

# Addendum to “CHAAHK: A Spatial Simulation Model of the Maya Elevated Core Region”

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## 1 Purpose

In summary, changes from CHAAHK 1.0 to 1.1 include:

- Released as an executable installer instead of as an Eclipse project directory.
- Improvements to Java code readability and simulation run time.
- Redone graphical interface for visual and/or real-time analysis.
- Improvements to readability and organization of R scripts.

In December of 2018 I published version 1.0.0 of the CHAAHK simulation model on the Network for Computational Modeling in Social and Ecological Sciences [1]. This included a downloadable directory including the model’s source code and a large, diverse collection of R-language scripts. These files are basically a time capsule: a perfect representation of the working directory associated with CHAAHK at the time that my thesis was submitted [2]. Things were not changed from their original state to render my thesis research transparent and reproducible. However, user-friendliness became something of a casualty in the process. Most critically, the uploaded directory was an Eclipse “project” directory, so the simulation itself could not be easily run without having Eclipse and Repast installed locally. This document accompanies a newer (1.1.0) release of CHAAHK, which comes packaged as an executable installer that only requires Java.

In addition, the updates reduced the simulation’s execution time, improved the code’s readability, and polished the graphical user interface. These considerations were originally low priorities when trying to meet my defense deadline, but are virtually prerequisites to the dissemination and reproduction of CHAAHK or any other social scientific simulation model. These updates’ purpose was to finalize CHAAHK as a deliverable while changing as little about the simulation’s actual behavior as possible. They provide a more approachable lens to judge my original thesis for what it’s worth.

In addition to cleaning up CHAAHK itself, I also reorganized the many R scripts included with the directory uploaded to CoMSES. Together, they provide all of the R code used to run the simulation, collect output data, and perform the analyses discussed in my thesis. Compared to before, the scripts feature more deliberate variable names, less redundant code, and improved readability.

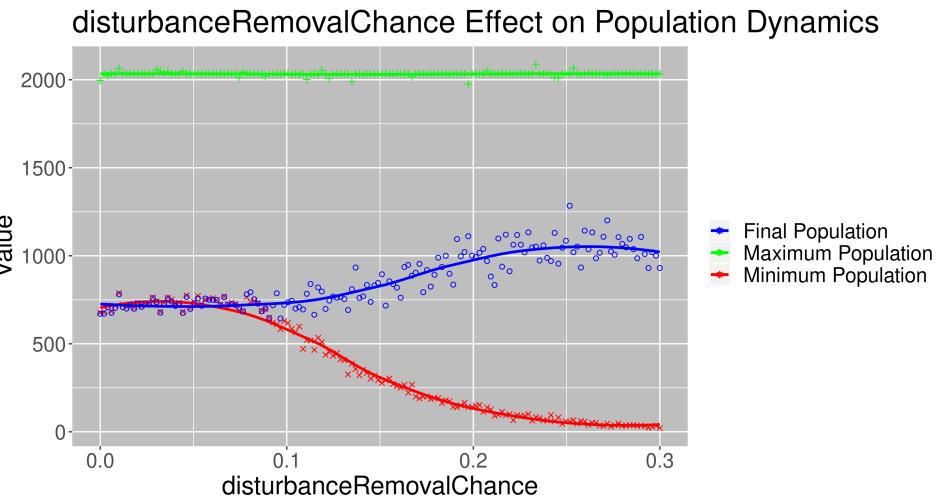
## 2 Results

This document illustrates the results of a new series of CHAAHK runs using the updated 1.1.0 implementation. The parameterization of this experiment is identical in terms of sample size and sampling strategy to that presented in my thesis. The same set of output analyses were likewise applied to the results of this experiment. Together, they demonstrate that the results of running the newer CHAAHK implementation are basically the same as those collected from the older implementation scrutinized in my thesis [2]. Key similarities include

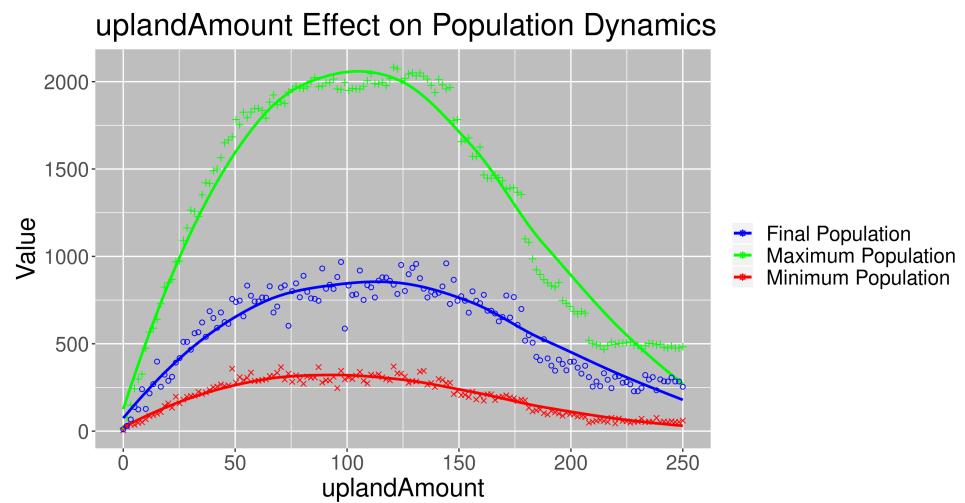
- Only a small number of parameter combinations produce an  $SLG$  less than 0.5. (246 originally, now 276).
- $C_{di}$  and  $F_{di}$  are the strongest predictors of model behavior when considering all output data.
- However, the distributions of  $C_{dr}$  and  $F_{dr}$  are more skewed than those of the other parameters among runs actually achieving  $SLG < 0.5$ .

## 3 Conclusion

There are differences between the original and updated model outputs, but the original synthesis still applies to this newer set of data just the same. I believe this synthesis can be improved through further quantitative analysis. Also, modifying or adding features to CHAAHK itself can improve its value as a model for social evolution in the central Maya Lowlands. CHAAHK 1.1.0 explicitly avoids doing either. However, it is hoped 1.1.0 simply provides more accessible means to scrutinize my masters thesis with all of its original details, for better or for worse, intact.

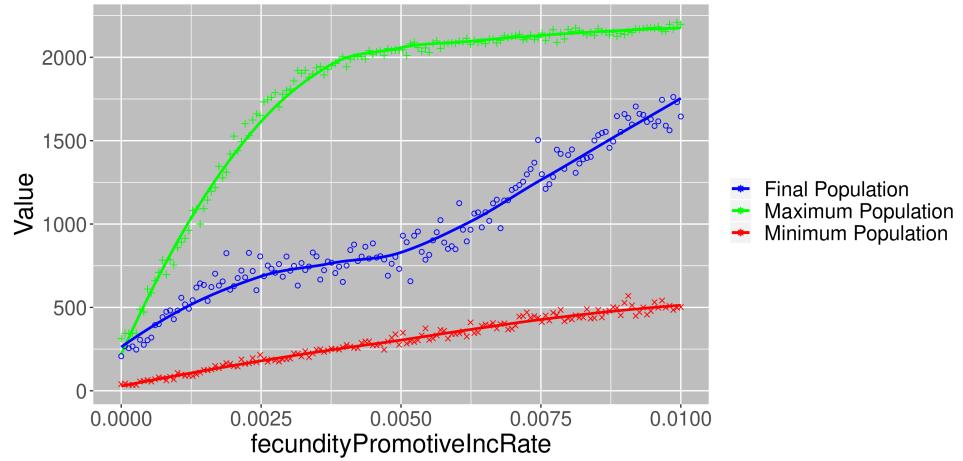


Plot corresponding to Figure 5.1 of Kara 2018



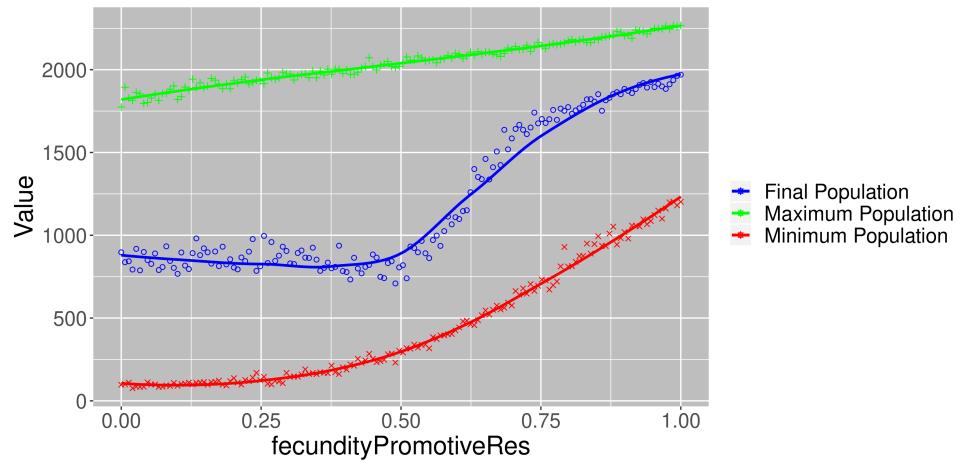
Plot corresponding to Figure 5.2 of Kara 2018

fecundityPromotiveIncRate Effect on Population Dynamics



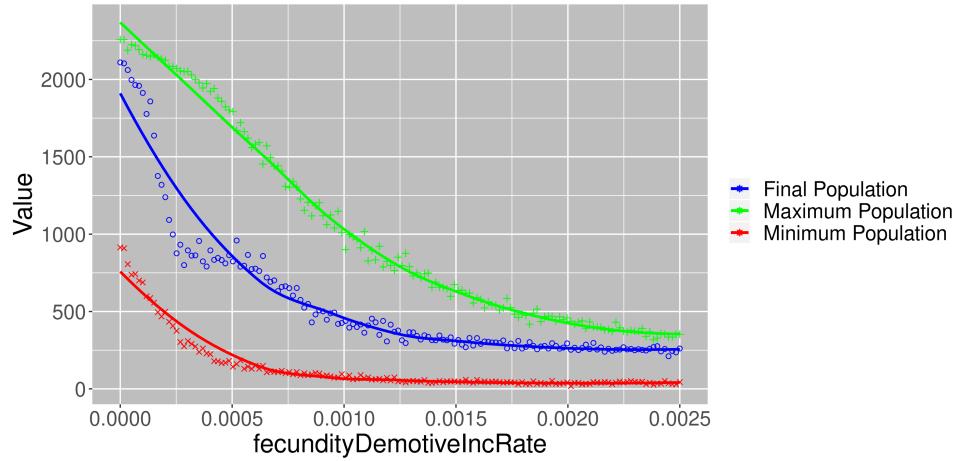
Plot corresponding to Figure 5.3 of Kara 2018

fecundityPromotiveRes Effect on Population Dynamics



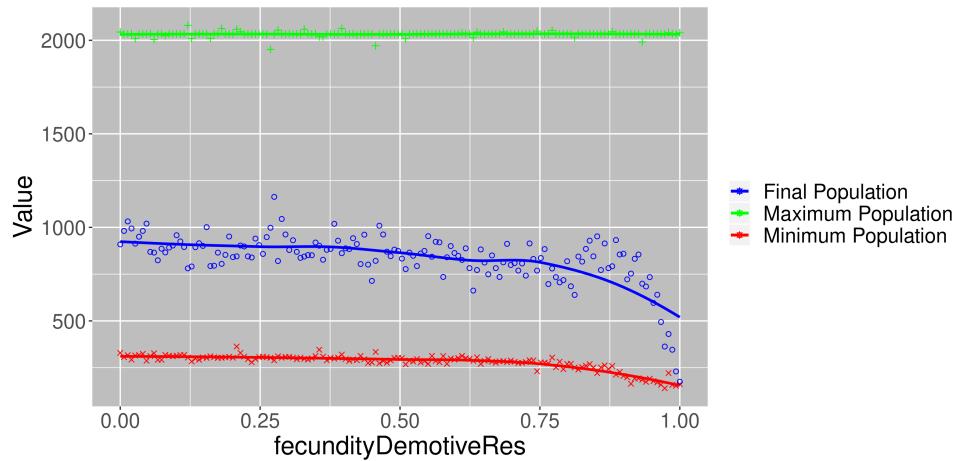
Plot corresponding to Figure 5.4 of Kara 2018

fecundityDemotiveIncRate Effect on Population Dynamics

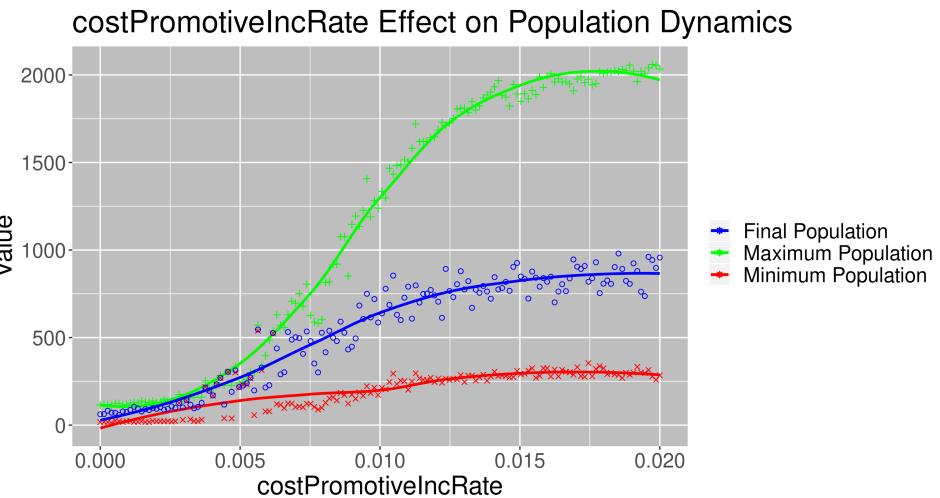


Plot corresponding to Figure 5.5 of Kara 2018

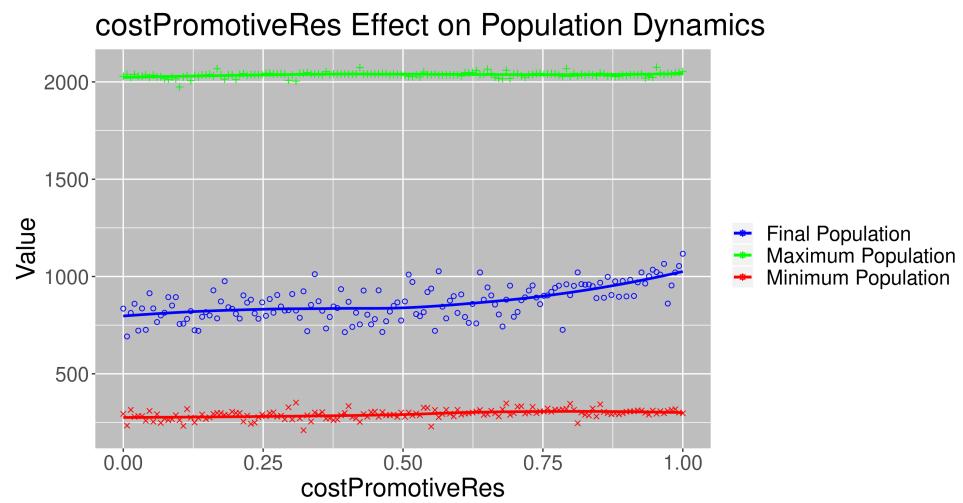
fecundityDemotiveRes Effect on Population Dynamics



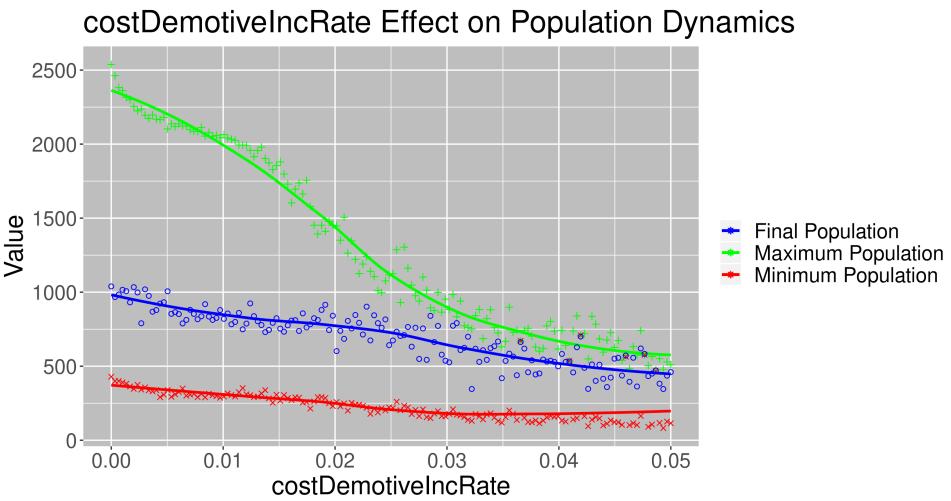
Plot corresponding to Figure 5.6 of Kara 2018



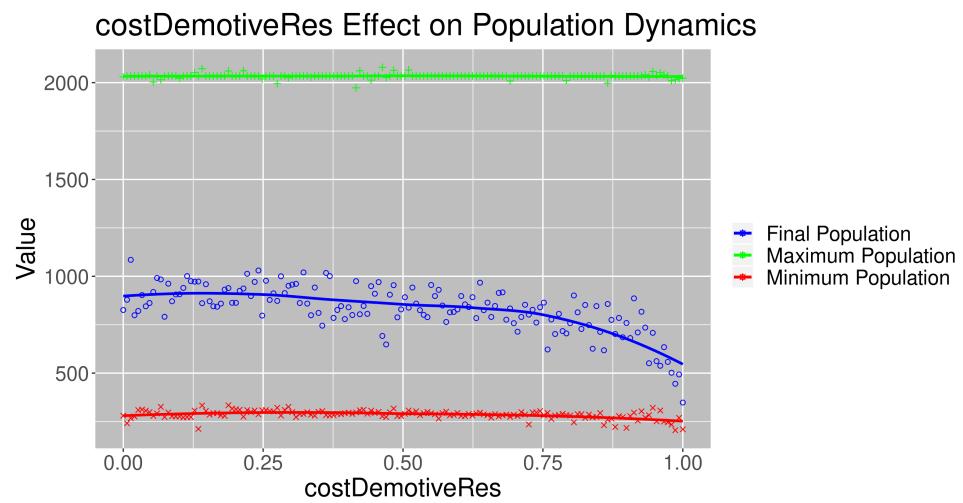
Plot corresponding to Figure 5.7 of Kara 2018



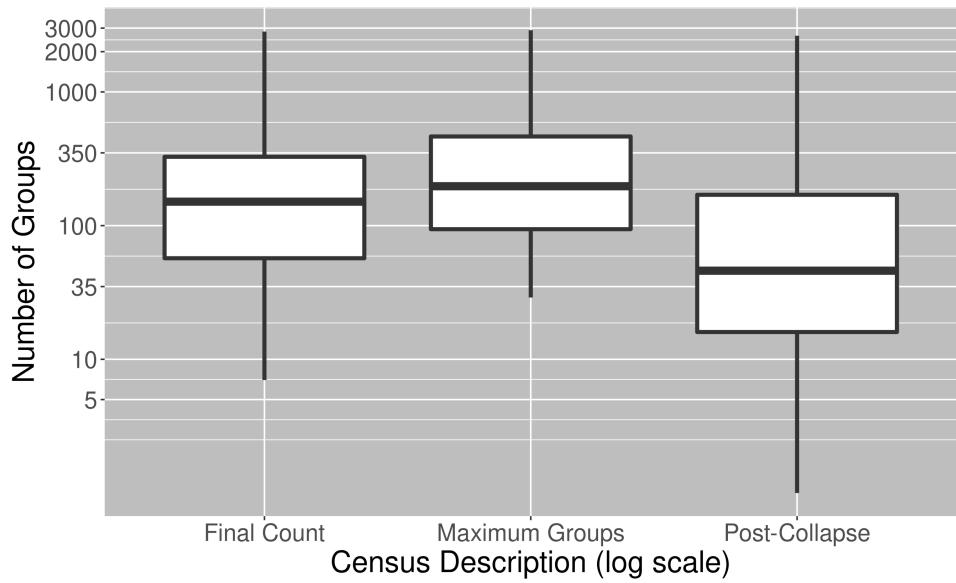
Plot corresponding to Figure 5.8 of Kara 2018



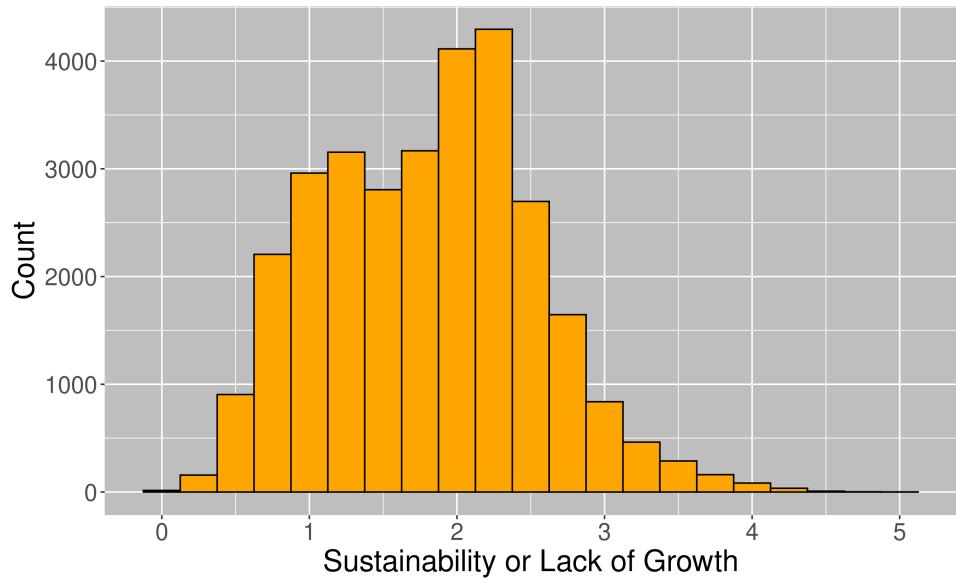
Plot corresponding to Figure 5.9 of Kara 2018



Plot corresponding to Figure 5.10 of Kara 2018



Plot corresponding to Figure 5.11 of Kara 2018



Plot corresponding to Figure 5.12 of Kara 2018

	Symbol	MaxPop	MinPop	FinalPop	SLG
Disturbance Removal Chance	$D_{rc}$	0.001	0.059	0.002	0.053
Fecundity Promotive Increase Rate	$F_{pi}$	0.061	0.036	0.051	0.089
Fecundity Promotive Resilience	$F_{pr}$	0.032	0.138	0.079	0.037
Fecundity Demotive Increase Rate	$F_{di}$	0.161	0.184	0.213	0.039
Fecundity Demotive Resilience	$F_{dr}$	0.001	0.005	0.005	0.008
Cost Promotive Increase Rate	$C_{pi}$	0.136	0.074	0.132	0.111
Cost Promotive Resilience	$C_{pr}$	0.001	0.006	0.004	0.006
Cost Demotive Increase Rate	$C_{di}$	0.406	0.072	0.265	0.386
Cost Demotive Resilience	$C_{dr}$	0.001	0.003	0.003	0.011

Table of first order sensitivity indices corresponding to Table 5.2 of Kara 2018.

	Symbol	MaxPop	MinPop	FinalPop	SLG
Intercept		546.326	191.847	332.097	1.675
Disturbance Removal Chance	$D_{rc}$	-70.299	-803.779	-156.378	-1.855
Fecundity Promotive Increase Rate	$F_{pi}$	38111.42	18862.517	27830.969	-44.875
Fecundity Promotive Resilience	$F_{pr}$	266.556	308.119	314.289	0.379
Fecundity Demotive Increase Rate	$F_{di}$	-233069.105	-116197.94	-178729.532	153.807
Fecundity Demotive Resilience	$F_{dr}$	-25.501	-53.906	-63.848	-0.174
Cost Promotive Increase Rate	$C_{pi}$	29973.085	13453.677	22920.684	-38.879
Cost Promotive Resilience	$C_{pr}$	34.597	59.526	57.944	0.134
Cost Demotive Increase Rate	$C_{di}$	-18183.764	-4785.314	-11531.995	28.84
Cost Demotive Resilience	$C_{dr}$	-27.103	-44.928	-57.768	-0.123

Table of multiple regression slopes associated with Table 5.3 of Kara 2018.

	Symbol	MaxPop	MinPop	FinalPop	SLG
Intercept		55.286	25.573	40.161	116.794
Disturbance Removal Chance	$D_{rc}$	-3.244	-48.863	-8.624	-58.966
Fecundity Promotive Increase Rate	$F_{pi}$	58.63	38.224	51.166	-47.554
Fecundity Promotive Resilience	$F_{pr}$	41.009	62.442	57.783	40.143
Fecundity Demotive Increase Rate	$F_{di}$	-89.639	-58.868	-82.147	40.748
Fecundity Demotive Resilience	$F_{dr}$	-3.923	-10.925	-11.739	-18.405
Cost Promotive Increase Rate	$C_{pi}$	92.229	54.531	84.284	-82.408
Cost Promotive Resilience	$C_{pr}$	5.323	12.063	10.653	14.199
Cost Demotive Increase Rate	$C_{di}$	-139.877	-48.489	-106.011	152.82
Cost Demotive Resilience	$C_{dr}$	-4.169	-9.104	-10.619	-13.077

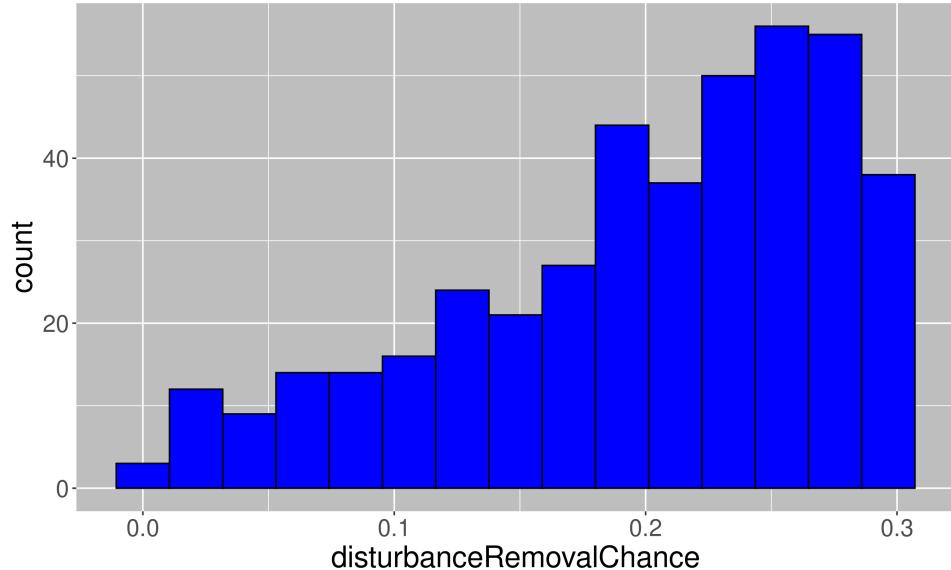
Table of multiple regression t values associated with Table 5.3 of Kara 2018.

	$R^2$
MaxPop	0.579
MinPop	0.359
FinalPop	0.511
SLG	0.57

Table of multiple regression  $R^2$  values associated with Table 5.3 of Kara 2018.

	Symbol	MaxPop	MinPop	FinalPop	SLG
Disturbance Removal Chance	$Drc$	43.3	19.743	30.933	56.45
Fecundity Promotive Increase Rate	$F_{pi}$	21.825	18.899	26.892	16.537
Fecundity Promotive Resilience	$F_{pr}$	18.908	17.891	18.788	11.862
Fecundity Demotive Increase Rate	$F_{di}$	9.847	17.796	12.179	5.858
Fecundity Demotive Resilience	$F_{dr}$	5.167	13.276	9.471	5.107
Cost Promotive Increase Rate	$C_{pi}$	0.293	9.273	0.725	3.934
Cost Promotive Resilience	$C_{pr}$	0.271	1.291	0.363	0.11
Cost Demotive Increase Rate	$C_{di}$	0.247	0.991	0.343	0.084
Cost Demotive Resilience	$C_{dr}$	0.143	0.84	0.306	0.058

Table variable importance corresponding to Table 5.4 of Kara 2018.



Plot corresponding to Figure 5.18 of Kara 2018

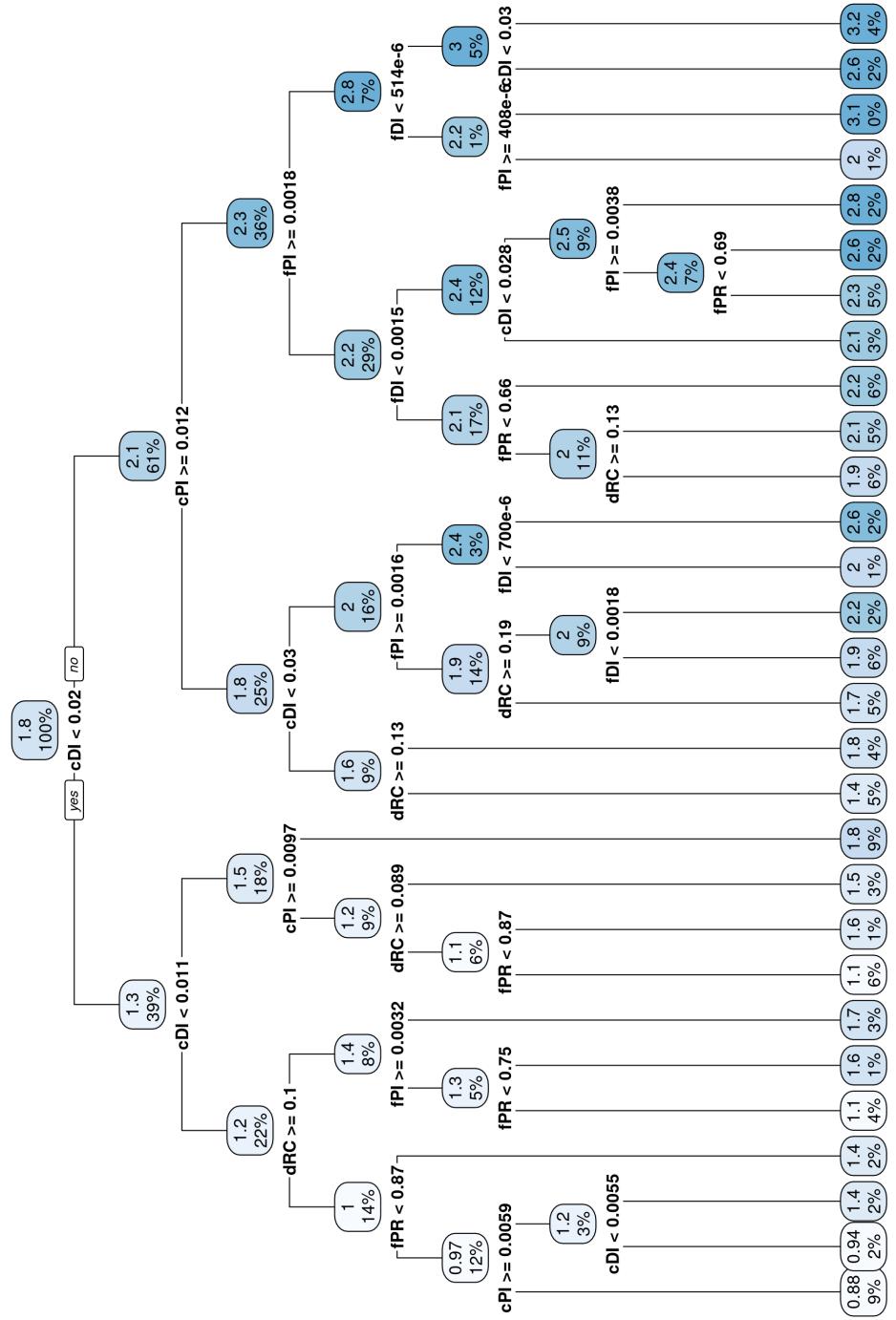
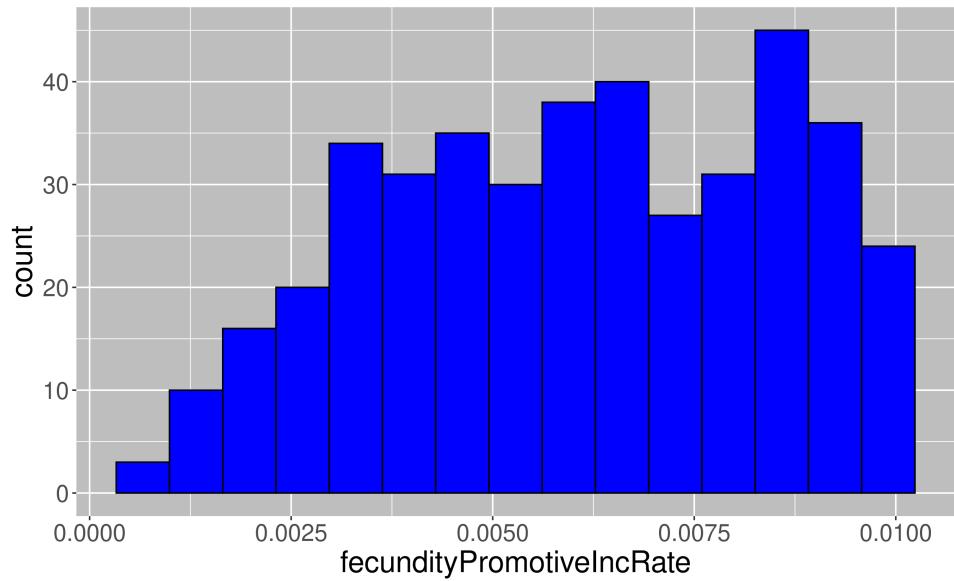
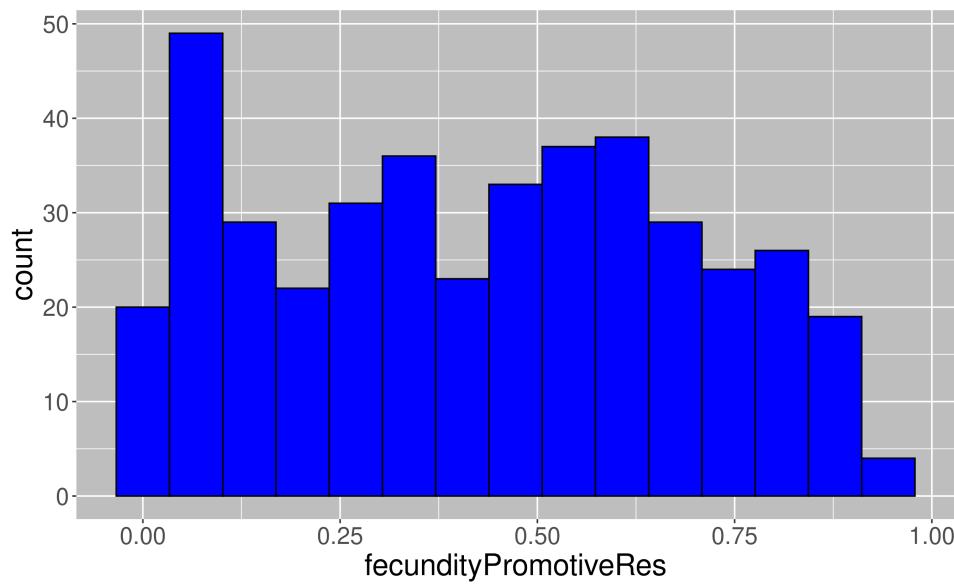


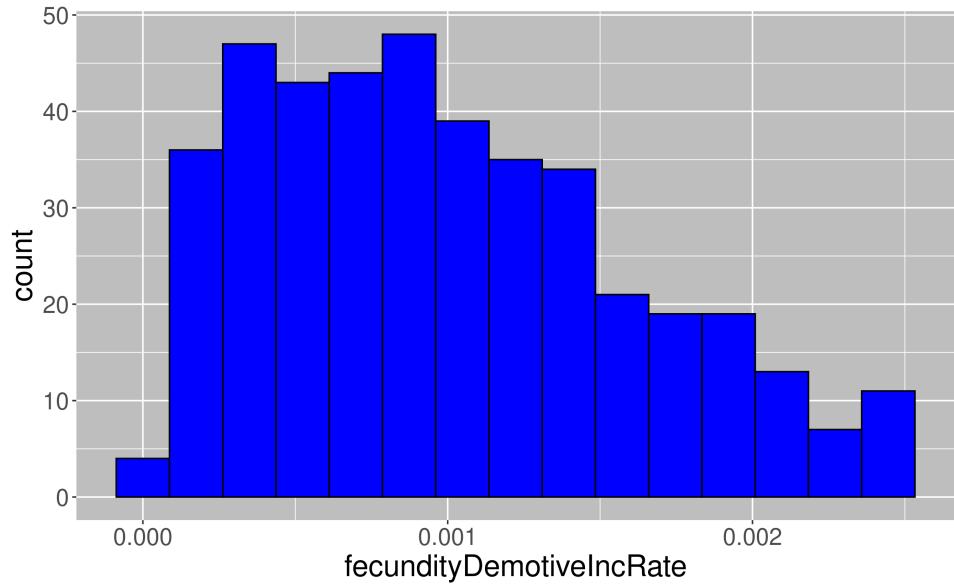
Figure 1: Plot corresponding to Figures 5.13, 5.14, 5.15, and 5.16 of Kara 2018



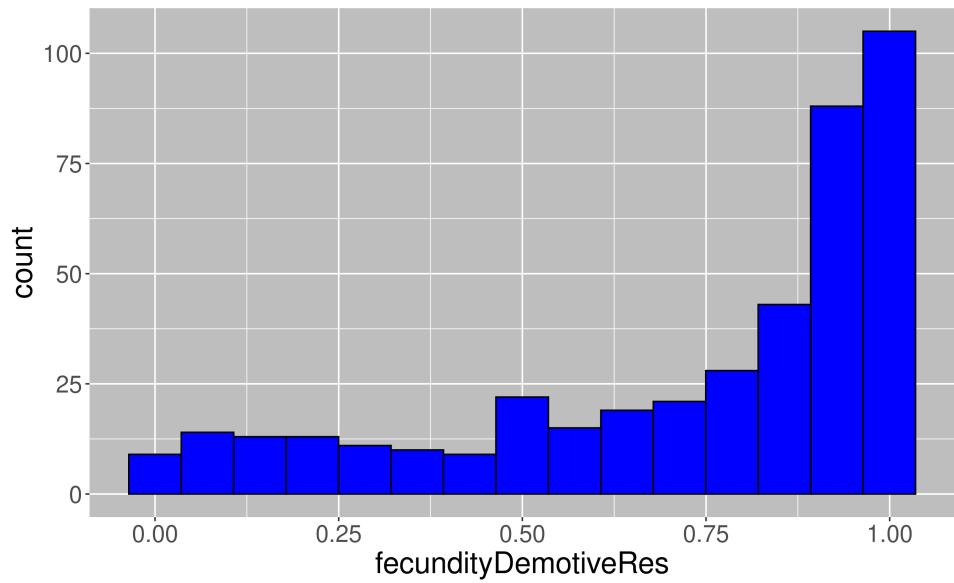
Plot corresponding to Figure 5.19 of Kara 2018



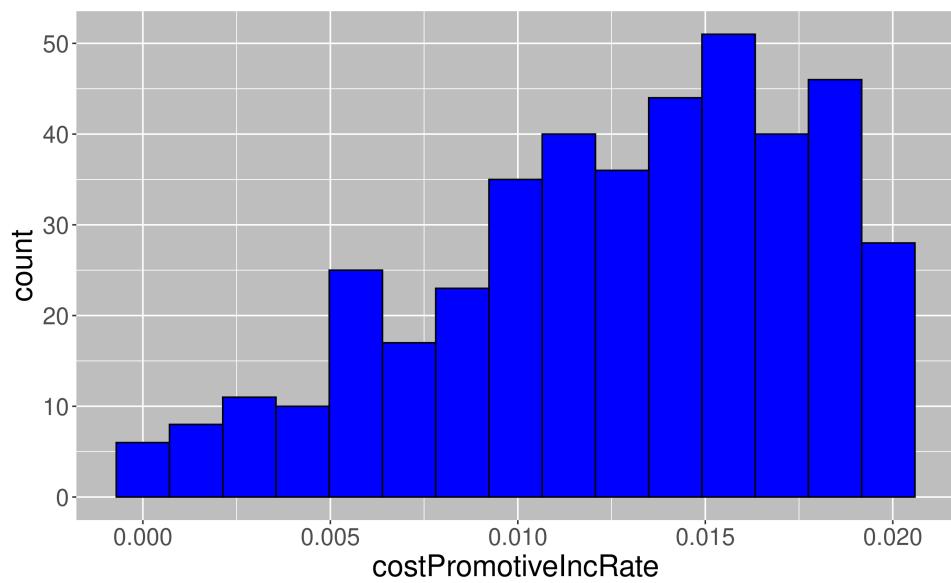
Plot corresponding to Figure 5.20 of Kara 2018



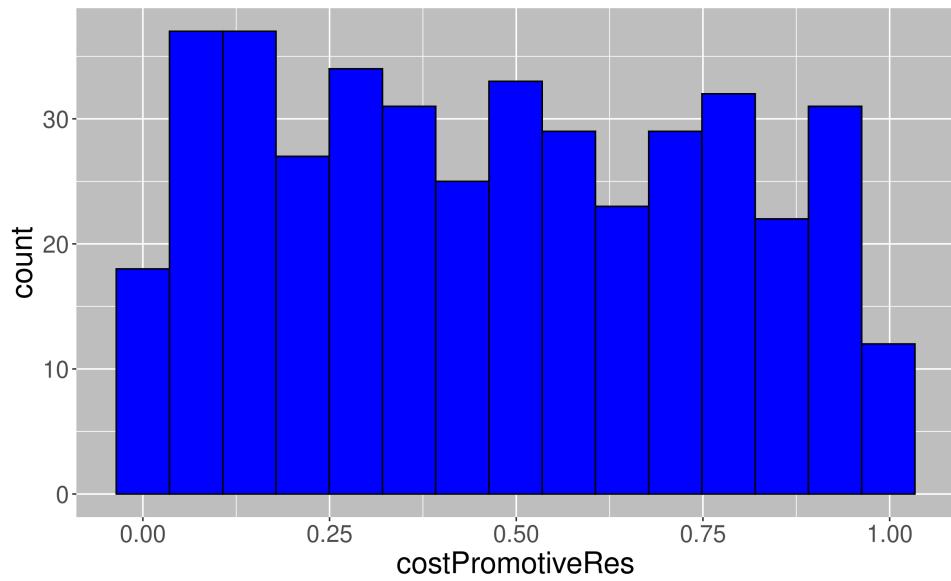
Plot corresponding to Figure 5.21 of Kara 2018



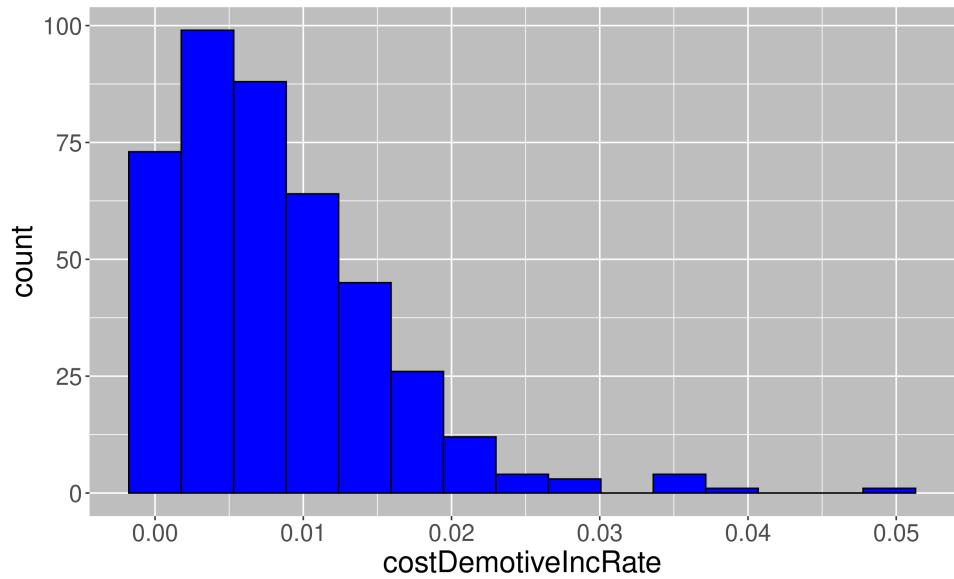
Plot corresponding to Figure 5.22 of Kara 2018



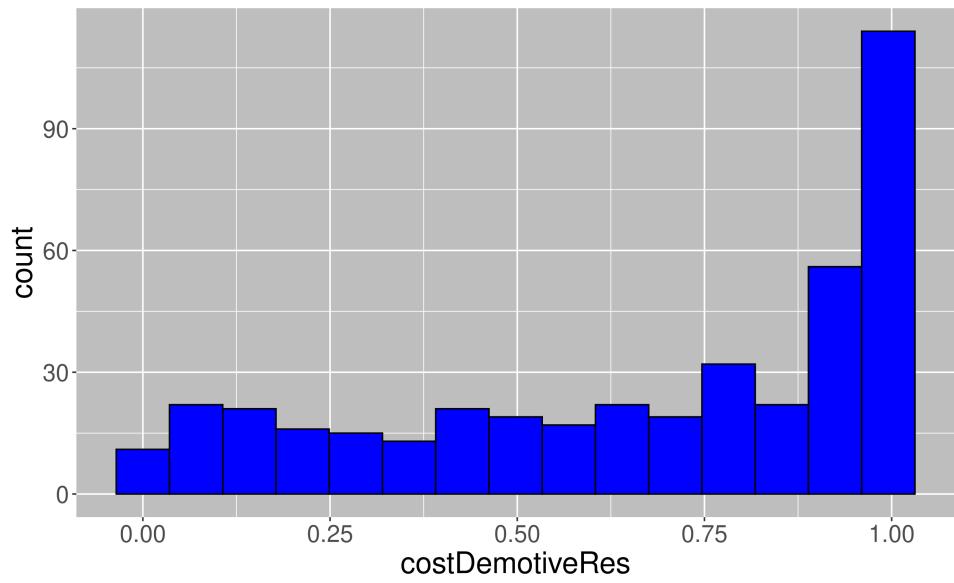
Plot corresponding to Figure 5.23 of Kara 2018



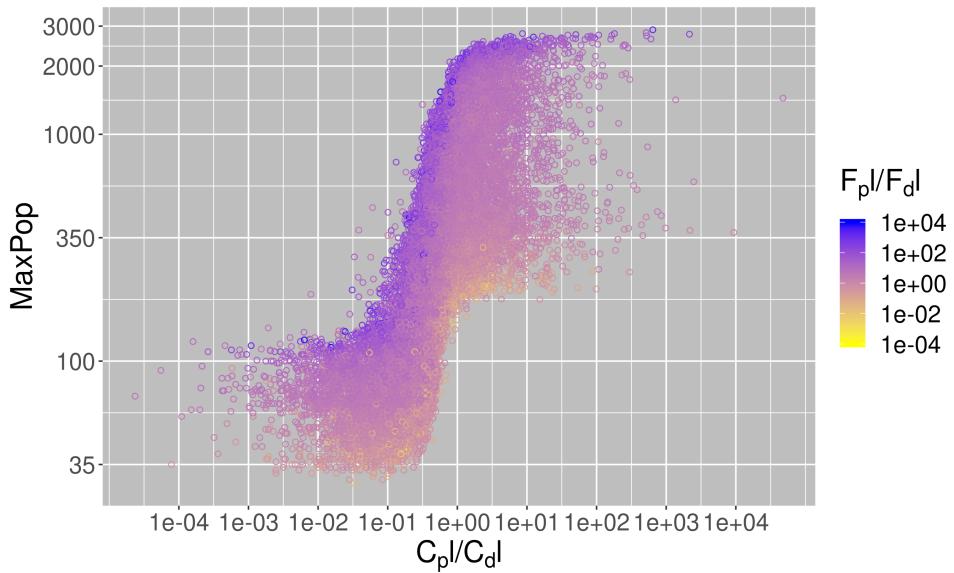
Plot corresponding to Figure 5.24 of Kara 2018



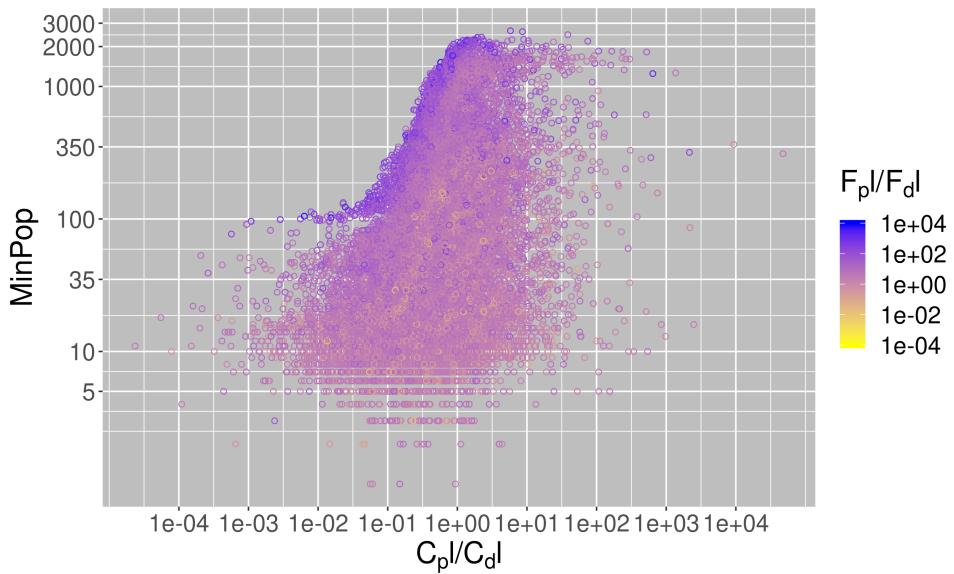
Plot corresponding to Figure 5.25 of Kara 2018



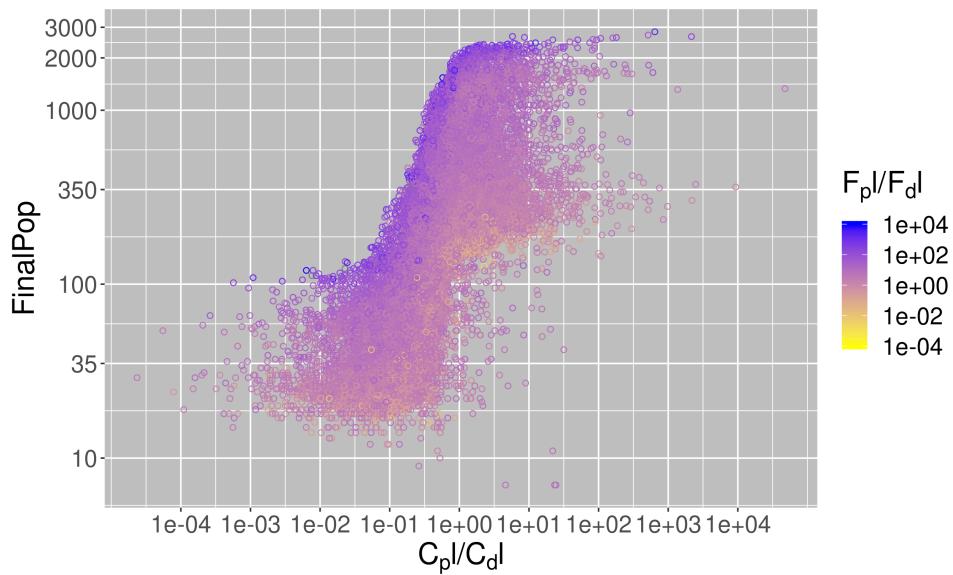
Plot corresponding to Figure 5.26 of Kara 2018



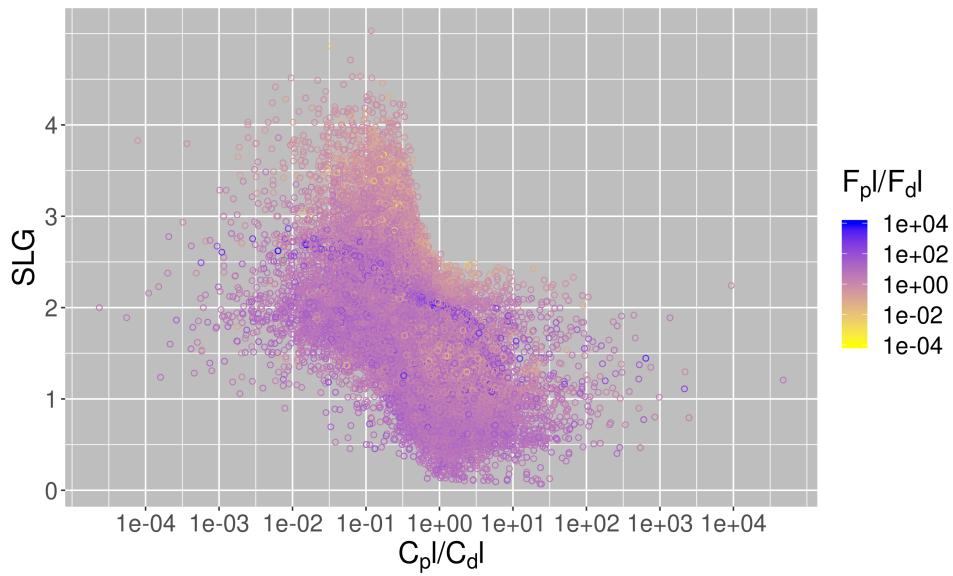
Plot corresponding to Figure 5.27 of Kara 2018



Plot corresponding to Figure 5.28 of Kara 2018



Plot corresponding to Figure 5.29 of Kara 2018



Plot corresponding to Figure 5.30 of Kara 2018

## References

- [1] Kara, Alex. “CHAAHK: a Spatial Simulation of the Maya Elevated Core Region” (Version 1.0.0). CoMSES Computational Model Library, 2018. <https://www.comses.net/codebases/b9335c92-f29e-42cf-aac8-712f6c587aad/releases/1.0.0/>
- [2] Kara, Alex. CHAAHK: A Spatial Simulation Model of the Maya Elevated Core Region. Diss. University of Cincinnati, 2018.