Integration of the model InVEST into the model EFForTS-ABM: new tool for dynamic simulation of socio-economic functions and ecological functions (biodiversity) simultaneously

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order have to be discussed

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**Target Journals:**Methods in Ecology and Evolution, PLOS Computational Biology, Ecological Modelling

**Keywords:**ecological functions, biodiversity, socio-economic functions, EFForTS-ABM, InVEST, trade-offs, software connection

**Key message:** Demonstration of the integration of the (python-based) static terrestrial biodiversity (habitat quality) model InVEST into the (netlogo-based) dynamic land-use change model EFForTS-ABM. As a result, synergies and trade-offs between biodiversity and socio-economic functions can be assessed simultaneously and dynamically at multiple temporal and spatial scales.

# 1. Introduction

* Relationship between ecological and socio-economic functions for conservation issues
  + Ecological and socio-economic sphere (biodiversity as key index)
  + Trade-offs and Synergies and possible problems when unbalanced
  + Open question: Unclear relationship over time and space and the consequence for conservation
* Representation of both models separately
  + InVEST: ecological functions + biodiversity via ecological production functions, static model, proven model: examples of applications
  + EFForTS-ABM: socio-economic functions via land-use change model, dynamic model
* Benefits of connection of EFForTS-ABM and InVEST:
  + InVEST was developed for changes of ecosystems at different spatial and temporal scales but is a static model (as only 3 different landscapes can be used as input for simulation). Rapid assessment of biodiversity patterns and status.
  + EFForTS-ABM is a land-use change model where landscape is managed and therefore changed at every time step, which can be used as dynamic input for InVEST
  + EFForTS-ABM fits requirements to generate input for InVEST
  + Output of InVEST can be processed dynamically within EFForTS-ABM
* Aim and Hypotheses
  + Aim: Tool for simultaneously model socio-economic functions and biodiversity over time and space
  + Hypothesis: As connection is possible through narrow integrationlayer it can be easily implemented, maintained and comprehended.

# 2. Methods

* Models and procedures
  + EFForTS-ABM: Economic submodel:

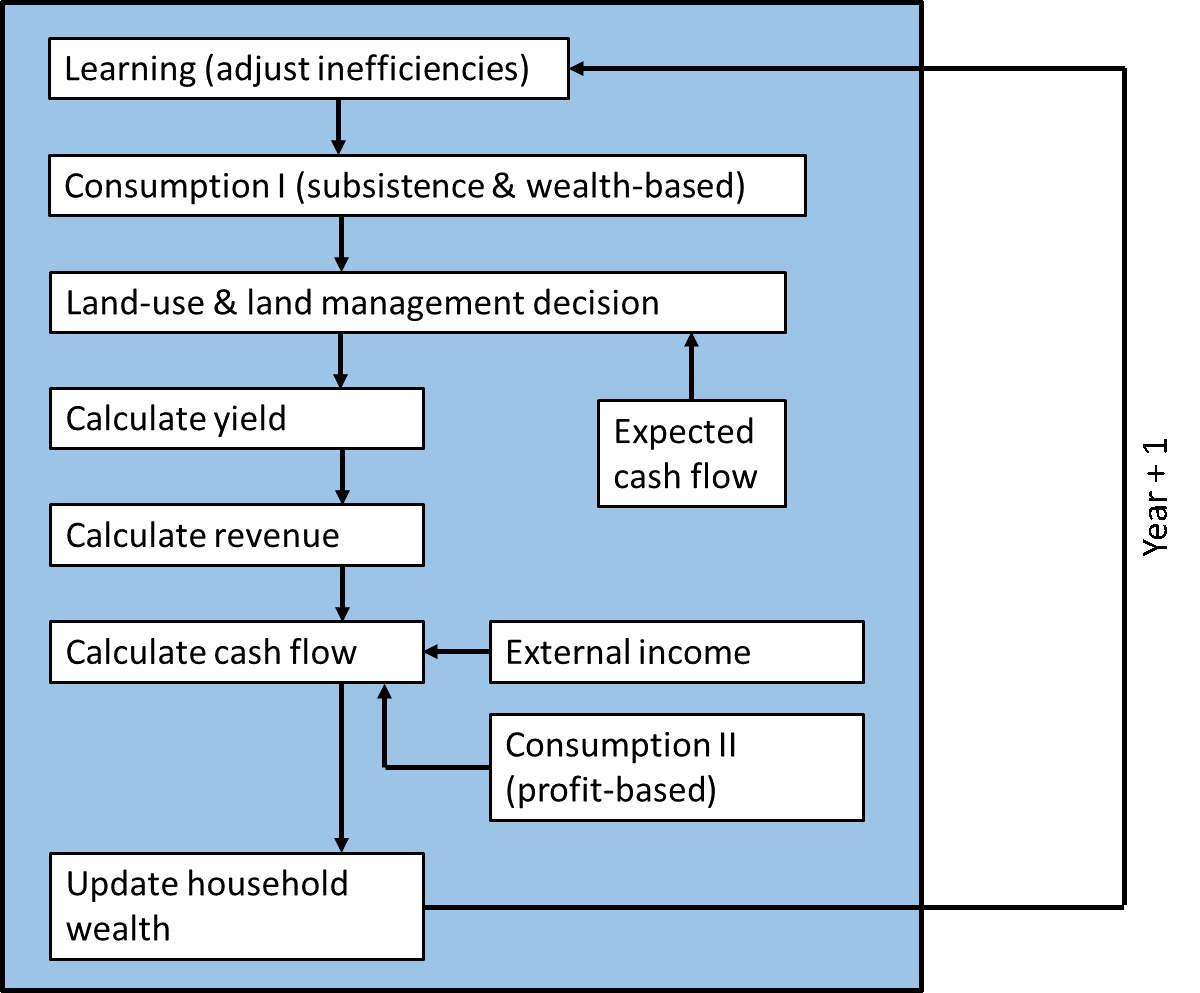
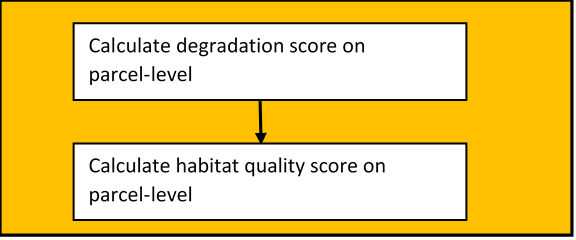


Figure x: Processes EFForTS-ABM:Economic Submodel

* InVEST: habitat analysis:
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* Figure x: Processes of InVEST:Terrestrial biodiversity
* Connection points and Input-Output-Transfer
* EFForTS-ABM: generation of input for InVEST (LULC-map, Impact-map, Sensitivity-table, impact-table, conversion (tif<->asc)
* InVEST Habitat Quality: generation of input for EFForTS-ABM (habitat quality map)
* Mapping of output EFForTS-ABM to input InVEST
* Mapping of output InVEST to input EFForTS-ABM

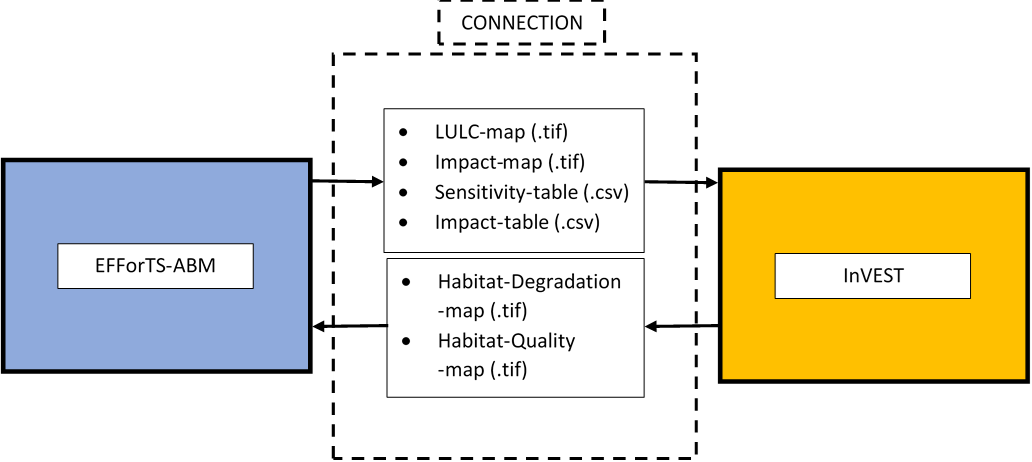


Figure x: Input-Output-Transfer

* Functional and non-functional requirements
  + Functional requirements: aggregated habitat quality calculation
  + Test functional requirements with Test Pyramid, built of unit-testing, integration-testing, acceptance-testing (application example: Parameter setting for InVEST, Parameter setting for EFForTS-ABM)
* Non-functional requirements: reproducibility

# 3. Results

* Connected Models:

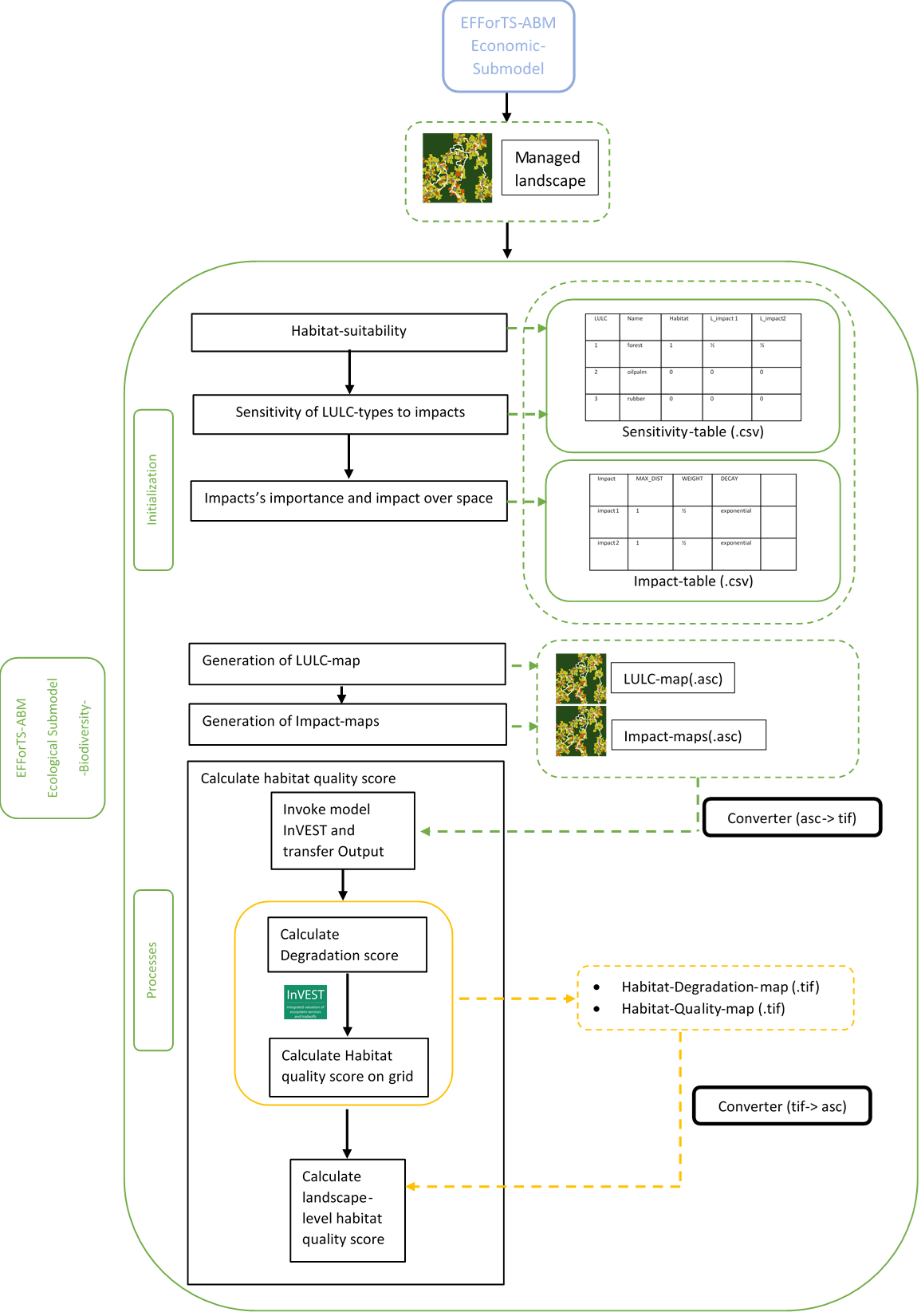


Figure x: Software-Architecture

* Implementation of Biodiversity Submodel as connection point and realization of Input-Output-Transfer:
  + set-up-invest, write-tables, write-maps, convert-maps, run-invest, convert-habitat-quality-to-asc, save-habitat-quality-to-patch, aggregate-habitat-quality
* Functional requirements: results from Test Pyramid
* Non-functional requirements: dockerfile and singularity-container

# 4. Discussion

* Possible points to discuss
  + Benefit of connection instead of usage separately (dynamic simulations, feedback between economic functions and biodiversity,….)
  + Reference to Acceptance Test
* Conclusions
  + Easy implementation, easy adjusting to different models
  + New tool for assessing socio-economic functions simultaneously with ecological functions and biodiversity over time and space

# 5. Acknowledgements

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# Open questions:

* Also mention or even implement model EFForTS-LGraf into figures, as model EFForTS-LGraf generates the initial landscape used by EFForTS-ABM?
* Also include more detailed Software-Architecture with every in- and output of both models (especially for economic submodel of EFForTS-ABM)?

# References:

<https://graberj.wordpress.com/2013/03/10/die-testpyramide/>

<https://martinfowler.com/articles/practical-test-pyramid.html#TheTestPyramid>

<https://files.ifi.uzh.ch/rerg/amadeus/teaching/courses/requirements_engineering_I_ws0607/Kapitel_01_Grundl.pdf>

Virtual Environment: Reference?

Unit Testing: Reference?

## R Markdown

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When you click the **Knit** button a document will be generated that includes both content as well as the output of any embedded R code chunks within the document. You can embed an R code chunk like this:

summary(cars)

## speed dist   
## Min. : 4.0 Min. : 2.00   
## 1st Qu.:12.0 1st Qu.: 26.00   
## Median :15.0 Median : 36.00   
## Mean :15.4 Mean : 42.98   
## 3rd Qu.:19.0 3rd Qu.: 56.00   
## Max. :25.0 Max. :120.00

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You can also embed plots, for example:



Note that the echo = FALSE parameter was added to the code chunk to prevent printing of the R code that generated the plot.