Appendix B:

Sensitivity Analysis on the Nice Musical Chairs model

Overview

This document offers detail on the behavior of the Musical Chairs model under the different conditions explored. In addition to the detailed results of the main design of the model, we present results obtained by performing the same experiments on a second version of the model, where there is no within-class competition. The comparison of these two versions allowed us to dismiss the presence of within-class competition as a relevant factor in producing the differences between the conditions explored.

Logic of the exploration

We followed the steps of Santos et al. (2015) to perform a robust exploration of the model's parameter space and evaluate the influence of each parameter on the state variables.

First, we applied the Latin Hypercube Sampling (LHS) technique to set up our simulation experiments (McKay et al., 1979). This procedure produces quasi-random values for each parameter, sampling the parameter space more homogeneously than other techniques available (B.1).

We assessed the importance of each of the parameters of the model on each of the two main state variables, i.e. the percentage of farming and the size of the biggest group. The parameter importance is here expressed by the Mean Standard Error (MSE) increase when attempting to predict the end value of the state variable without each permuted parameter (Breiman, 2001). To do that, we performed random forest analyses for each of the eight scenarios explored, using the "randomForest" package (Liaw and Wiener, 2002) implemented in R (R Core Team, 2015) and sampling 2000 trees per analysis (ntree=2000). Combining the results obtained with Random Forest analysis with bivariate scatter plots we interpreted the influence of each parameter in terms of absolute differences in the state variables.

Moreover, to render more clearly the influence of restricted access, management and pairing in the model, we performed an additional Random Forest analysis where these three aspects are included as binomial parameters in a data set encompassing the end values under all scenarios.

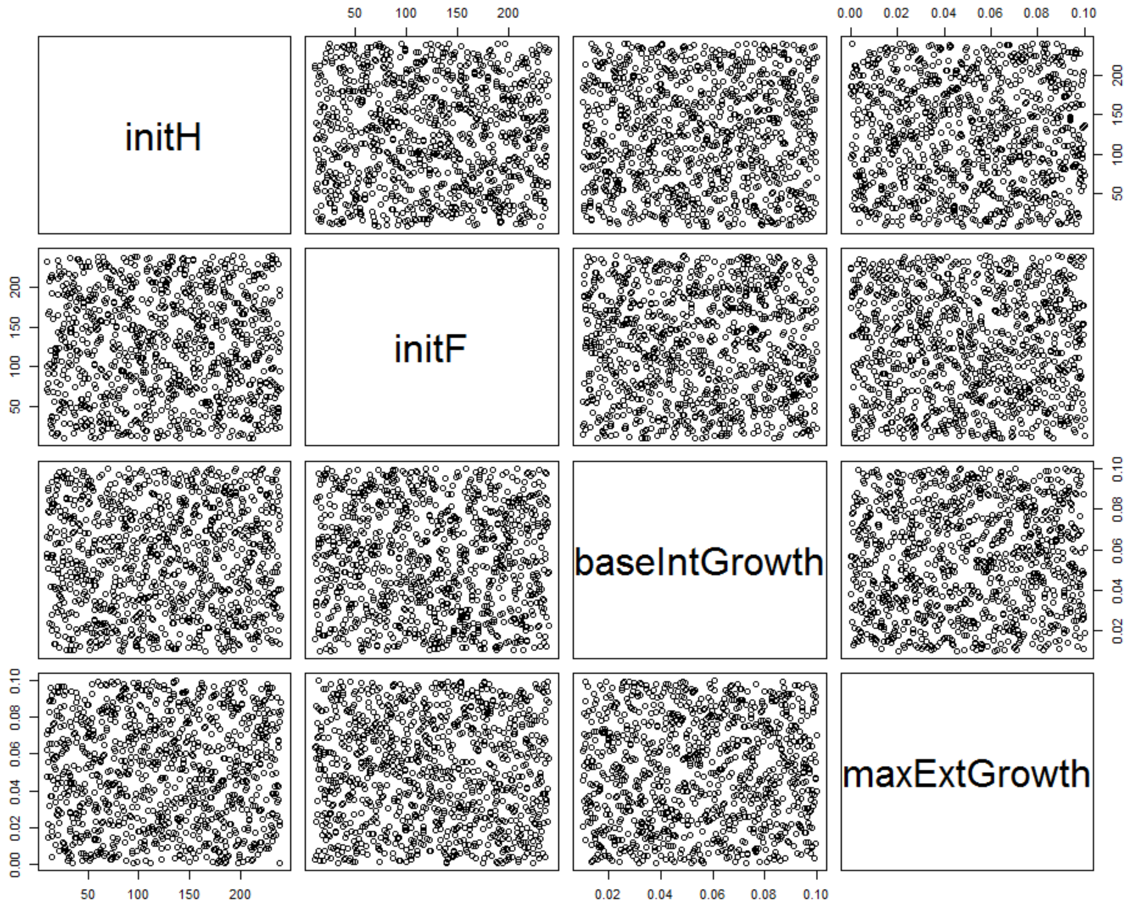


Figure B.1 An example of the sampling of the model's parameter space with LHS (N = 1000). Only four parameters are displayed, for the sake of visualization.

The effect of parameters

The initial number of farming and herding land units

The parameters determining the initial share of land dedicated to farming and herding (init_farming and init_herding) may generally be dismissed as influent factors. The scenario-wise Random Forest analyses in relation to the proportion of farming indicate an exception in scenario Ar (B.2). However, even within this scenario, the effect of these parameters can be described as a slight offset, in Ar towards more farming (greater init_farming) or more herding (init_herding) against a much stronger tendency towards balanced land use patterns (B.3).

Intrinsic and extrinsic growth rates

Overall, the growth rates have a significant impact on the configuration of land use patterns only in the absence of management (Ao, Ar, Bo and Br, B.2). Both parameters are marked as especially important under an open access regime (Ao and Bo), under which the influence of the extrinsic growth rate is the most significant. Regarding their relationship with the size of the biggest group, the extrinsic growth rate is also the one noteworthy, though in this case particularly under the combination of management and open access (Co and Do, B.3).

Whenever significant, a greater intrinsic growth rate improves the share of farming and strengthens centralization, while the increment of the extrinsic growth rate push results towards a balanced and fragmented pattern (B.4 and B.5).

Although prominent among parameters, the growth rates have mild effects in comparison to the differences among scenarios.

Initial diversity of groups

The initial number of groups is a parameter with broadly no significant effect on the final values observed. A discernable exception occurs in relation to the size of the biggest group under scenarios with management and open access (Co and Do), where the initial group diversity have a slight negative influence over centralization (B.3 and B.5).

Group effectiveness gradient

Generally, the effectiveness gradient is an important parameter of the model. Most clearly, it is the main constraint on the size of the biggest group under all scenarios (B.3 and B.5), as intended in the model design. Concerning the configuration of land use, this parameter is also relatively relevant, though to a lesser degree. Its influence is especially noticeable whenever there is no management and access to pasture is open (Ao and Bo, B.2 and B.4). Nonetheless, the small scale of the variation produced suggests that the final share of farming land use is broadly independent of the constraints of centralization.

The maximum rate of group change

This parameter constrains the potential migration of individual land units between groups. As expected, it affects mainly the size of the biggest group (B.3), slightly facilitating or obstructing centralization depending on the presence of management (B.5). Moreover, when management and open access are combined (Co and Do), this parameter is the most relevant in configuring the land use pattern (B.2), explicably since the most probable state under these scenarios is the fragmentation of land use in multiple groups. Specifically, in this case, reducing group changing facilitates the emergence of a dominant group specialized in farming (B.4).

Optimal farming ratio and growth increase at the optimum

As anticipated, when pairing is enabled (Bo, Br, Do and Dr), the optimal farming ratio is among the most important parameters in defining the percentage of farming (B.2). Its role is most significant when there is no management and access to pastures is restricted (Br). However, in absolute terms, the effect caused is relatively small, even under scenario Br, where at least some end values can be found for any optimal farming ratio (B.4).

In contrast, the growth increase at the optimum always has a weaker effect on the farming ratio, in both relative and absolute terms.

Finally, the size of the biggest group is broadly non-affected by different values of optimal farming ratio and growth increase at the optimum (B.3 and B.5).

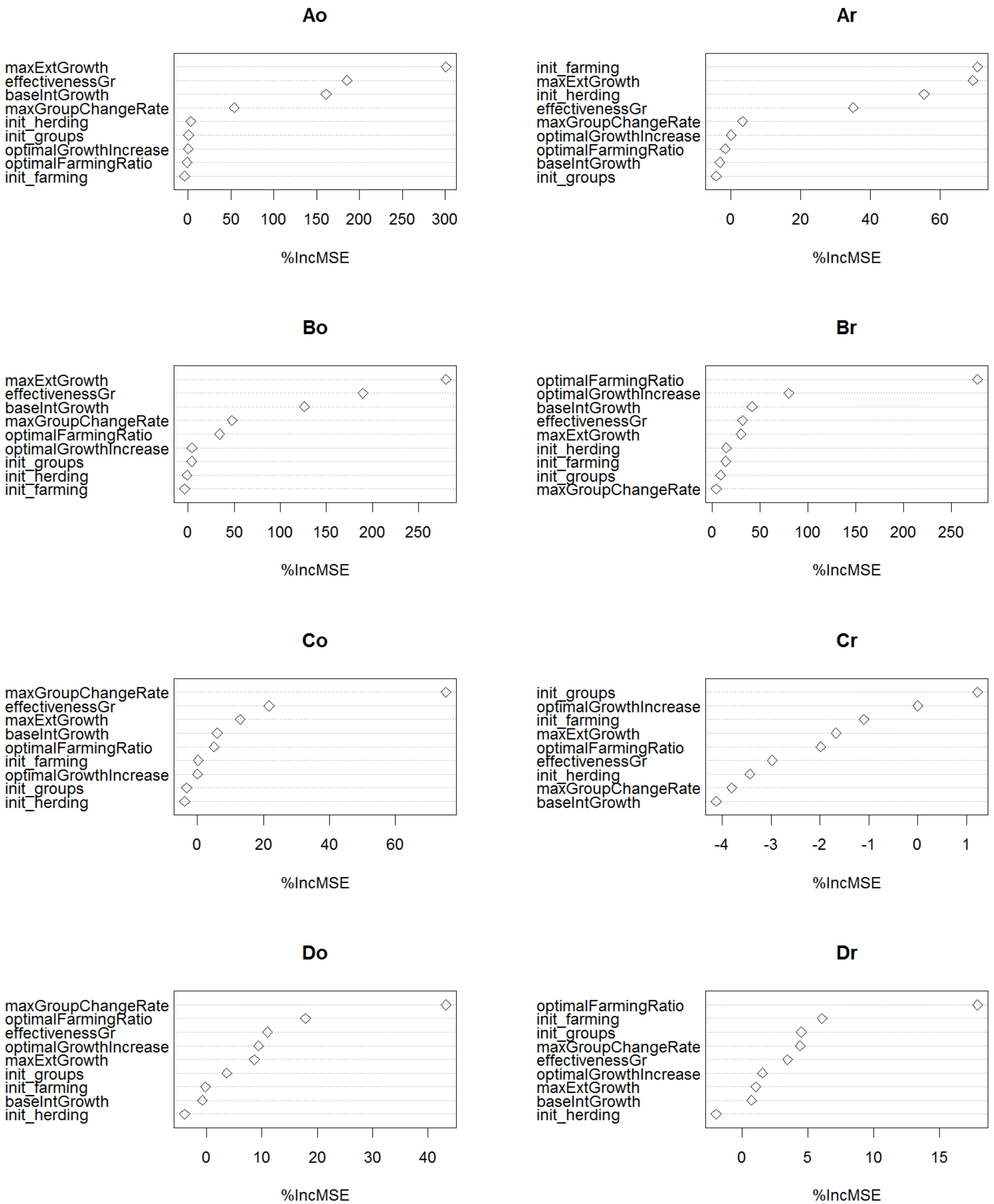


Figure B.2: The ranked parameter's importance in respect to farming across all experiments

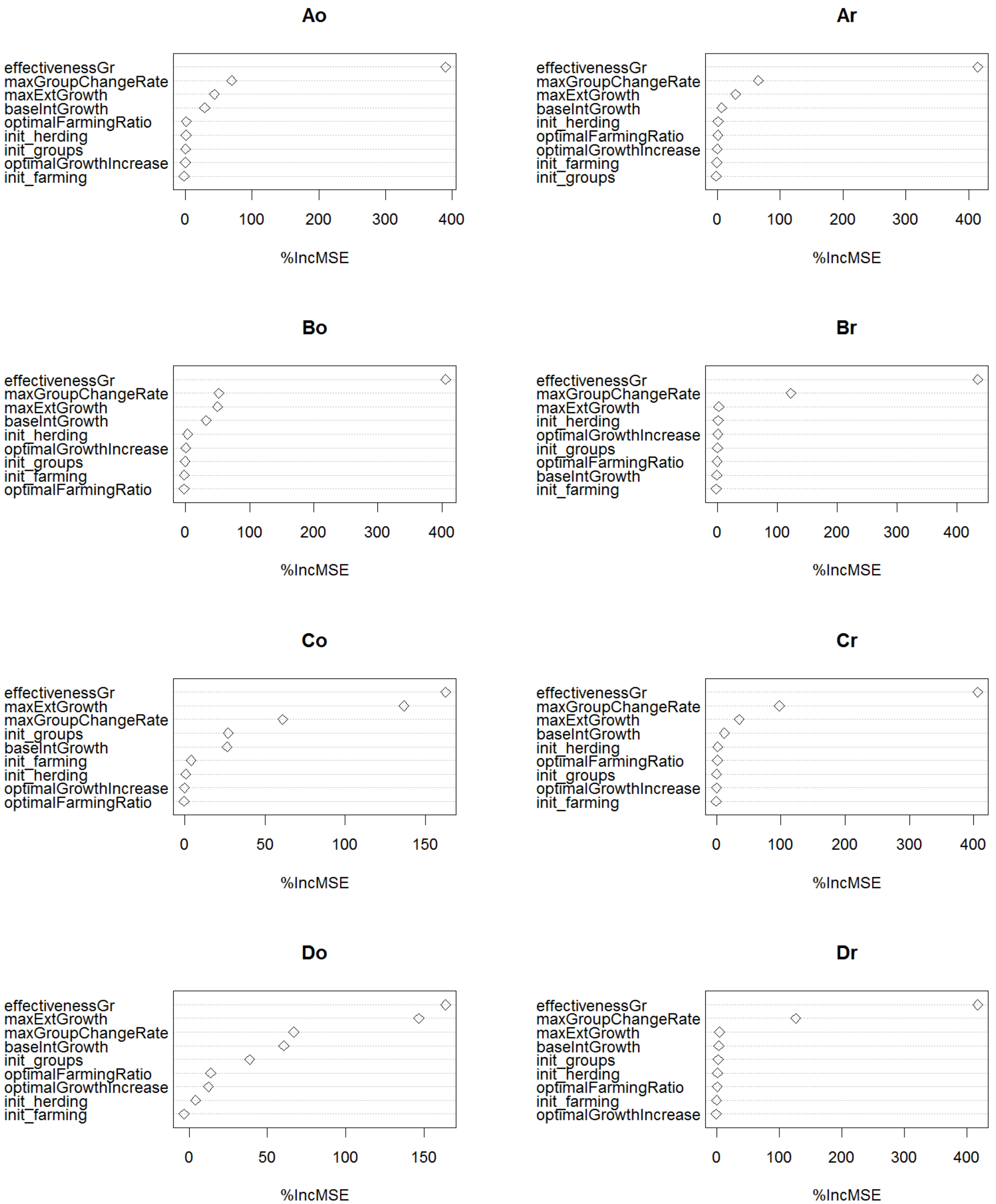


Figure B.3: The ranked parameter's importance in respect to the size of the biggest group across all experiments

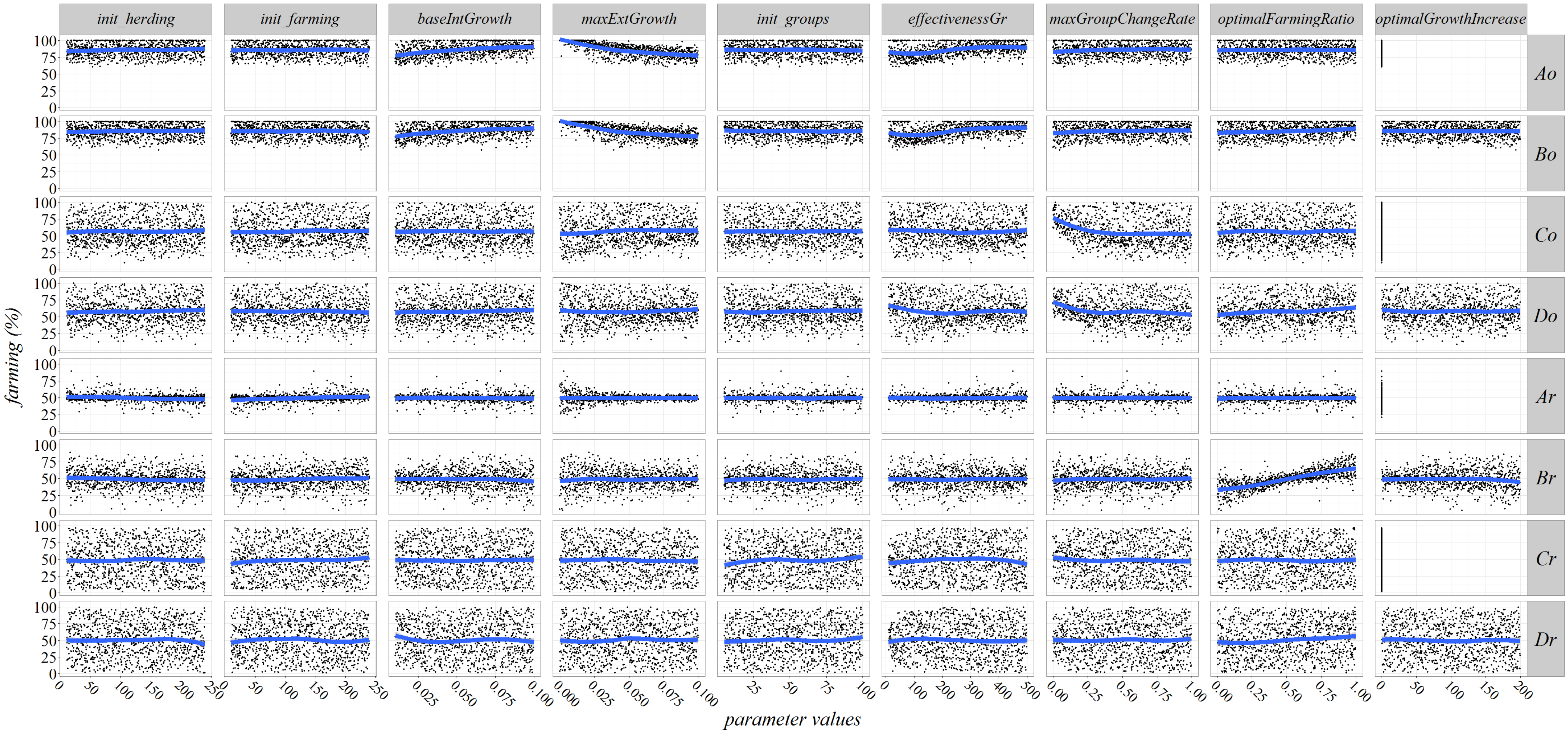


Figure B.4: The extent of farming according to scenario and parameters' values

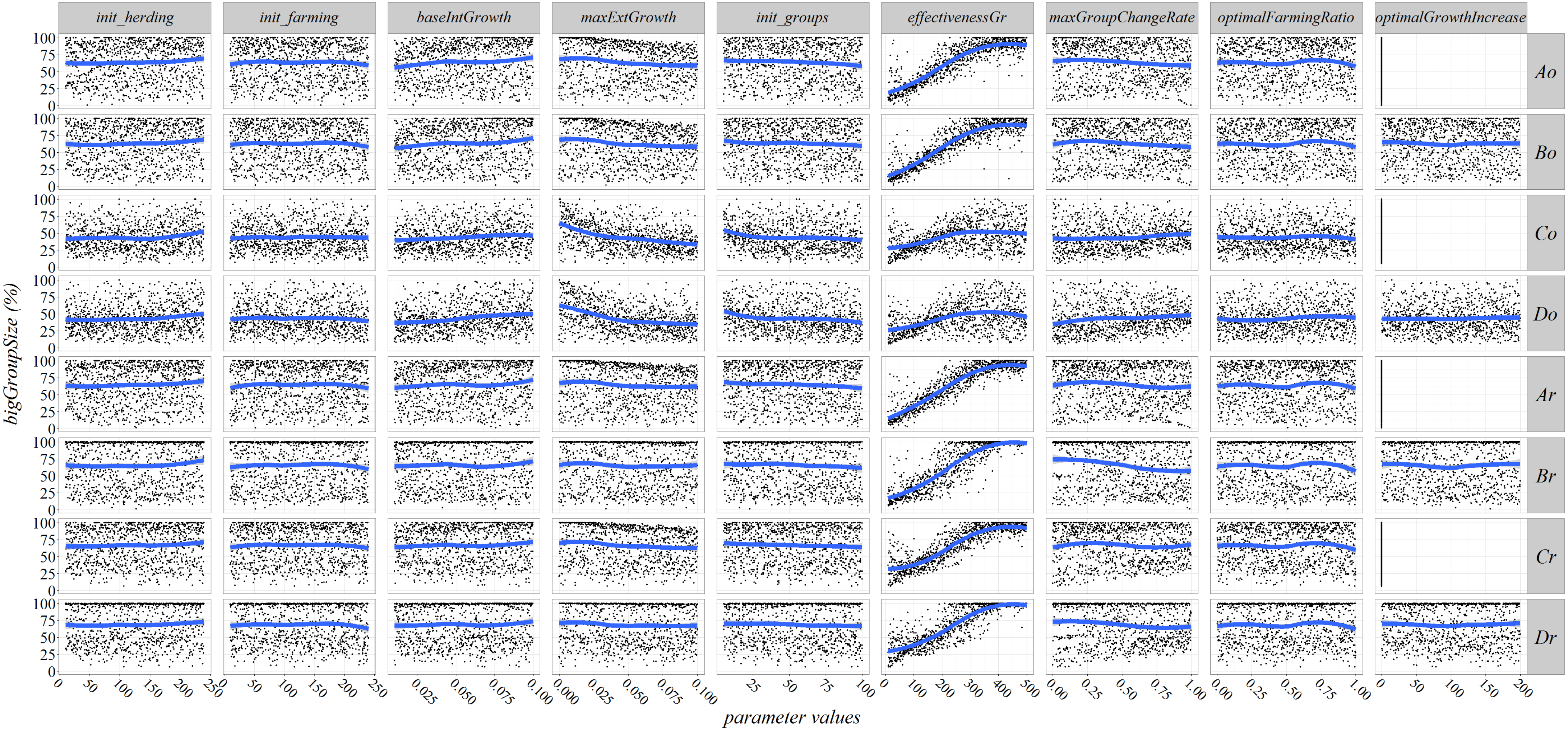


Figure B.5: The the size of the biggest group according to scenario and parameters' values

Version without within-class competition

Given the introduction of within-class competition (farming-farming and herding-herding competition), which was absent in the Musical Chairs model, we deemed relevant to evaluate its effect, especially in contrast with the variations observed between scenarios. For this purpose, all sets of experiments were repeated consenting only between-class competition (farming disputing herding land units, and vice-versa).

The effect of scenarios

Regarding the differences between scenarios, only minor variations are appreciable in respect to the main version of the model (B.6 and B.7). Essentially, the presence of within-class competition eases centralization, explicably because groups compete more intensively, disregarding their internal farming ratio. In this sense, when this aspect is excluded from the model, the system dynamic will more frequently be trapped in local equilibria where specialized groups coexist. The amplitude of this phenomenon is greater with open access to pastures and no management (Ao and Bo), when trajectories converge either in fragmented more diversified land use patterns or the complete centralization and specialization in farming. In contrast, under scenarios Cr and Dr, within-class competition is of little consequence to the long-term land use pattern.

This version is consistent with the main version of the model also when considering the relative importance of the three aspects varying between scenarios (B.8). The most important aspect in defining the percentage of farming is the regime of access to pasture, followed by management, while the size of the biggest group is most affected by the effectiveness gradient, and again by the regime of access to pastures and management.

The effect of parameters

Without within-class competition, most parameters hold the same importance and produce the same effects described above regarding the main version (B.9, B.10, B.11, and B.12).

The highlights and exceptions are the following:

- The **initial number of farming and herding land units** are generally unimportant, except under the scenario Ar, where these parameters produce a slight unbalance in the otherwise balanced farming ratio (B.9 and B.11).
- The **intrinsic and extrinsic growth rates** are generally less important than they are in the main version (B.9 and B.10), explicably because part of the pressure generated by growth is dismissed when within-class competition is not possible.
- In contrast with the main version, the **initial number of groups** has a mild but relevant effect over the percentage of farming with open access to pastures (B.9), especially without management (Ao and Bo), while it has still a significant influence on the size of the biggest group under the scenarios Co and Do (B.10 and B.12).
- As in the main version, the **group effectiveness gradient** is one of the most influent parameters of the model, especially under scenarios Ao and Bo where it heavily impacts the percentage of farming (B.9 and B.11).
- The **maximum rate of group change** has exactly the same effect and importance when there is no within-class competition (B.9 and B.10).
- The two parameters regulating pairing, the **optimal farming ratio** and the **growth increase at the optimum**, are even less important without within-class competition (B.9 and B.10). The exception occurs under scenario Br regarding the proportion of farming; however, as in the main version, the absolute effect is quite small (B.11).

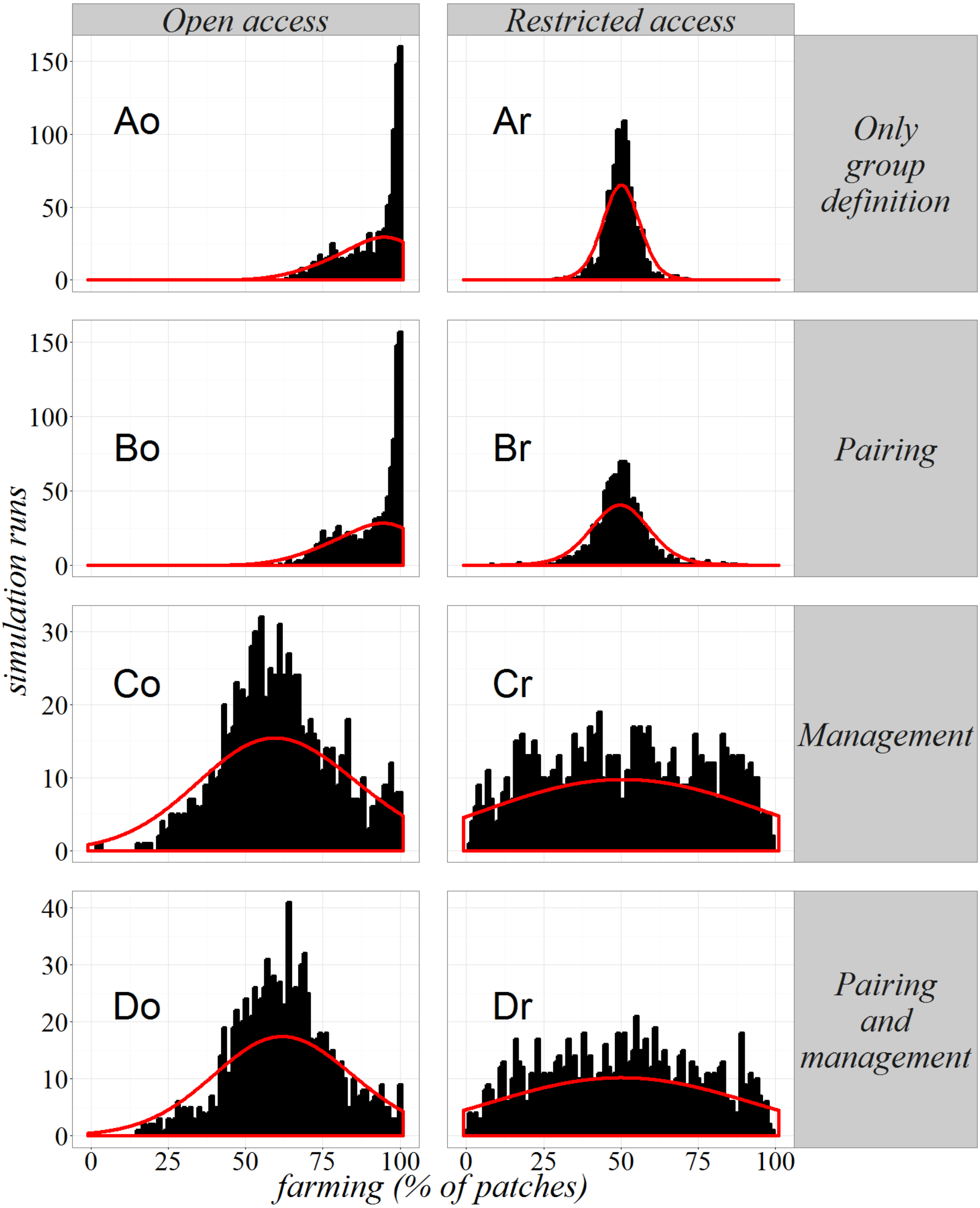


Figure B.6: The count of simulation runs stabilizing at different extents of farming and the respective density projections (lines) for each of the eight scenarios explored in experiments without intra-class competition

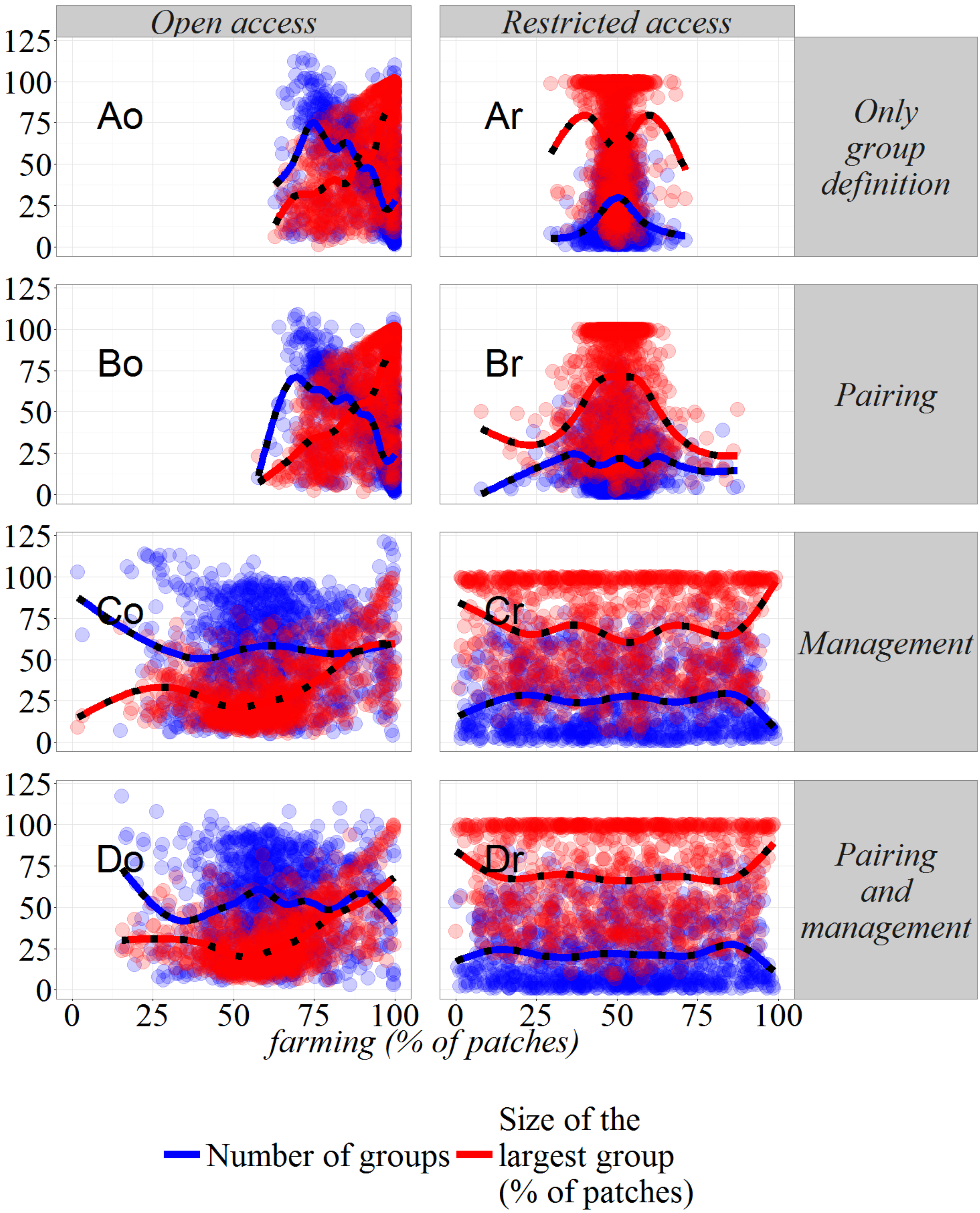
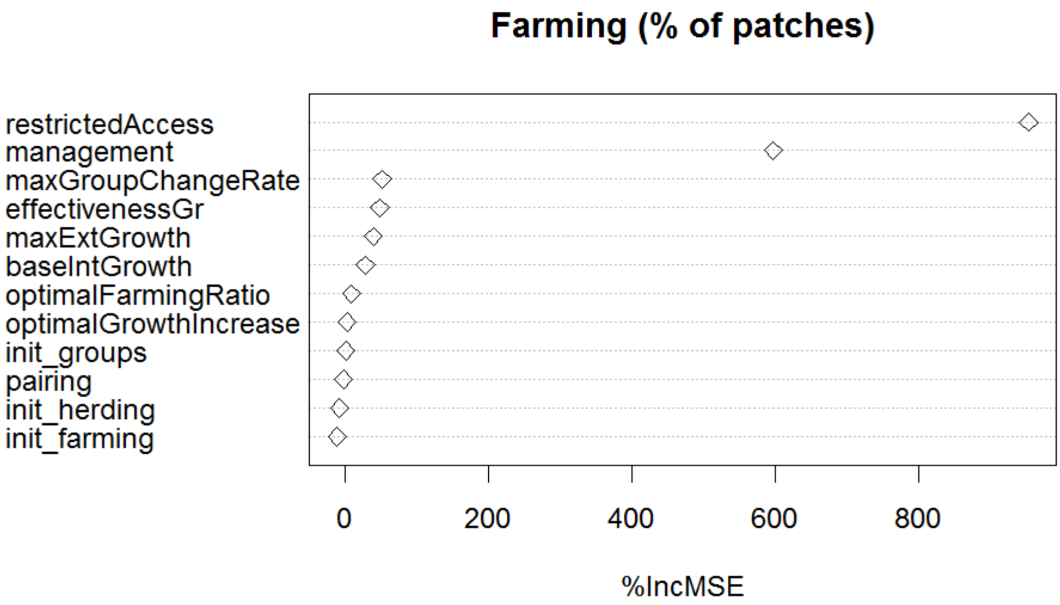


Figure B.7: The extent of farming versus the number of groups and the size of the biggest group. The lines represent the generalized additive model (GAM), using a cubic regression spline, for the each variable in experiments without intra-class competition



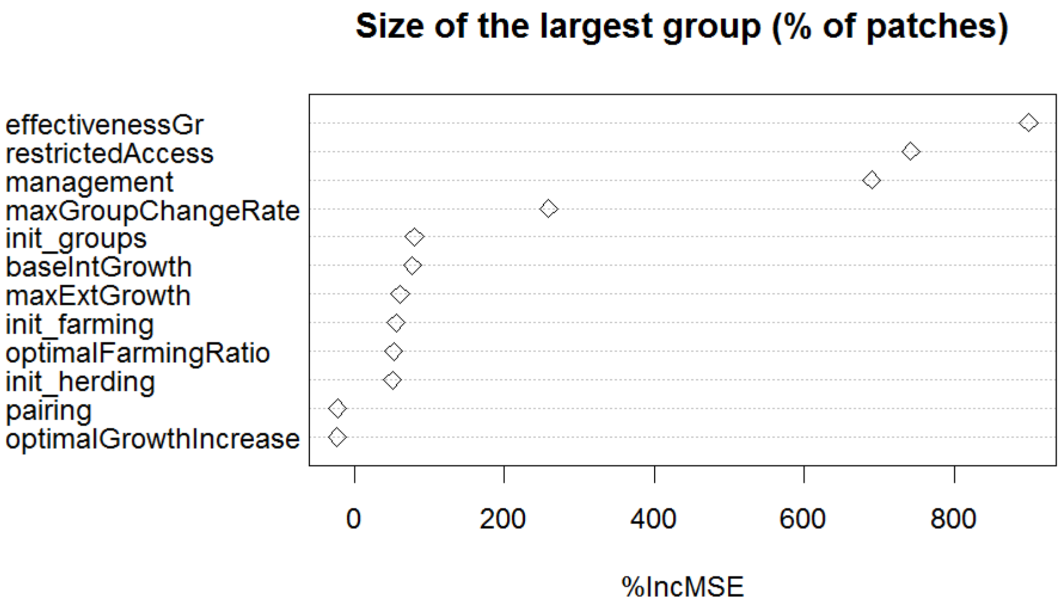


Figure B.8: The ranked parameter's importance in respect to farming and the size of the biggest group across all experiments without intra-class competition

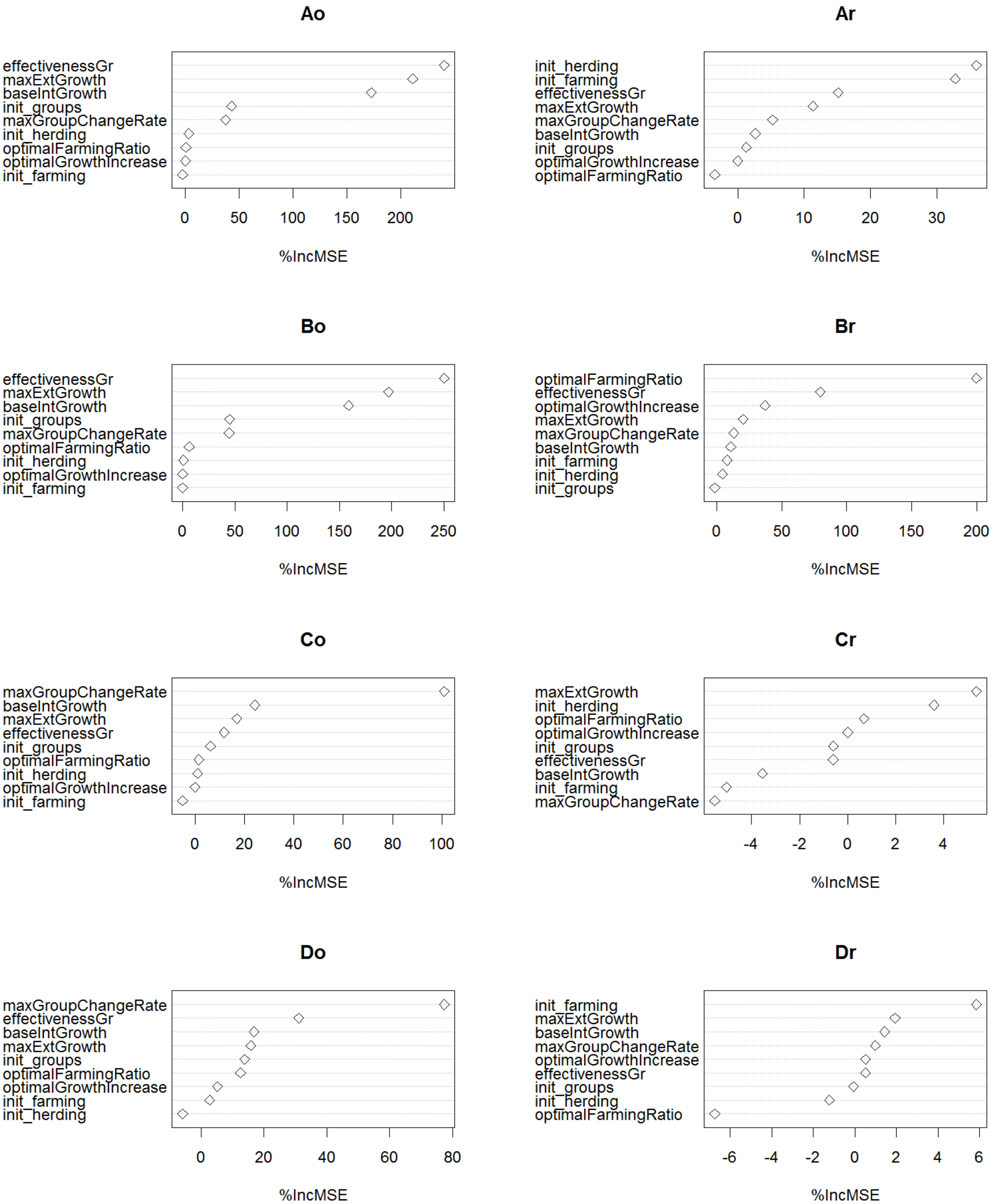


Figure B.9: The ranked parameter’s importance in respect to farming across all experiments without intra-class competition.

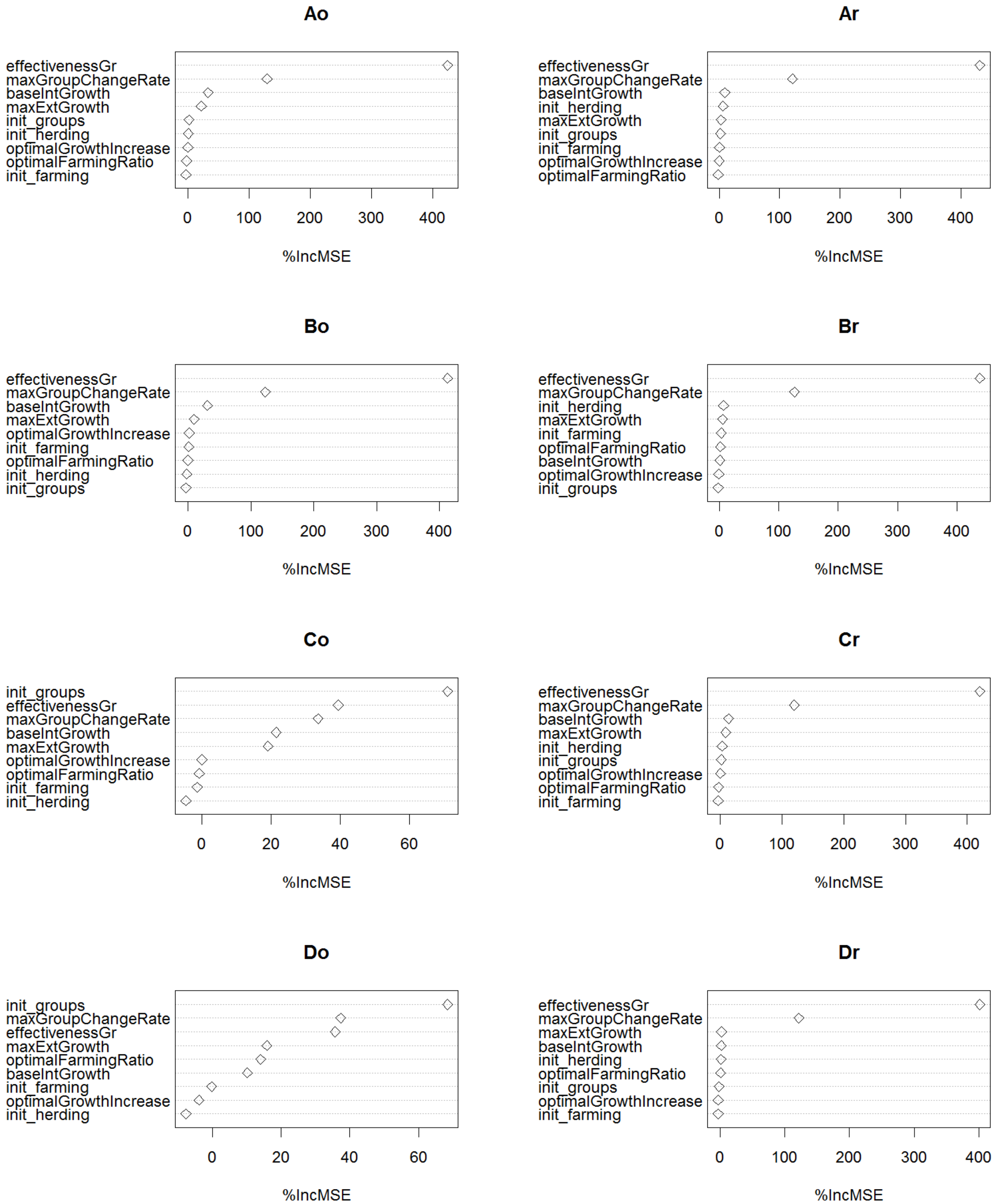


Figure B.10: The ranked parameter's importance in respect to the size of the biggest group across all experiments without intra-class competition

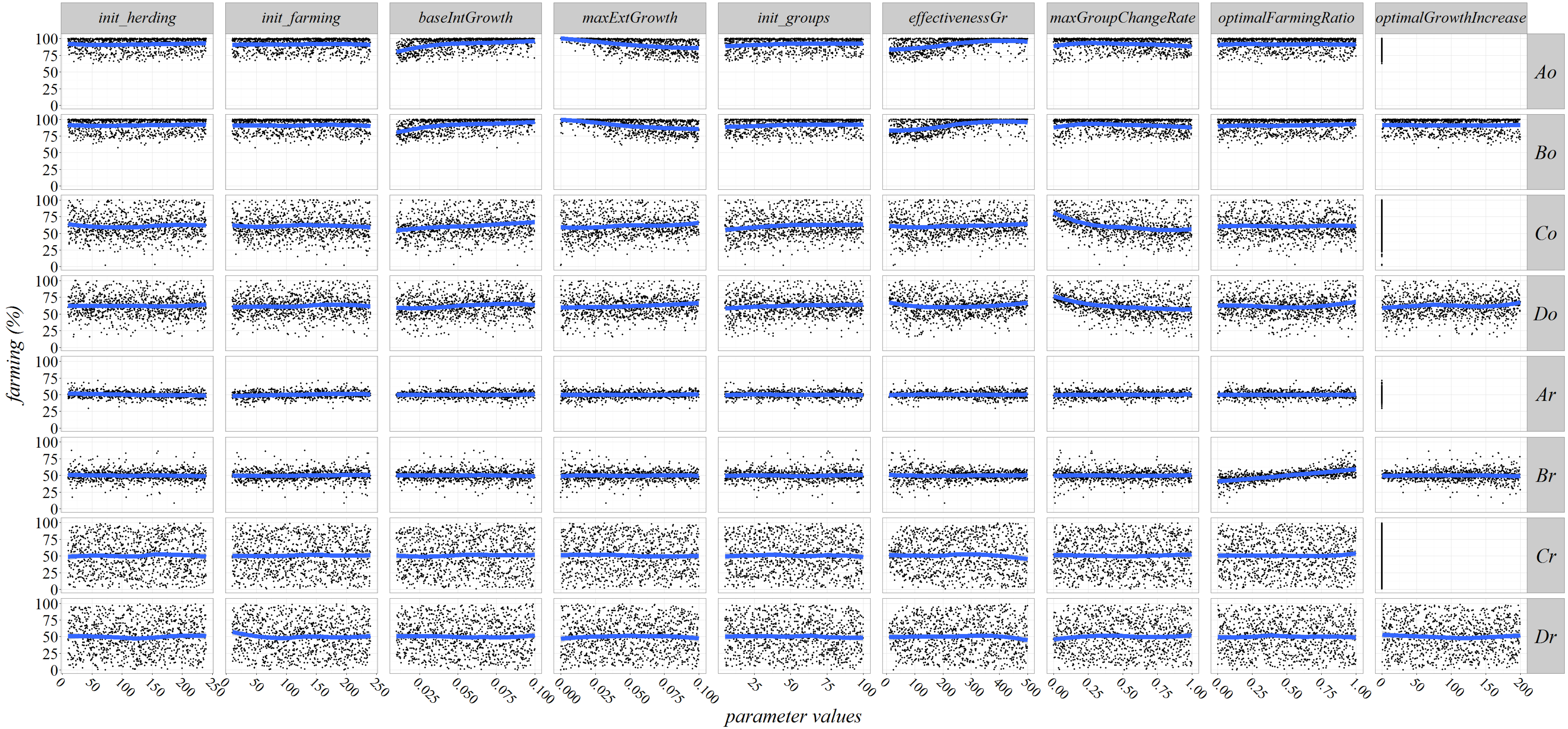


Figure B.11: The extent of farming according to scenario and parameters' values

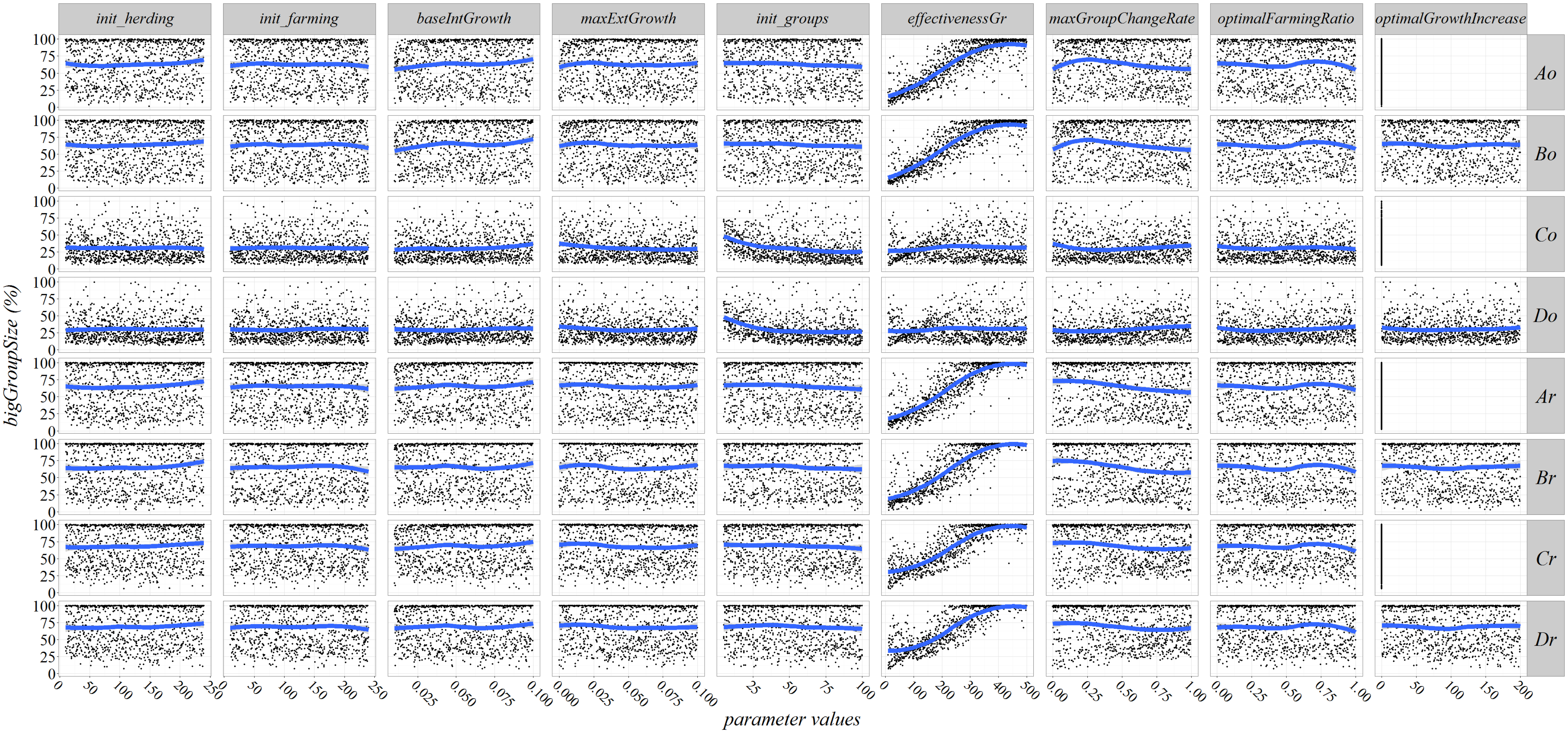


Figure B.12: The the size of the biggest group according to scenario and parameters' values

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