Project Owner	Malcolm Francis and James Leitch
Science Maintainers	Rob de Ligt Juha Metsaranta Cris Brack Marcela Olguin Geoff Roberts
Science Editors	Rob de Ligt
Science Review Panel	Stephen Roxburgh
Science Approval	Werner Kurz
Code maintainers	Max Fellows Malcolm Francis James Leitch
Code Coach	
Documentation Lead	
Release Approval	Werner Kurz

PLEASE READ THIS BEFORE YOU CONTINUE:
This is an open source document. Everybody is welcome to contribute. To allow us to be efficient we have only a few rules:

- All contributors use comments to ask questions or make substantive and structural suggestions. Always suggest solutions in your comments not problems.
- Only Maintainers can resolve comments.
- All contributors make edits in "suggesting mode" (even if you are a maintainer or editor, so the other maintainers or editors can cross-check and accept your contribution.)
- Write suggested edits directly into the text in 'suggesting mode' do NOT use comments to suggest edits
- Only Editors assigned to the document can approve edits
- Spelling will be UK English
- Referencing Style is Harvard (author-date) type. Tools such as Zotero may be useful.

More info about how the moja global community works on projects can be found here.

FLINT Monte Carlo Uncertainty Manual

April 30, 2020

Introduction

The purpose of this manual is to describe the FLINT Monte Carlo Uncertainty functionality, that has been implemented as a series of modules and improvements to the FLINT code. This functionality has benefited from the support of multiple contributors, including the support of the Government of Canada and the United Nations Framework Convention on Climate Change. This initial implementation of the Monte Carlo functionality for the FLINT was developed following the design concepts for the module described in the Design for Monte Carlo and Propagation of Error Uncertainty in the Full Lands Integration Tool document. This document should be consulted for a description of the science and methods underpinning the functionality.

Version 1.0 of the module addresses three key components of the Monte Carlo design. The first is the ability to randomly sample parameter values from defined probability density functions, for the input variables for which Monte Carlo analysis is to be performed. The second is the ability to conduct iterative simulations of the FLINT using the randomly sampled input variables. Finally, the ability to conduct the Monte Carlo simulations on spatially explicit simulations by randomly selecting the spatial units (pixels) that will be simulated for the purposes of the Monte Carlo Analysis.

Overview:

With the support of the UNFCCC Secretariat, monte-carlo uncertainty functionality was developed for use with the Full Lands Integration Tool (FLINT). The module allows users to run multiple iterations of point or spatial simulations and generate a confidence interval for carbon stock change. In conjunction with the uncertainty module, a number of test modules were also developed, including a forest growth module using the Chapman Richard's growth curve and events. The uncertainty functionality is incorporated into FLINT, while the test modules are available through moja global.

Setting Up the FLINT

The uncertainty module has been developed to run using a standard FLINT implementation. This is to enable uncertainty analysis for any model using the FLINT framework to be carried out without modification to the model. Documentation and guides for building and setting up a FLINT environment are available on [GitHub](#) and available for comment through google docs.

These guides include:

- Building moja base libraries
- Building moja FLINT libraries
- Building moja FLINT implementation

Uncertainty Functionality

The uncertainty functionality is a relatively simple process to describe, although there is complexity in the implementation of this functionality especially for a spatial modelling system, and to allow for flexibility for the user.

In general terms, when the FLINT is running a simulation, a module will call for specific variables required to operate. These may be a single value, an object like variable or a table. A provider will return the relevant variables to the module. As the variables are returned to the module, the uncertainty functionality will 'intercept' them, and replace them with a random selection from a defined probability distribution based on the user input. The FLINT will then run multiple iterations of the simulation (e.g. 1000 times), returning randomly sampled values from these distributions.

There are three main components for using the uncertainty functionality:

1. Uncertainty File Writer
   The uncertainty file writer is an output component that computes and outputs the uncertainty statistics for an aggregation of a simulation run.
2. Aggregator Uncertainty
   The uncertainty aggregator, as the name suggests, aggregates the outputs from each iteration of the simulation and optionally multiple pixels during a simulation to make it available for output..

Landscape Sampler

The Configuration File contains all the parameters for describing and controlling a FLINT simulation with the addition of some sections and parameters the uncertainty will be calculated, as well as the controls for the users to modify the way the data is presented. Users will interact with the uncertainty functionality through the configuration file.

These are applicable for both a point base and spatial simulation using the FLINT. Put simply, the point based simulation is where all variables and events are described within the configuration file, while a spatial simulation the events and certain variables will be pulled from spatial files. For a point based run, all variables are varied in accordance with the uncertainty configuration. For spatial runs, a sampling approach is taken, where a subset of all available pixels are simulated due to the computational intensive nature of monte carlo simulations simulating potentially thousands of iterations per pixel.

The Configuration File

The configuration file contains the controls necessary to modify the uncertainty functionality. This includes:

- Turning on or off uncertainty functionality as a whole
- Selecting if outputs will be written to the screen
- Selecting if raw data (uncertainty simulation results) will be included in output
- Selecting the reported confidence intervals
- Determining the number of iterations, and
- Detailing the variables and values to be replaced and the data for varying these values.

The uncertainty simulation requires three additions; the processes are contained in two main sections of the configuration file. The Uncertainty section (Figure 1) and the Uncertainty File Writer (Figure 1)

Variables

Uncertainty Simulation Unit Data

Uncertainty simulations require the `UncertaintySimulationUnitData` variable to be configured in the run as follows. This variable maintains state between each iteration of the uncertainty simulation and also between each pixel of a spatial simulation. It also is used by both the aggregator and output modules

```
{
	"uncertaintySimulationUnitData": {
		"flintdata": {
			"library": "internal.flint",
			"type": "UncertaintySimulationUnitData"
		}
	}
}
```

Figure 1 - Example configuration file section, specifying the uncertaintySimulationUnitData variable.

Uncertainty

The Uncertainty section of the configuration file, must as a minimum include:

General

General settings for the uncertainty simulation

Property	Value	Description
enabled	true/false	Enable or disable the uncertainty calculations for this simulation
iterations	number	The number of times the simulation will be repeated sampling values from the configured distributions.

Sampling

Property	Value	Description
enabled	true/false	Enable or disable the uncertainty calculations for this simulation
inclusion_variable	text	Name of variable providing inclusion probabilities

```
"sampling":{
      "enabled": true,
      "inclusion_variable": "inclusion_probability"
},
```

Variables

An array of variables selected for replacement buy random sampled distributions during the simulation. Each variable consists of:

Property	Value	Description
variable	text	The unique name of a flint variable to be replaced with a distribution for example the forest_types table variable in the example

Replacements

Replacements are made to fields within a FLINT variable the replacement has an optional query section that filters the values the variable returns which is required when a variable returns multiple values for example a variable that returns a collection of objects or row of a table. Multiple replacements can then be made to fields within that object or columns within a table. The example provided filters a list of forest_types returned by the forest_types variable and replaces the “k” and “max” attributes with a triangular and normal distribution. The replace attribute then defines the attribute replacements to apply to this variable result. The uncertainty variables must be specified to apply probability distributions for model parameters in uncertainty analysis. These variables must have a type that can take three forms in the current implementation:

Normal distribution

Uncertainty Variable	Value	Description
type	text	Type refers to the distribution function used for calculating the uncertainty. “normal”
seed	number	Optional seed used for generating the numbers. A known seed value is used to allow repeatability of the uncertainty calculations. If not

		defined a random distribution selection occurs every simulation
mean	number	The mean value for the normal distributed uncertainty values.
std_dev	number	The standard distribution of normally distributed uncertainty values.

Triangular distribution

Uncertainty Variable	Value	Description
type	text	Type refers to the distribution function used for calculating the uncertainty values. “triangular”.
seed	number	Optional seed used for generating the numbers. A known seed value is used to allow repeatability of the uncertainty calculations. If not defined a random distribution selection occurs every simulation
min	number	The minimum value for a triangular distribution.
peak	number	The peak value for a triangular distribution.
max	number	The maximum value for a triangular distribution.

Manual distribution

Uncertainty Variable	Value	Description
type	text	Type refers to the distribution function used for calculating

		the uncertainty. “manual”.
distribution	array of numbers	Array of values representing the distribution.

```
"uncertainty": {
      "enabled": true,
      "iterations": 100,
      "sampling": {},
      "variables": [{
            "variable": "forest_types",
            "replacements": [{
                  "query": {
                        "id": 13
                  },
                  "replace": {
                        "k": {
                              "type": "triangular",
                              "seed": 12345,
                              "min": 0.02,
                              "peak": 0.037,
                              "max": 0.045
                        },
                        "max": {
                              "type": "normal",
                              "mean": 51.64,
                              "std_dev": 2
                        }
                  }
            }]
      }]
}
```

Figure 2 - Example uncertainty configuration section, specifying the variables to be modified, and how to modify them.

Output

Once the simulation has processed the landscape, the Uncertainty File Writer outputs the simulation results. The Uncertainty File Writer allows the user to:

- Change the output file name
- Change the reported confidence interval
- Change to show output the screen, and
- Include raw data in outputs

This is done through the configuration file settings. The uncertainty functionality writes out a .csv file, users can define options for this file here.

Uncertainty Variable	Value	Description
output_filename	text	File name to write the output to.
confidence_interval	text	Confidence interval used in the output report. Values are: eighty_percent, eighty_five_percent, ninety_percent, ninety_five_percent, ninety_nine_percent
output_to_screen	true/false	Enable/disable output to screen.
include_raw_data	true/false	Enable/disable output of raw results to the output file. The raw results contain values for each output for each iteration
output_info_header	true/false	Enable/disable output of a header in the output file.

```
"UncertaintyFileWriter": {
      "library": "internal.flint",
      "order": 8,
      "settings": {
            "output_filename": "Forest_Point_Uncertainty.csv",
            "confidence_interval": "ninety_percent",
            "output_to_screen": false,
            "include_raw_data": true,
            "output_info_header": true
      }
}
```

Figure 3 - Example file writer configuration section, specifying the parameters the user can change for the file output..

The outputs from the uncertainty analysis will be written to a CSV file defined by the "***output_filename***" value. The results include:

- Year of the flux (year)
- Location ID (localdomain_id)
- Flux source pool (src pool)
- Flux sink pool (sink_pool)
- Mean flux from all iterations (mean)
- Standard deviation from all iterations (S.D.)
- Margin of error (margin of error)
- The lower limit of the estimate (90% limit low)
- The upper limit of the estimate (90% limit high)
- Optional raw values

This will allow for further analysis of the outputs in Excel or other statistical packages (Table 2).

Table 2 - Example output of the Uncertainty functionality, with the distribution characteristics for the flux values.

year	localdomain_id	src pool	sink pool	mean	S.D.	margin of error	90% limit low	90% limit high
2001	1	atmosphereCM	aboveGroundCM	0.032	0.008	0.001	0.031	0.033
2001	1	atmosphereCM	belowGroundCM	0.007	0.002	0.000	0.007	0.008
2002	1	atmosphereCM	aboveGroundCM	0.091	0.024	0.004	0.087	0.095
2002	1	atmosphereCM	belowGroundCM	0.021	0.005	0.001	0.020	0.022
2003	1	atmosphereCM	aboveGroundCM	0.144	0.037	0.006	0.138	0.150
2003	1	atmosphereCM	belowGroundCM	0.033	0.008	0.001	0.032	0.035
2004	1	atmosphereCM	aboveGroundCM	0.191	0.047	0.008	0.183	0.199
2004	1	atmosphereCM	belowGroundCM	0.044	0.011	0.002	0.042	0.046
2005	1	atmosphereCM	aboveGroundCM	0.232	0.056	0.009	0.223	0.241
2005	1	atmosphereCM	belowGroundCM	0.053	0.013	0.002	0.051	0.056

Running An Uncertainty Simulation

To use the uncertainty functionality after it is set up, the FLINT is run as normal through the command lines in Powershell. No additional alterations are required.

```
PS C:\Uncertainty> moja.cli.exe --config config\point_forest_config.json
```

Example point simulation.

```
PS C:\Uncertainty> moja.cli.exe --config config\forest_config.json
--config_provider config\provider.json --inclusion_config_file
config\inclusion.json
```

Example spatial simulation.

Example model

Under this project, a Tier 3[1] method is used for estimation of aboveground carbon for forests, as estimated using the Chapman-Richards function (eqn. 1). The curve provides an estimate of total aboveground biomass based on age. Belowground biomass is calculated as a ratio from aboveground biomass. The equations are within the Forest Growth Module.

Eqn. 1 Chapman-Richards Function

(eqn. 1)

$$AGC = \max \times \left[1 - e^{-k \cdot age}\right]^{\left(\frac{1}{1-m}\right)}$$

where:

AGC — Aboveground stand carbon (Tonnes carbon per hectare);
max — asymptote – maximum peak carbon yield (Tonnes carbon per hectare);
k — parameter used in modeling tree growth, dimensionless;
age — age of the forest (years);
m — parameter used in modeling tree growth, dimensionless.This curve has two variables, the k value and max value which can be used to test uncertainty. Within the configuration file, this is written as:

For the demonstration of uncertainty calculations, only k and max are varied for forest types with an id of 13. Within the configuration file, this is written as:

[1] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf

```
"uncertainty": {
	"enabled": true,
	"iterations": 100,
	"sampling": {},
	"variables": [{
		"variable": "forest_types",
		"replacements": [{
			"query": {
				"id": 13
			},
			"replace": {
				"k": {
					"type": "triangular",
					"min": 0.02,
					"peak": 0.037,
					"max": 0.045
				},
				"max": {
					"type": "normal",
					"mean": 51.64,
					"std_dev": 2
				}
			}
		}]
	}]
}
```

Where multiple variables are replaced, they can simply be repeated with a comma separation:

```
"variables": [{
		"variable": "forest_types",
		"replacements": [{
			"query": {
				"id": 1
			},
			"replace": {
				"k": {
					"type": "triangular",
					"min": 0.02,
					"peak": 0.037,
					"max": 0.045
				},
				"max": {
					"type": "normal",
					"mean": 51.64,
```

```
                                    "std_dev": 2
                             }
                      }
              }]
       },
       {
              "variable": "my_new_variable",
              "replacements": [{
                      "query": {
                             "id": 1
                      },
                      "replace": {
                             "my_field": {
                                    "type": "triangular",
                                    "min": 0.02,
                                    "peak": 0.037,
                                    "max": 0.045
                             }
                      }
              }]
       }
]
```

Appendix 1: Point uncertainty configuration for the Chapman Richards growth model

```
{
   "LocalDomain": {
       "type": "point",
       "start_date": "2000/01/01",
       "end_date": "2100/12/31",
       "sequencer_library": "internal.flint",
       "sequencer": "CalendarAndEventFlintDataSequencer",
       "simulateLandUnit": "simulateLandUnit",
       "landUnitBuildSuccess": "landUnitBuildSuccess"
   },
   "operationManager": {
       "name": "Simple",
       "use_kahan": false,
       "allow_zero_result_transfers": false
   },
   "Libraries": {
       "moja.modules.chapman_richards": "external"
   },
   "Pools": [
       "initialValues",
       "atmosphereCM",
       "aboveGroundCM",
       "belowGroundCM"
   ],
   "uncertainty": {
       "enabled": true,
       "iterations": 100,
       "variables": [
           {
               "variable": "forest_types",
               "replacements": [
                   {
                        "query": {
                             "id": 1
                        },
                        "replace": {
                             "k": {
                                 "type": "triangular",
                                 "seed": 12345,
                                 "min": 0.02,
                                 "peak": 0.037,
```

```
                        "max": 0.045
                    },
                    "max": {
                        "type": "normal",
                        "seed": 12345,
                        "mean": 51.64,
                        "std_dev": 2
                    }
                }
            }
        ]
    }
    ]
},
"Variables": [
    {
        "localDomainId": 1
    },
    {
        "uncertaintySimulationUnitData": {
            "flintdata": {
                "library": "internal.flint",
                "type": "UncertaintySimulationUnitData"
            }
        }
    },
    {
        "simulateLandUnit": true
    },
    {
        "landUnitBuildSuccess": true
    },
    {
        "landUnitArea": 1.0
    },
    {
        "forest_types": {
            "flintdata": {
                "library": "moja.modules.chapman_richards",
                "type": "ForestTypeList",
                "settings": {
                    "items": [
                        {
                            "id": 1,
                            "type": "chapman_richards.ForestType",
                            "name": "Dryland Forests",
                            "carbon_frac_ag": 0.49,
```

```json
                                "carbon_frac_bg": 0.48,
                                "max": 51.64,
                                "k": 0.037,
                                "m": 0.5,
                                "root_to_shoot": 0.235
                            }
                        ]
                    }
                }
            }
        },
        {
            "eventqueue": {
                "flintdata": {
                    "library": "internal.flint",
                    "type": "EventQueue",
                    "settings": {
                        "events": [
                            {
                                "date": {
                                        "$date": "2001/01/01"
                                },
                                "id": 1,
                                "type": "chapman_richards.ForestPlantEvent",
                                "name": "Plant Dryland Forests",
                                "forest_type_id": 1,
                                "age": 0.0
                            },
                            {
                                "date": {
                                        "$date": "2050/01/01"
                                },
                                "id": 1,
                                "type": "chapman_richards.ForestClearEvent",
                                "name": "Clear Dryland Forests"
                            }
                        ]
                    }
                }
            }
        },
        {
            "forest_exists": false
        },
        {
            "forest_age": 0.0
        },
```

```json
        {
            "forest_type": null
        }
    ],
    "Modules": {
        "TransactionManagerEndOfStepModule": {
            "library": "internal.flint",
            "order": 1
        },
        "CalendarAndEventFlintDataSequencer": {
            "library": "internal.flint",
            "order": 2
        },
        "DisturbanceEventModule": {
            "library": "moja.modules.chapman_richards",
            "order": 3
        },
        "ForestGrowthModule": {
            "library": "moja.modules.chapman_richards",
            "order": 4
        },
        "AggregatorUncertainty": {
            "library": "internal.flint",
            "order": 5,
            "settings": {}
        },
        "OutputerStream": {
            "library": "internal.flint",
            "order": 6,
            "settings": {
                "output_filename": "Forest_Point_Stock.csv",
                "output_to_screen": false,
                "output_info_header": false
            }
        },
        "OutputerStreamFlux": {
            "library": "internal.flint",
            "order": 7,
            "settings": {
                "output_filename": "Forest_Point_Flux.csv",
                "output_to_screen": false,
                "output_info_header": false
            }
        },
        "UncertaintyFileWriter": {
            "library": "internal.flint",
            "order": 8,
```

```
            "settings": {
                "output_filename": "Forest_Point_Uncertainty.csv",
                "confidence_interval": "ninety_percent",
                "output_to_screen": false,
                "include_raw_data": true,
                "output_info_header": true
            }
        }
    }
}
```

Appendix 2: Probability inclusion configuration for the Chapman Richards growth spatial model run

```json
{
    "strata": [
        {
            "layer": "admin_level_4",
            "path": "data/DMA_AL4.geojson"
        },
        {
            "layer": "GEZ",
            "path": "data/DMA_GEZ.geojson"
        }
    ]
}
```

Appendix 3: Spatial uncertainty configuration for the Chapman Richards growth model


```
{
      "LocalDomain": {
            "type": "spatial_tiled",
            "start_date": "2000/01/01",
            "end_date": "2020/12/31",
            "sequencer_library": "internal.flint",
            "sequencer": "CalendarAndEventFlintDataSequencer",
            "simulateLandUnit": "simulateLandUnit",
            "landUnitBuildSuccess": "landUnitBuildSuccess",
            "landscape_cells": {
                  "iteration_type": "CellIndex",
                  "num_threads": 0,
                  "provider": "FlintTiled",
                  "cells": [
                        {
                              "tile_index": 26758,
                              "block_index": 35,
                              "cell_index": 98697
                        }
                  ]
            },
            "landscape": {
                  "iteration_type": "BlockIndex",
                  "num_threads": 0,
                  "provider": "FlintTiled",
                  "blocks": [
                        {
                              "tile_index": 26758,
                              "block_index": 35
                        },
                        {
                              "tile_index": 26758,
                              "block_index": 36
                        },
                        {
                              "tile_index": 26758,
```

```
        "block_index": 45
    },
    {
        "tile_index": 26758,
        "block_index": 46
    },
    {
        "tile_index": 26758,
        "block_index": 47
    },
    {
        "tile_index": 26758,
        "block_index": 55
    },
    {
        "tile_index": 26758,
        "block_index": 56
    },
    {
        "tile_index": 26758,
        "block_index": 57
    },
    {
        "tile_index": 26758,
        "block_index": 65
    },
    {
        "tile_index": 26758,
        "block_index": 66
    },
    {
        "tile_index": 26758,
        "block_index": 67
    },
    {
        "tile_index": 26758,
        "block_index": 76
    },
    {
        "tile_index": 26758,
        "block_index": 77
    }
```

```json
            ]
        },
        "operationManager": {
            "name": "Simple",
            "use_kahan": false,
            "allow_zero_result_transfers": false
        },
        "settings":{
            "sampling_interval": 100
        }
    },
    "Libraries": {
        "moja.modules.chapman_richards": "external",
        "moja.modules.gdal": "external"
    },
    "Pools": [
        "initialValues",
        "atmosphereCM",
        "aboveGroundCM",
        "belowGroundCM"
    ],
    "Uncertainty": {
        "enabled": true,
        "iterations": 100,
        "sampling":{
            "enabled": true,
            "inclusion_variable": "inclusion_probability"
        },
        "variables": [
            {
                "variable": "forest_types",
                "replacements": [
                    {
                        "query": {
                            "id": 13
                        },
                        "replace": {
                            "k": {
                                "type": "triangular",
                                "seed": 12345,
                                "min": 0.02,
                                "peak": 0.037,
```

```
                                        "max": 0.045
                                    },
                                    "max":{
                                        "type": "normal",
                                        "seed": 12345,
                                        "mean": 51.64,
                                        "std_dev": 2
                                    }
                                }
                            }
                        ]
                    }
                ]
            },
            "Variables": [
                {
                    "localDomainId": 1
                },
                {
                    "simulationUnitData": {
                        "flintdata": {
                            "library": "moja.modules.chapman_richards",
                            "type": "SimulationUnitData"
                        }
                    }
                },
                {
                    "uncertaintySimulationUnitData": {
                        "flintdata": {
                            "library": "internal.flint",
                            "type": "UncertaintySimulationUnitData"
                        }
                    }
                },
                {
                    "spatialLocationInfo": {
                        "flintdata": {
                            "library": "internal.flint",
                            "type": "SpatialLocationInfo"
                        }
                    }
                },
```

```
            {
                  "simulateLandUnit": true
            },
            {
                  "landUnitBuildSuccess": true
            },
            {
                  "landUnitArea": 1.0
            },
            {
                  "forest_types": {
                        "flintdata": {
                              "library": "moja.modules.chapman_richards",
                              "type": "ForestTypeList",
                              "settings": {
                                    "items": [
                                          {
                                                "id": 13,
                                                "type":
"chapman_richards.ForestType",
                                                "name": "Tropical dry
forest",
                                                "carbon_frac_ag": 0.49,
                                                "carbon_frac_bg": 0.48,
                                                "max": 52,
                                                "k": 0.037,
                                                "m": 0.5,
                                                "root_to_shoot": 0.235
                                          },
                                          {
                                                "id": 11,
                                                "type":
"chapman_richards.ForestType",
                                                "name": "Tropical
rainforest",
                                                "carbon_frac_ag": 0.5,
                                                "carbon_frac_bg": 0.49,
                                                "max": 132,
                                                "k": 0.035,
                                                "m": 0.4,
                                                "root_to_shoot": 0.4
                                          }
```

```
                        ]
                    }
                }
            }
        },
        {
            "eventqueue": {
                "flintdata": {
                    "library": "internal.flint",
                    "type": "EventQueue"
                }
            }
        },
        {
            "forest_exists": false
        },
        {
            "forest_age": 0.0
        },
        {
            "forest_type": null
        },
        {
            "forest_cover": {
                "transform": {
                    "library": "moja.modules.chapman_richards",
                    "type": "HansenForestCoverTransform"
                }
            }
        },
        {
            "tree_gain": {
                "transform": {
                    "data_id": "gain",
                    "library": "internal.flint",
                    "provider": "FlintTiled",
                    "type": "LocationIdxFromFlintDataTransform"
                }
            }
        },
        {
            "tree_loss_year": {
```

```
            "transform": {
                "data_id": "lossyear",
                "library": "internal.flint",
                "provider": "FlintTiled",
                "type": "LocationIdxFromFlintDataTransform"
            }
        }
    },
    {
        "tree_cover_2000": {
            "transform": {
                "data_id": "treecover2000",
                "library": "internal.flint",
                "provider": "FlintTiled",
                "type": "LocationIdxFromFlintDataTransform"
            }
        }
    },
    {
        "admin_level": {
            "transform": {
                "data_id": "dma_al4",
                "library": "internal.flint",
                "provider": "FlintTiled",
                "type": "LocationIdxFromFlintDataTransform"
            }
        }
    },
    {
        "gez": {
            "transform": {
                "data_id": "gez",
                "library": "internal.flint",
                "provider": "FlintTiled",
                "type": "LocationIdxFromFlintDataTransform"
            }
        }
    },
    {
        "reporting_classifiers": {
            "transform": {
                "library": "internal.flint",
```

```
                        "type": "CompositeTransform",
                        "vars": [
                            "admin_level"
                        ],
                        "allow_nulls": true
                    }
                }
            },
            {
                "run_statistics": {
                    "flintdata": {
                        "library": "moja.modules.chapman_richards",
                        "type": "RunStatistics",
                        "settings": {}
                    }
                }
            }
        ],
        "Modules": {
            "TransactionManagerEndOfStepModule": {
                "library": "internal.flint",
                "order": 1
            },
            "CalendarAndEventFlintDataSequencer": {
                "library": "internal.flint",
                "order": 2
            },
            "BuildLandUnitModule": {
                "library": "moja.modules.chapman_richards",
                "order": 3
            },
            "DisturbanceEventModule": {
                "library": "moja.modules.chapman_richards",
                "order": 4
            },
            "ForestGrowthModule": {
                "library": "moja.modules.chapman_richards",
                "order": 5
            },
            "AggregatorStockStep": {
                "enabled": false,
                "library": "internal.flint",
```

```
                "order": 6
            },
            "AggregatorUncertainty": {
                "enabled": true,
                "library": "internal.flint",
                "order": 7,
                "settings": {
                    "aggregate_stock": true
                }
            },
            "AggregatorError": {
                "enabled": true,
                "library": "moja.modules.chapman_richards",
                "order": 8,
                "settings": {
                    "log_errors": true,
                    "log_errors_max_number": 32000,
                    "log_errors_per_block": true
                }
            },
            "UncertaintyFileWriter":{
                "library": "internal.flint",
                "order": 11,
                "settings": {
                    "output_filename":
"Forest_Uncertainty_spatial.csv",
                    "confidence_interval": "ninety_percent",
                    "output_to_screen": false,
                    "include_raw_data": false,
                    "output_info_header": true,
                    "output_stock": true
                }
            }
        }
}
```