Combining Non-Parametric based models for multisource predictive forest mapping

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Abstract Using a single model for forest type predictive mapping will not produce good estimates of confidence in the prediction of individual pixels, even with good overall accuracy. A new strategy which combines several models based on different philosophy could not only reduce the uncertainty of predictive modelling, but also improve the mapping accuracy. In our study, a Artificial Neural Networks, a Decision Trees, and a model of Dempster-Shafer's Evidence Theory were individually applied to a common data set. Two ways for combining the results of the three models were then evaluated. One approach was to separately harden the probability results of the three models at first, then the three thematic maps were combined to a single classification map. On the second approach, before hardening, the probabilities of the three models for each pixel were simply averaged, then hardened to a single classification map. The 3% increase of overall accuracy for the second approach compared with the best individual model is encouraging. More important, a confidence map was produced based on the comparison between the three models, something which is impossible by using a single model. It was also demonstrated that deferring the hardening process to the last stage gives the greatest benefit for the combining process.

1. INTRODUCTION

Predictive forest mapping is an important part of forest management. However, the overall predictive accuracy of forest cover mapping is disappointing, especially where forest types are discriminated at the Anderson *et al* (1976) level III (Skidmore & Turner, 1988). This is mainly due to inherent limitations involved in separating complex continuum of forest characteristics into distinct classes. As pointed out by Lees (1996), this leads inevitably to the generation of errors of omission and commission, and results in an upper limit on predictive accuracy.

Recently, non-parametric-based methods have demonstrated better performance on land cover classification than traditional parametric-based methods. Among them, Artificial Neural Networks (ANN), Decision Trees (DT), Dempster-Shafer's Theory of Evidence (Shafer, 1976), and Expert Systems are most distinguished. Some applications of this group have been given by Lee *et al* (1987), Hepner (1990), Benediktsson *et al* (1990), Paola and Schowengerdt (1995), Lees and Ritman (1991), Moore et al (1991), and Skidmore and Turner (1988).

Non-parametric-based models have obvious advantages over parametric-based models for multisource predictive forest mapping. One major drawback of parametric-based models is that they assume a particular statistical distribution on dataset, which is usually not compatible with multisource data. Non-parametric-based models, on the other hand, make no assumption on data distribution, and therefore have avoided the significant error source.

In this study, the author suggests a supervised, combined, non-parametric-based, multisource strategy for predictive forest mapping

2. METHODS

In this study, an ANN, a DT, and a Theory of Evidence were individually applied to a common data. Results are the measurement of probabilities or degrees of belief of each class for individual pixels instead of crisp forest types. In the second stage, the outcomes of the three models are combined to produce a new result for individual pixels. Two types of combination are evaluated. One approach is to first separately harden the probability measure of each model, then combine the resulting three thematic maps into a single classification map using the Maximum Likelihood Rule. The other is simply average the three probability measurements of each class for individual pixels. They are then hardened to produce a single classification map the same way as the last approach. In the final stage, a confidence map is created by evaluating the agreement between the new combined classification map with the three old classification maps of the stand-alone models. It is emphasized that confidence measurement can provide higher level information than the traditional accuracy assessment such as the overall accuracy and the Kappa index.

3. THE STUDY AREA

The study area – Kioloa, is located on the south coast of New South Wales, Australia. The area is extremely complex in both physiography and parent material. This has resulted in a great variety of vegetation types with complex distributions from eucalypt-dominated sclerophyll forest to warm-temperate rain forest (Moore *et al*, 1991).

The nine classes as well as the number of samples of each class are listed below:

- Dry Sclerophyll (303);
- *E. botryoides* (69);
- Lower slope wet forest (52);
- Wet *E. maculata* (255);
- Dry *E. maculata* (180);
- Rainforest Ecotone (99);
- Rainforest (85);
- Cleared land/Paddock (166); and
- Water/Sea (499).

Within the 1708 samples, 80% of them are randomly selected as training set, and remaining 20% as test set.

4. RESULTS AND DISCUSSION

Among the three models, the DT has achieved the best overall accuracy, followed by the ANN and the Theory of Evidence on both overall accuracy and Kappa accuracy. The first combination approach (Combine2) gives little improvement in test accuracy, but the second approach (Combine1) achieved about 2.9% increase of overall accuracy, and nearly 3.6% increase of Kappa accuracy (Table 1). This is very encouraging because of having an upper limit accuracy posed on the complicated predictive forest mapping (Lees, 1996). Compared with the first approach, it is found that deferring the hardening process to its last stage has given the greatest improvement. Some interesting results are found when visually compare the classification map of the second combination approach (Figure 2) and the classification map of DT (Figure 1). The spatial patterns of both maps look quite different. The combination approach has acted as a filter, where consistent evidence tends to be retained, and conflicting evidence tends to be smoothed. Looking at the confidence map (Figure 3) reveals that most of the forest area predicted can give users moderate to high confidence levels. The confidence measurement doesn't depend on any single model but based on the combination of outcomes from the three models. It is an important aspect for accuracy assessment of classification, which is different from the overall accuracy and the Kappa index.

Table 1: Overall accuracy and Kappa index of classifications

Accuracy assessment	Decision Tree	Neural Network	Theory of Evidence	Combine1	Combine2
Overall Accuracy	0.6368	0.6081	0.5792	0.6657	0.6369
Kappa Index	0.5659	0.53246	0.51	0.6017	0.5687

5. CONCLUSION

Non-parametric-based classifiers - ANN, DT, and Theory of Evidence have been chosen for complicated predictive forest mapping. A new strategy for combining the three models was suggested. Two approaches were subsequently implemented. Improved performance on accuracy was achieved, and a confidence map has been produced to give decision makers higher-level information, which is impossible using a single model.

Figure 1: Classification map of Decision Tree

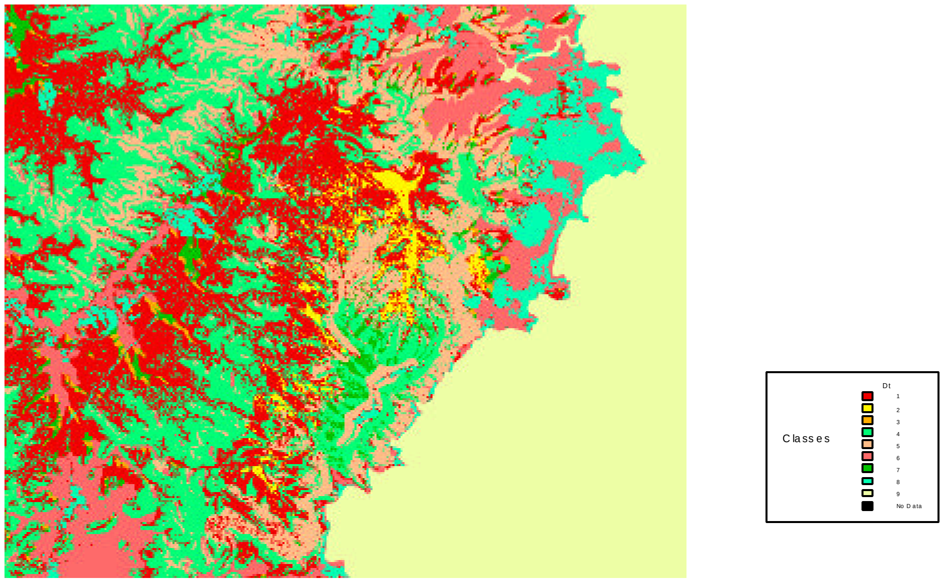


Figure 2: Classification approach of second combination approach

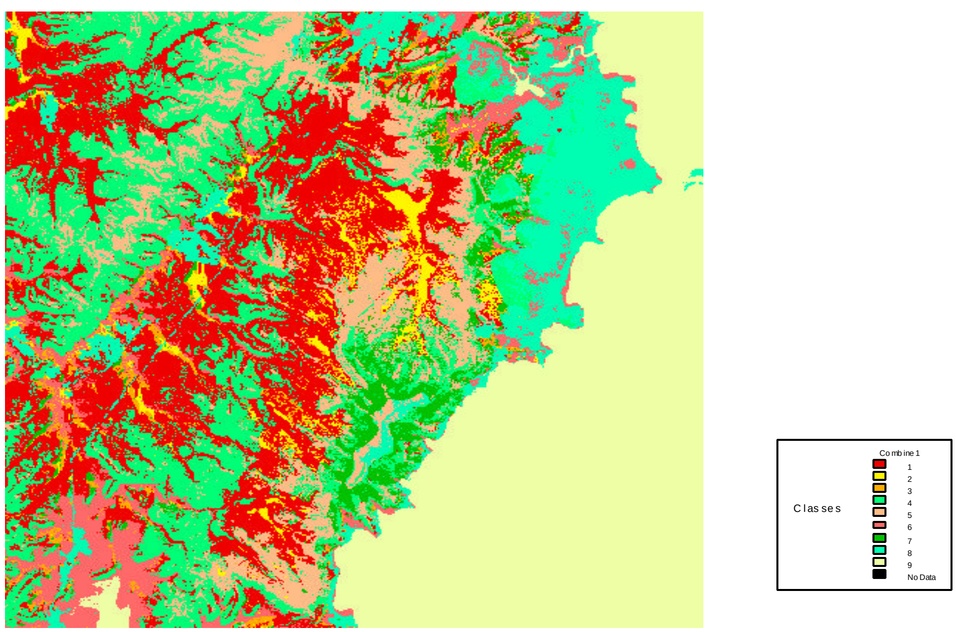
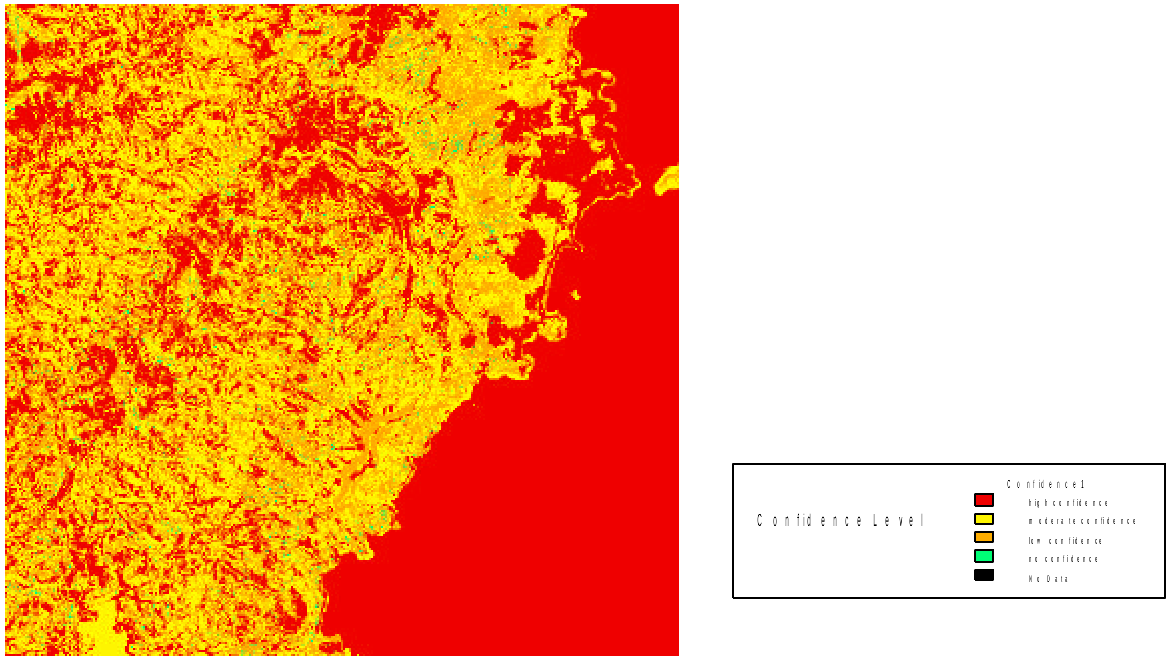


Figure 3: Confidence map of second combination approach



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