How to optimize BMPs implementation orders

1. Getting familiar with SEIMS operations

Make sure you have read through *SEIMS-UserManual.pdf* and followed the steps described in it and the execution commands for the major steps.

2. Recompile

Since the C++ code of this branch has been modified, SEIMS needs to be recompiled to use this branch. You can follow these commands on Linux:

```
cd ~/Programs/SEIMS
mkdir build
cd build
cmake ..
make -j4
make install
```

Or these commands on Windows:

```
cd D:\demo\SEIMS
d:
mkdir build
cd build
cmake -G "Visual Studio 12 2013 Win64" ..
msbuild.exe ALL_BUILD.vcxproj /p:Configuration=Release
msbuild.exe INSTALL.vcxproj /p:Configuration=Release
```

3. Data preprocessing

Run the preprocessing script to re-import the meteorological and precipitation data during simulation period, demo spatial data at 30m resolution, BMPs' stepwise economic benefit and environmental effectiveness, and model output configurations into the database.
Use the commands below to run the preprocessing script:

```
cd ~/Programs/SEIMS/seims/preprocess
python main.py -ini ~/Programs/SEIMS/data/youwuzhen/workspace/preprocess.ini
```

Note that to output the annual sediment yield data, the same OUTPUTID (SED_OL) and different FILENAME must be set in the *file.out* file, as shown in .

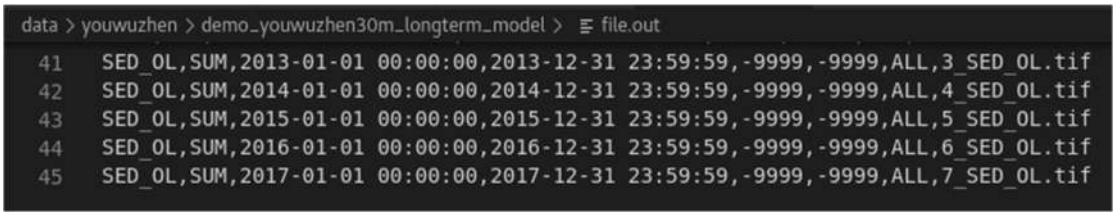

Figure 1. file.out example

4. Run the model

After the data import is complete, you can run the model to check whether the calculation results are correct. Calibrated parameters (*param.cali*) for 10m resolution data are provided in the model folder for demonstration purposes only. You can calibrate the model according to your needs. Please refer to the relative chapters in *SEIMS-UserManual.pdf*.

Use the commands below to run the model:

```
cd ~/Programs/SEIMS/seims
python run_seims.py -ini ~/Programs/SEIMS/data/youwuzhen/workspace/runmodel.ini
```

5. Scenario analysis

You can review whether you need to optimize spatial configurations of the BMP scenarios first according to your own situation. The scenario in the Pareto fronts of this step can be used as the starting scenario for the next step: optimization of the implementation orders of BMPs. Alternatively, the spatial configuration of the BMP scenario developed by the expert can be selected.

Use the commands below to run scenario analysis:

```
cd ~/Programs/SEIMS/seims/scenario_analysis/spatialunits
python main_nsga2.py -ini ~/Programs/SEIMS/data/youwuzhen/workspace/scenario_analysis.ini
```

6. Optimization of BMPs implementation orders

6.1 Starting scenario

Starting scenario information must be provided as text in the model folder at least containing the Scenario ID, Gene number, and Gene values. The other items are optional. For demo data, please refer to the file *Scenario_196508708.txt* in the model folder.

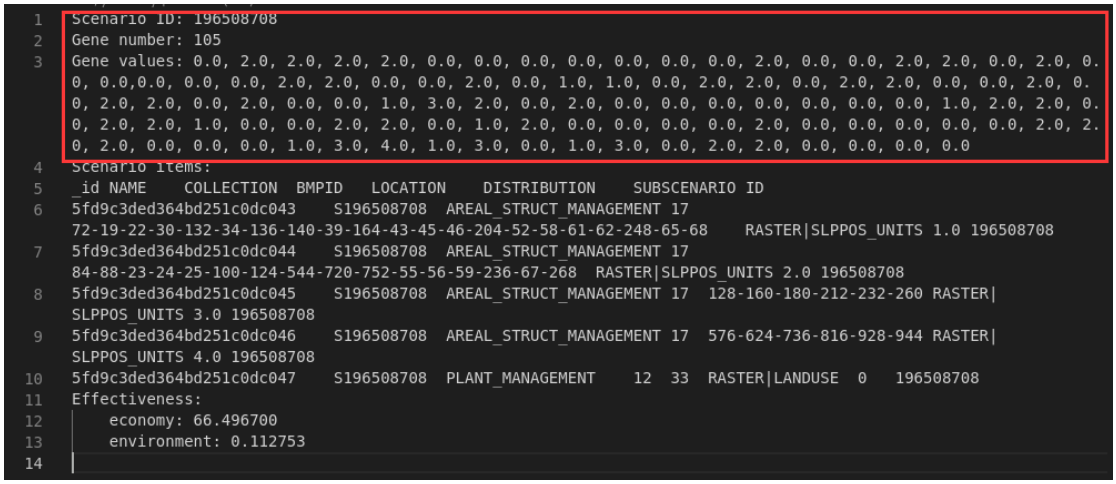

Figure 2. Example of the starting scenario file

6.2 Configuration file

The configuration file *scenario_analysis_bmps_order.ini* in workspace folder adds some configuration items for the BMPs implementation orders, which are explained as follows.

```
# implementation periods (in year)
implementation_period = 5
# whether BMPs effectiveness variable and, if so, what is the change frequency (in year)
effectiveness_changeable = True
change_frequency = 1
# whether to consider stepwise investment and, if so, what are the respective investment limits.
enable_investment_quota = False
investment_each_period = [90, 70, 30, 20, 20]
# the discount rate during the stepwise investment periods
discount_rate = 0.1
# starting scenario to optimize BMP implementation oders
selected_scenario_file = Scenario_196508708.txt
# average and annual sediment yield of the baseline scenario
Eval_info = {"OUTPUTID": "SED_OL", "ENVEVAL": "SED_OL_SUM.tif", "BASE_ENV": 1688493,"BASE_SED_PERIODS":[1347426, 818153, 1009664, 3634481, 1632739]}
```

6.3 Run the optimization of BMPs implementation orders

Use the commands below to run the optimization of BMPs implementation orders:

```
cd ~/Programs/SEIMS/seims/scenario_analysis/spatialunits
python bmps_order_nsga2.py -ini ~/Programs/SEIMS/data/youwuzhen/workspace/scenario_analysis_bmps_order.ini
```

6.4 Examine optimization results

Optimization results are saved in *SA_NSGA2_SLPPOS_HILLSLP_Gen_*_Pop_?* folder in model folder, where * refers to the generation number, and ? refers to the population size set in the optimization algorithm. For example, *SA_NSGA2_SLPPOS_HILLSLP_Gen_2_Pop_8* will be generated when *GenerationsNum* is set to 2 and *PopulationSize* is set to 8 in the configuration file *scenario_analysis_bmps_order.ini.*

The results folder contains several files and subfolders that has already described in Section 2:8.1 in *SEIMS-UserManual.pdf*. The main differences are:

- Scenarios folder: The BMP scenario information in plain text file and the corresponding spatial distribution raster file are extended to present the BMP implementation orders. For example, one BMP scenario information of the 2nd generation is as follows.

Scenario ID: 218840362
Gene number: 105
Gene values: 0.0, 2005.0, 2002.0, 2002.0, 2002.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 2001.0, 0.0, 0.0, 2001.0, 2003.0, 0.0, 2005.0, 0.0, 0.0, 0.0, 0.0, 0.0, 2005.0, 2005.0, 0.0, 0.0, 2001.0, 0.0, 1001.0, 1004.0, 0.0, 2001.0, 2002.0, 0.0, 2004.0, 2002.0, 0.0, 0.0, 2004.0, 0.0, 2004.0, 2005.0, 0.0, 2001.0, 0.0, 0.0, 1001.0, 3005.0, 2002.0, 0.0, 2002.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1001.0, 2003.0, 2001.0, 0.0, 2002.0, 2004.0, 1003.0, 0.0, 0.0, 2005.0, 2003.0, 0.0, 1004.0, 2001.0, 0.0, 0.0, 0.0, 0.0, 2004.0, 0.0, 0.0, 0.0, 0.0, 0.0, 2001.0, 2003.0, 2003.0, 0.0, 0.0, 0.0, 1002.0, 3001.0, 4004.0, 1001.0, 3003.0, 0.0, 1005.0, 3002.0, 0.0, 2004.0, 2004.0, 0.0, 0.0, 0.0, 0.0
Scenario items:
BMPID NAME COLLECTION DISTRIBUTION LOCATION SUBSCENARIO ID EFFECTIVENESSVARIABLE CHANGEFREQUENCY _id
17 S218840362 AREAL_STRUCT_MANAGEMENT RASTER|SLPPOS_UNITS 72|5-288|2-19|2-76|2-22|1-23|1-92|3-24|5-30|5-120|5-124|1-33|1-132|2-34|4-136|2-140|4-36|4-144|5-39|1-640|2-164|2-180|3-720|1-184|2-736|4-51|5-204|3-208|1-55|4-58|1-232|3-928|3-67|4-268|4 2 218840362 0 31536000 63142544e655f47554a24611
17 S218840362 AREAL_STRUCT_MANAGEMENT RASTER|SLPPOS_UNITS 32|1-128|4-40|1-45|1-47|3-52|4-61|2-62|1-65|5 1 218840362 0 31536000 63142544e655f47554a24612
17 S218840362 AREAL_STRUCT_MANAGEMENT RASTER|SLPPOS_UNITS 160|5-244|1-248|3-260|2 3 218840362 0 31536000 63142544e655f47554a24613
17 S218840362 AREAL_STRUCT_MANAGEMENT RASTER|SLPPOS_UNITS 976|4 4 218840362 0 31536000 63142544e655f47554a24614
PLANT_MANAGEMENT RASTER|LANDUSE 33 0 12 S218840362 218840362 0 -1 63142544e655f47554a24615
Effectiveness:
economy: 146.002763

environment: 43.772761
sed_sum: 949393.000000
sed_per_period: [745785.4, 583586.5, 569093.6, 1907091.1, 941408.44]

- Runtime.log: The file *runtime.log* has changed a lot and stores many stepwise data of the simulation scenario, such as sediment per period, net cost per period, cost per period and income per period. All of them are stored in array which is easy to read and parse for the further analysis.

Figure 3. Example of runtime.log file

The optimization of BMPs implementation orders is time-consuming mainly because the optimization framework needs to repeatedly execute the watershed model many times. For example, with these optimization parameters (GenerationsNum = 2, PopulationSize = 8, CrossoverRate = 0.8, MaxMutatePerc = 0.2, MutateRate = 0.1, SelectRate = 0.8), under the general computer configuration (Intel(R) Core(TM) i7-6700HQ CPU @ 2.60GHz, 6GB memory), the single-process execution optimization programs took a total of 948.87 seconds (about 16 minutes). Parallel execution libraries (e.g., SCOOP) or even multiple supercomputer nodes can be used to improve the efficiency of the optimization programs.