4. Discussion and conclusion

In this study, a form of GA-based band selectors was challenged to select spectral subsets of very highdimensional, species-level data. Unlike the broad-level data (i.e. Anderson's level I or II (Anderson et al., 1976)) used in the existing studies (Lofy and Sklansky, 2001; Kavzoglu and Mather, 2002; Yu et al., 2002; Ulfarsson et al., 2003), spectral profiles of the specieslevel data were very similar (Figs. 1 and 2). Despite that, the results in Table 2 and Fig. 6 demonstrated that the GA-based band selector overcame spectral similarity of the species-level data as it was able to select spectral subsets that maintained class separability at an acceptable level (i.e. ≈an 80% level of classification accuracy).

Additionally, the results of hypothesis testing in Table 3 also confirmed that band selection done by the GA-based band selector was meaningful. By majority, spectral separability between 16 mangrove species when the spectral bands were selected by chance was significantly lower than when the spectral bands were selected by the GA-based band selector (i.e. with a 95% level of confidence).

The success of the GA-based band selector may be explained by the chosen spectral locations (Fig. 8), as each location directly related to principal physio-chemical properties of plants that helped distinguish between the species. The details of the relationships between these spectral locations and plants can be found in the following literature. In brief, the band selected from the visible area was needed for discriminating between mangroves that possessed different leaf pigments and different sensitivity levels to the visible light source (Elvidge, 1987, 1990; Curran, 1989; Menon and Neelakantan, 1992; Basak et al., 1996; Kumar et al., 2001; Das et al., 2002). The band on the red-edge slope was for separating mangrove species that contained different leaf pigments, internal leaf structure and water (Elvidge, 1987, 1990; Curran, 1989; Kumar et al., 2001;Williams andNorris, 2001). Similar to the red edge band, the near-infrared band helped sort different plants according to the dissimilarity of their leaf internal structure such as the size of intercellular volume (Elvidge, 1987, 1990; Curran, 1989; Kumar et al., 2001; Williams and Norris, 2001). Finally, the spectral information of the mid-infrared region (i.e. the infrared slope, the mid-infrared absorption pitch, and the mid-infrared peak) was necessary for dissolving the internal structure variables and foliar biochemical contents other than the leaf pigments (Himmelsbach et al., 1988; Curran, 1989; Kumar et al., 2001).

The reader may note that the form of GA and its parameters used in this study were not the only options available. To tackle the problemat hand, itwas possible to alter the encoding scheme, population size, crossover rate, and mutation rate. Additionally, the fitness function could be replaced with any popular pattern classifier other than SAM. Using other decision criteria for assigning parental chromosomes instead of the biased roulette wheel, suggested by Goldberg (1989), is also possible. Even though the alteration may affect the evolution process depicted in Fig. 3, it was expected that the robustness of the evolutionary search could still produce a similar outcome (see "freedom of choice" in Goldberg (1989), page 80). In other words, GA was likely to find meaningful spectral bands that possess high spectral separability despite the alteration. It is, however, beyond the scope of this study to compare different designs of GA and the use of different search parameters.

The optimism gained from the results of this laboratory-level study (i.e. using laboratory spectra) encouraged further investigation into the potential of the GA-based band selector for vegetation discrimination when hyperspectral images taken by airborne or satellite sensors above mangrove canopies are in use. This will surely increase the complexity of measured spectral signals as a number of additional factors are involved (e.g. the fluctuation of light source energy, the change of daily atmospheric states, the effect of canopy formations, the cost of accessibility, the coarser spatial and spectral resolutions of on-board hyperspectral sensors, the effect of seasonal changes, the effect of background soils and water, the difference between the energy of artificial lamps used in the laboratory and the sun, etc.). The reader may consult Ramsey and Jensen (1996) on this issue. They have illustrated the differences between leaf level and canopy-level spectra measured from Florida mangroves. Furthermore, it was also anticipated that the use of the GA-based band selector was not limited to the application of vegetation discrimination. The GA-based band selector is now being tested by the author to detect spectral bands that show strong vegetation responses to different physio-chemical treatments (e.g. nitrogen, illumination, etc.) in both laboratory and field scenarios. It is hoped that the GA-based band selector could be used as an alternative to traditional methods such as statistical and derivative analyses that are normally used for detecting vegetation responses to external influences (Tsai and Philpot, 1998; Mutanga et al., 2003).

In conclusion, this study strengthened the confidence of using GA as band selection tools. The results confirmed that the GA-based band selector was able to cope with spectral similarity at the species level. It meaningfully selected spectral bands that related to principal physio-chemical properties of plants, and, simultaneously, maintained the separability between species classes at a high level. Additionally, the application of the GA-based band selector other than vegetation discrimination such as the investigation into vegetation spectra in response to different physio-chemical treatments was also anticipated.