Review: Human induced regeneration: A spatiotemporal study

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I have been asked to review the report by Dr Stephen Beare and Professor Raymond Chambers, *Human induced regeneration: A spatiotemporal study.*

Human induced regeneration (HIR) is a carbon capture initiative for creating carbon credits overseen by the Australian Clean Energy Regulator. The study uses a suite of models to assess the effectiveness of HIR projects in the arid and semi-arid regions of New South Wales and Queensland.

The data considered come from 72 projects in NSW and 51 in QLD all of which have been under HIR project management for at least four years. Within a project data is collected from carbon estimation areas, CEA, an area of land of at least 0.2 hectare, eligible for project activities. CEAs constitute about 90% of the total project area, (median values 88.8% and 90.6% for NSW and QLD respectively). Data from individual CEAs is agglomerated and the unit of analysis is the project year. I will not discuss in detail the data assembly and pre-processing. It will suffice to note that the preliminary form of data for analysis is the classification of land cover in a CEA into Open i.e., canopy cover < 5%, sparse Woody i.e., canopy cover 5 – 19%, and Forest, i.e., at least 20% cover of vegetation more than 2m high. This classification into three classes is then summarised further, and success is defined as a transition of a CEA from open to woody or forest cover.

A simple analysis of the data shows increases in change in woody plus forest (WF) cover in the project areas. Comparison of pre- and post-start areas on NSW, (see Fig. 2.3) shows reduction in Open, a small increase in Woody, and a relatively large increase in Forest. The data for QLD, (Fig. 2.4), show a similar pattern, but not so pronounced as in NSW. The excluded areas are also compared. In NSW, (Fig 2.5) the results mirror those in the CEAs, but in QLD there is no real change in the excluded areas. The analysis in this report seeks to confirm that these increases in WF cover can be attributed to HIR.

There are two possible objections that are required to be overcome:-

- WF cover will tend to increase over the passage of time. The increase due to HIR, the additionality, must be estimated, and shown to be (significantly) greater than zero. This additionality requires the estimation of the counterfactual, that is the change in woody plus forest (WF) cover that would have been expected, had a project not participated in the HIR method.
- "Cherry picking", i.e., the projects used for this assessment somehow reflect a selection that is not representative of all projects that might become involved in the program. Cherry picking, if it occurs, implies that the probability that a project enters the HIR method early is related to the capacity of the CEA to be re-forested. Cherry picking is a concern if the most promising or 'prospective' areas for regeneration entered the program early, and later and future areas entering the project are increasingly less prospective in terms of re-establishing forest cover. This is a concern

for the management of the HIR method as future benefits from entering the program would diminish, so that earlier projections could not be generalised.

Counterfactual modelling:

The first substantial statistical modelling exercise in the report is the counterfactual prediction of the change in cover that would have occurred without the HIR method. For each project a matched 'quasi' control area was constructed for each project. The modelling was carried out in a careful way, clearly described in the report. Once the control area for each CEA is determined and its WF cover calculated then any change in this WF cover allows the prediction of the counterfactual WF cover had the CEA had not participated in the HIR method and hence the change in cover that can be attributed to the HIR method.

These counterfactual models are similar but differ slightly for NSW and QLD, but for both states the correlation between the actual changes in cover for the CEAs and the same changes observed using the control areas was high.

The counterfactual models were further refined by considering whether or not an HIR project had commenced by a given year, and the number of years that a project had been in the program by that time.

The results from this modelling are very clear, particularly in NSW. Table 3.5 gives the estimated programme attributions as a percentage of pre-start WF cover. For NSW overall 13.3, (95% confidence interval 12.4 – 14.1), and for QLD 6.3 (5.0 – 7.7). By considering estimates for 2020 only all of the data is used and the corresponding estimates are 17.8 and 9.5 for NSW and QLD respectively. The confidence intervals are tight, and the full- and 2020- estimates for both NSW and QLD are consistent, suggesting that the modelling is robust. The fact that the NSW estimates are approximately twice those for QLD is a question for subject matter experts.

Assessment of cherry picking:

Do projects used for this assessment somehow reflect a selection that is not representative of all projects that might become involved in the program? Cherry picking, if it occurs, implies that the probability that a project enters the HIR method early is related to the capacity of the CEA to be re-forested.

Cherry-picking creates a self-selection bias, because the use of the length of time that a CEA has been in the HIR program as a predictor in the counterfactual model means that, the estimate for the 'length of time' coefficient would be overestimated.

Accounting for changes in prospectivity over time can be achieved by amending the model to allow for decreasing impacts due to lower prospectivity over time; e.g., by replacing the zero-one program start term by a decreasing time trend. However, fitting such a non-linear model would require post-start data over a longer time period than is currently available.

The report uses an alternative approach is to differentially weight the data to reduce the impact of post-start data for projects that entered the program earlier. These weights reflect decreasing prospectivity associated with a later program entry. Effectively, more prospective projects tend to enter earlier and so have larger entry probabilities and hence smaller weights.

The report considers two ways in which to use these weights to correct the potential bias in estimated attribution. These two alternative weighting-based approaches and the original approach to estimating the attribution are compared. All three approaches yield attribution estimates that are positive and not significantly different in both NSW and Queensland. Since all three approaches concur in terms of their estimated values the report concludes that there is no evidence that cherry picking has an effect.

The report checks this conclusion by using permutation tests where the start dates of projects are permuted and pre- and post-start cover data is re-classified. to create a permutation distribution of attributions based on scrambled start dates. to rule out the possibility that the length of time a project participates in the HIR method is unrelated to level of change in WF cover, and that time in the program does, in fact, matter. If there is no relationship, the calculated attribution should lie in the main body of this distribution. If there is a significant positive effect of time in program, however, then the actual attribution value would be expected to be positioned at the extreme upper end of the permutation distribution with an extremely small significance value. If cherry picking is present, the resulting downward bias should lead to a larger number of permutations that generate attributions greater than those based on the actual times in the program, and hence a more moderate significance value. The results of the permutation tests are given in Table 3.7. The p-values are all highly significant for both NSW and QLD, and both average post-start and 2020. The report concludes that cherry picking is unlikely for the HIR data that was used in the analysis and that these data also indicate the presence of a significant positive attribution.

Overall, the analysis presented in the report provides strong evidence that projects established under the HIR method have resulted in significant increases in WF cover in the arid and semi-arid regions of NSW and Queensland.

Comments on Statistical Modelling

The report notes, see Fig. 2.1, that the response variable used, the change in WF cover, will not be appropriate if data continues to be collected over a long period of time. This is because WH cover cannot increase above 100%. (Fig. 2.1 indicates an upper bound of ~75%). Thus the models employed in this report are not universal. No statistical model ever can be. All models are simplifications which try to capture the essential features of the phenomenon under study. Conclusions drawn from a statistical model must be assessed for robustness.

Similarly, there is never one “correct” or “best” model in any given situation. Consider the counter factual attribution models in the report. Construction of the matching control area for each CEA includes excluded Open or Woody, excluded Forest, and some subset of adjacent excluded areas. The authors of the report have chosen this subset of predictors after a careful analysis of a range of models. This means that not only can we have confidence in conclusions drawn from the output of those models, but also confidence that the models used are robust in the sense that the conclusions will be very similar if slightly different subsets of predictors, particularly choice of the adjacent control areas were used.

This concern for robustness can also be seen in the construction of the models to assess whether cherry picking exists. Several related models are used, and their results compared. In addition there is an overall check using a testing method which requires very few assumptions about the data to ensure the reliability of its conclusions.

The choice of modelling methods is appropriate throughout. The data analysis is careful, and results are checked by being derived in two or more ways, and compared using external testing methods. We can have confidence in the robustness of the conclusions of the analysis in this report.