2011–2015 with no significant difference in the number of fire hotspots in certified and non-certified concessions. The pre-treatment time band (1999–2004) captures the period post the 1997 El Niño fire crisis, where 13.18 million hectares of Kalimantan were burned (17% of the total landmass) (Fuller and Fulk 2000). The low number of hotspots detected by the MODIS data during this time period is likely a result of the reduced fuel load susceptible to burning in the years immediately following the fire crisis. The increased number of hotspots detected in the 2011–2015 time band capture the prolonged El Niño conditions that culminated in the 2015–2016 fire crisis.

Social sustainability

Villages neighbouring certified plantations were expected to have distributed fewer SKTM certificates than non-certified plantations due to the social provisioning outlined by RSPO principle 6. However, the number of SKTM letters per capita increased in villages neighbouring both certified and non-certified plantations. This result is in line with the findings of Jagger and Rana (2017) who found an increase in SKTM letters when evaluating the social benefits provided by REDD+ initiatives in Kalimantan. It is plausible that the overall increase in the number of SKTM letters distributed is due to increased access to STKM related services, rather than an increase in poverty per se (Priebe and Howell 2014, Jagger and Rana 2017).

All villages neighbouring certified and non-certified plantations experienced a decline in the number of healthcare facilities per capita available. This is surprising, as Indonesia has experienced overall growth in both public and private health infrastructure since 1990. Nationwide, the number of health centres (Puskesmas) and hospitals per capita is considered adequate, with 3.5 health centres per 100 000 people and 2.5 hospital beds per 10 000 people (Rokx *et al* 2010). However, on a provincial level, large disparities in provision and access exist. The decline in the number of health facilities per capita may, therefore, reflect population growth in villages surrounding palm oil concessions and the continued tendency for health care facilities to be concentrated in large urban centres (Gunawan and Aungsuroch 2017, Sparrow *et al* 2017).

Economic sustainability

RSPO certification showed economic benefits for plantation companies. Share prices of publicly listed palm oil companies increased overall between 2011–2016. RSPO certified companies showed the greatest increase with an average share price of $2.69 SGD, $0.60 SGD more than those of non-certified companies. This difference is reflected at a finer temporal scale within individual company portfolios. For example, the expulsion of IOI corporation from the RSPO in March 2016 and subsequent loss of contracts resulted in a 16% decrease in share value. Whilst RSPO certification may not have delivered higher price premiums (Edwards and Laurance 2012), it is plausible that membership and certification may add value through improved public perceptions of corporate identity Giovannucci *et al* (2014). Similarly, import commitments for Certified Sustainable Palm Oil (CSPO) such as the European Union palm oil and deforestation resolution for 100% CSPO by 2020, has created exclusive market segments for the RSPO licensees, that in turn may lead to higher share prices for certified companies.

Although not significantly different, Fresh Fruit Bunch yields tended to be higher in certified plantations than non-certified plantations. This result may reflect improved suitability of land selected for concessions as well as better plantation management. Mangrove and flooded forest land have been shown to be unsuitable for plantation development (Abram *et al* 2014). As eligibility for RSPO certification requires concession owners to avoid establishing new plantations on substandard land (RSPO P&C 7 and 7.4), our results likely reflect the improved viability of preferable production areas. Since 2010, the oil palm industry has been able to produce more fruit than available labour forces are able to harvest Sayer *et al* (2012). It is also plausible that companies with the capital to afford RSPO certification may also be able to hire more employees than smaller competitors (Sanderson 2016).

Our study provides the first assessment of RSPO in delivering improved environmental, social and economic sustainability. Whilst our analysis shows no significant difference between certified and non-certified concessions, there are limitations to our assessment that should be considered. Primarily, our assessment utilizes six proxies (orangutan density, fire occurrence, poverty levels, access to health facilities, profits and yield) to assess broad, complex and dynamic facets of sustainability. Proxies were selected based on published criticisms of the RSPO, relevance to the schemes P&C as well as data availability. These proxies therefore serve as useful indicators of the schemes performance, particularly in regards to the specific criteria summarized in table S1, however they are not comprehensive enough to allow for definitive conclusions. In addition, although our analysis accounted for major confounding variables, there are certainly additional confounding factors that we were unable to account for and are likely to influence both the decision to participate in RSPO as well as concession performance. Upon the availability of more, fine scale and transparent data, a broader range of RSPO sustainability criteria should be assessed controlling for additional confounding factors.

Summary and recommendations

Certification offers a valuable opportunity for improving practices in a frequently and highly criticised industry (Koh and Wilcove 2007, Fitzherbert *et al* 2008, Wilcove and Koh 2010, Wicke *et al* 2011, Abram *et al* 2017). However, our analysis demonstrates that desired goals of the program are not being realised