system borders,
  - understanding of system borders,
  - identification of crucial components,
  - building of model,
  - testing,
  - verifying processes.

Materials & data

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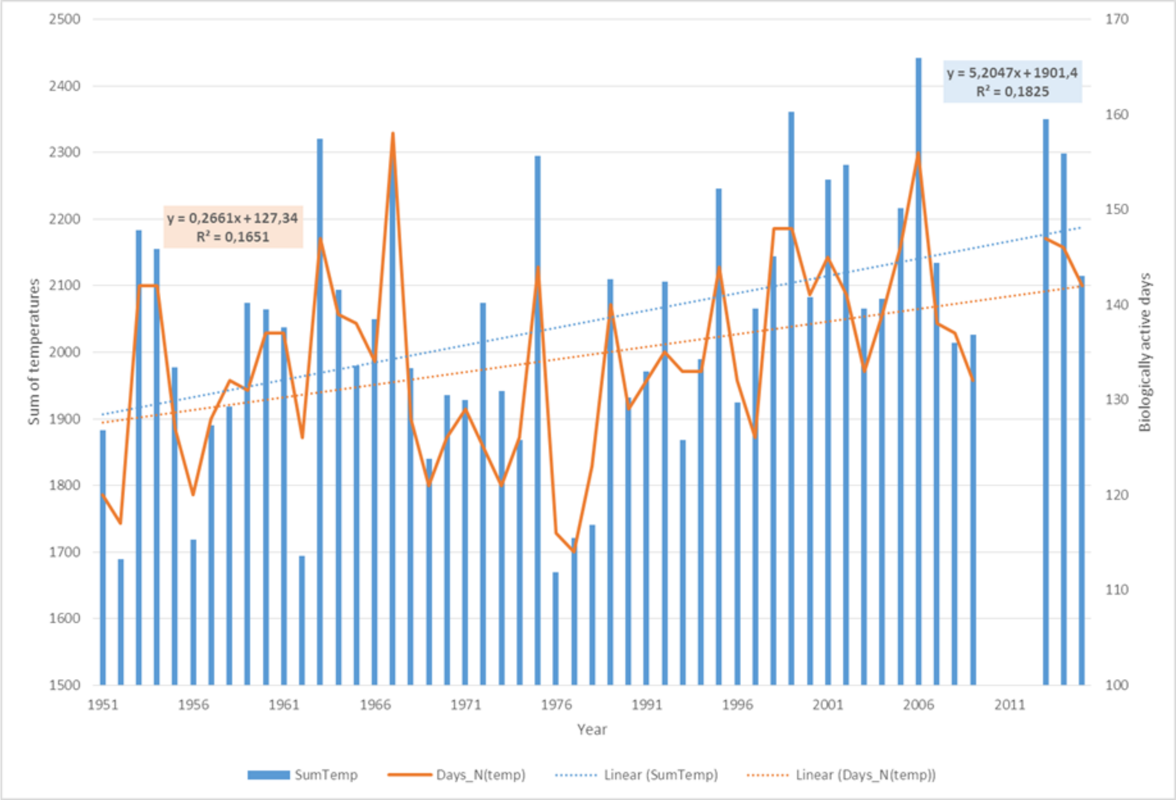
No	Parameter	Value	Unit	Period	Data Source
1	Natural monuments	6	#number	2016	Actual data[1]
2	Marine				
3	Volum				
11	Biodiverse areas (conservancy areas)	64	#number	2015	Monitoring data[9]
25	Health indicator	negative	trend	2010-2014	HealthData[16]
26	Share of higher education	14,3	%	2011	Census, 2011
4 / 27	Lifelong learning	Data not available			
28	Education level	Data not available			
29	Nature objects, biotopes	11	#number	2015	Monitoring data[9]
5 / 30	Fishing boats	157	#number	2006	Mazo ostu …[17]
31	Visual change quality	1	Good quality	2015	Field asessment
6 / 32	Dredge works	Data not available			
7 / 33	Financial resources indicator	Data not available			
8 / 34	Agricultural land	20,5	%	1995-2012	ĢIS Latvija 10.2 (2015); Corine Land Cover (2012)
35	River (Salaca) ecological quality indicator	Good	-	2010-2015	Gauja basin management plan, 2010-2015
9 / 36	Number of mobile WC	15	#number	2016	Actual data
37	Equipt sites	10	#number	2016	Actual data
38	Tourist trails	10	#number	2016	Actual data
10 / 39	Tourism centers	1	#number	2016	Actual data
40	Swim water quality	Good	-	2010-2015	Gauja basin management plan, 2010-2015
		AVG=6,56			
23	Income rate	252-322	EUR	2010-2014	CSB[15]
24	Migration rate, saldo	-3;-3;-31;-6	abs	2011-2014	CSB[15]

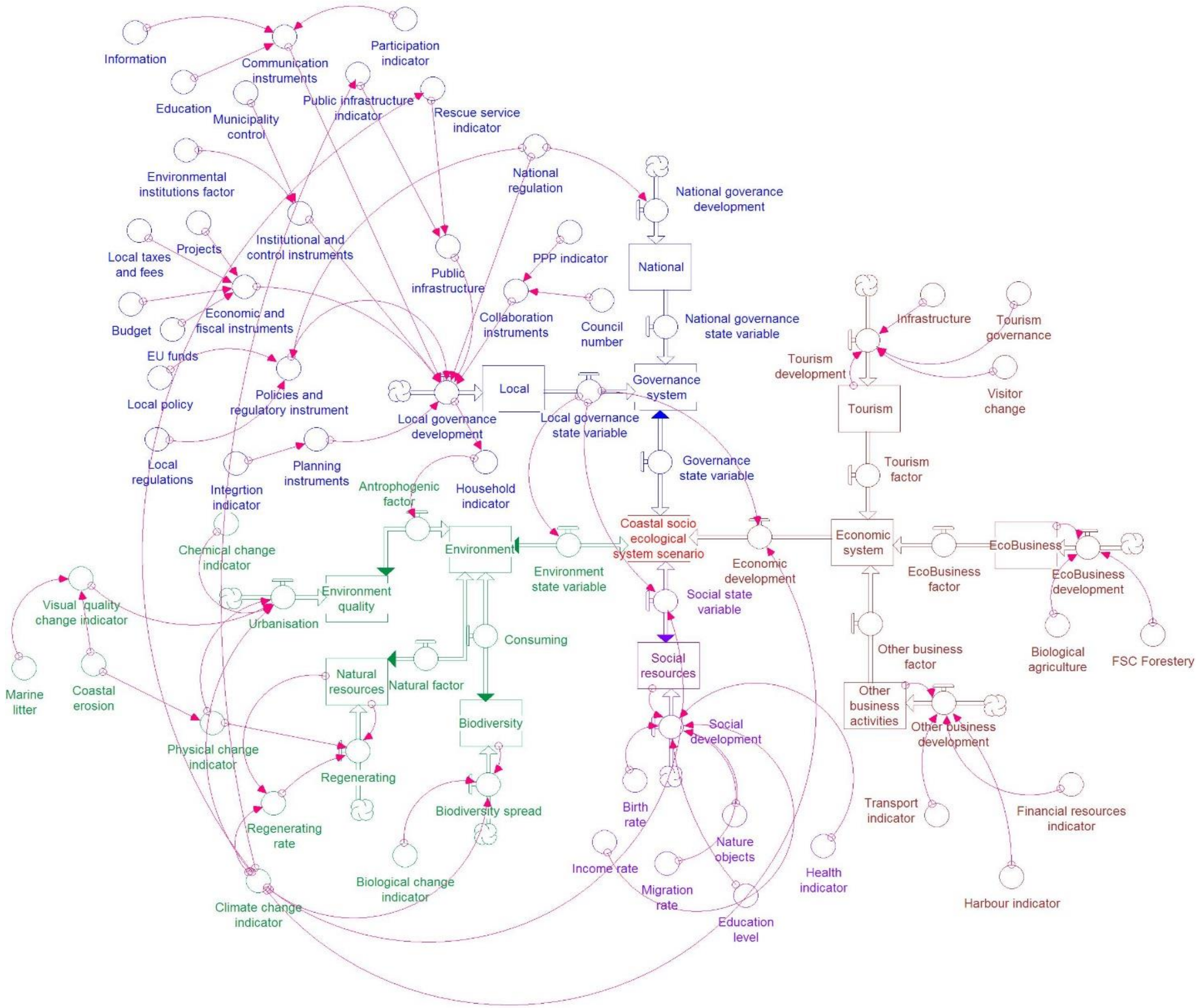
Preparation of input data

Example: variable «Biologically active days»



Number of biologically active days, 1951 – 2015

Model: coastal SEGS



Results (1)

Driving force	Formulae	Descriptives
Climate change (ClC)	$ClC = BAD * 0.13 + SWD * 0.35 - PED * 0.28$	BAD – biologically active days SWD – strong wind days PED – precipitation extreme days
Coastal changes (CoC)	$CoC = VCQ * 0.05 + VPD * 0.01 + VSS * 0.01 + ML * 0.05$	VCQ – visual change quality VPD – volume of primary dune VSS – volume of seashore silt ML – marine litter
Environment changes (EC)	$EC = NP * 0.05 + SEQI * 0.05 - SWQ * 0.01 + APS * 0.1$	NP – noise pollution SEQI – Salaca ecological quality indicator SWQ – swim water quality APS – air pollution sources
Structural changes (SC)	$SC = NM_{WC} * 0.25 + TF * 0.1 + ES * 0.15 + EBF * 0.10 + E * 0.05 + NV * 0.3$	NM_{WC} – number of mobile WC TF – traffic flow ES – equipt sites EBF – employment in bio-farming E- employment NV – number of visitors
Impact asessment (IA)	$\mathbf{IA = SC * 0.8 + EC * 0.05 + CoC * 0.1 + ClC * 0.05}$	ClC – climate change CoC – coastal changes EC – environment changes SC – structural changes

Rezults (2)

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Parameter	Baseline	Change from baseline (%)
Number of biologically active days	137 days	++ (13)
Number of strong wind cases	51 cases	++ (35)
Precipitation extreme cases	83 cases	-- (-28)
Volume of primary dune	2–4 m^3/m; Class 2	+ (<1)
Volume of seashore	10–15 m^3/m; Class 3	+ (<1)
Visitors (tourists)	1000 #/day	++ (30)
Mobile WC	15	++ (25)
Traffic flow	4399	+ (10)
Air pollution sources	4418	+ (10)
Noise pollution sources, level	High	+ (5)
Marine litter	104 pieces	+ (5)
Swim water quality	Good	- (-1)
Employment (crafts)	15	+ (5)
Employment in biological farming, forestry	10	+ (10)
Visual quality change	Good	+/- (5/-5)
Salaca ecological quality indicator	Good	- (-5)
Equipped sites	10	- (-15)

Paskaidrojumi: (+/-) – nebūtiskas izmaiņas; (++/--) – būtiskas izmaiņas

Conclusions

1. Systemic analysis of influencing factors shows main 15 key factors, which have been chosen during the study out of initially selected 40 factors - sufficiently characterising coastal socio-ecosystem and were included into the model in order to describe live and open, but also complex coastal system.
2. Detailed analysis, formulation process indicates main 4 agglomerated process drivers – environmental, coastal, climate and structural, while structural changes indicates most impressive impact.
3. It should be noted that some of factors are independent and for short term period couldn`t be affected by human while just few of these factors (e.g. structural changes in the system) are human dependent.
4. Elaborated tourism scenario shows that increase of tourists actually will have comparatively minor influence on coastal socio-ecosystem. It`s expected that even climate change impact will be more evident.

During the experts discussions SAF application shows positive practical results for several reasons:

1. during the model development phase crucial data and knowledge gaps were identified leading to practical steps and solutions between any new measures and future scenarios;
2. developed model shows kind of universality, at any development point model could be reduced or made wider according to necessity of particular social-ecological governance system.
3. tested conceptual complex system dynamic model and STELLA modelling software approach applied are showing their eventual applicability and flexibility to use it for other processes, territories and different local coastal/municipal development scenarios after some revisions depending on related new specifics.

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