THE UNIVERSITY of ADELAIDE

Mapping and Monitoring Forest Cover Changes in Lao PDR Using Remote Sensing

A thesis submitted to the University of Adelaide in fulfilment of the requirements for the degree of Doctor of Philosophy

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Dedication

This thesis is dedicated to my beloved father, Dr. Bounlope Phompila

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Abstract

There has been a rapid change in forest and land cover globally, especially in tropical forests due to heavy deforestation. The highest rate of deforestation is found predominantly in the developing world. Tropical deforestation is a process of transforming forests into cleared land for other uses. Tropical deforestation is the second largest source of greenhouse gas emissions, responsible for about 17 - 30% of global emissions of CO_2 to the atmosphere, causing global warming. Precise and up to date information on the distribution and rate of forest cover change, especially in tropical regions, is required urgently for government policies aiming to control and manage forests and land development. Information on deforestation in tropical regions has been unavailable or inconsistent, including in the Lao PDR, due to socio-economic deficits, political interests and geographical constraints.

Remote sensing technology has played a crucial role in providing the information required for reliable mapping and monitoring of forest cover changes at local, regional and global levels, but its application in tropical regions has been lagging. The overall goal of this research was to demonstrate and evaluate remote sensing methods for assessing and monitoring forest cover changes in tropical environments, particularly in the context of the Lao People's Democratic Republic (PDR). The first aim of the research was to understand phenology of tropical forests and related vegetation types, which has been little studied. Improved understanding of the phenology of tropical forests and other land covers involved in forest clearance and land use change is an important step towards the use of remote sensing to identify and track changes in forest cover. Long-term averages of land surface temperature (LST) and enhanced vegetation index (EVI) 16-day time series of MODIS over the seven-year period from 2006 to 2012 were calculated and their monthly transitions compared for forests, and for land covers that commonly replace forests. The findings showed the complex interrelationship of LST and EVI and their monthly transitions for the different land covers: they each showed distinctly different intra-annual LST and EVI variations. Secondly, the research evaluated whether the combined use of these indices (LST and EVI) can classify these land covers. It was found that there was high overall accuracy of separation of land covers by long-term means of these indices (86%). This knowledge can be potentially useful for further broadscale mapping of land cover and detection of

deforestation in tropical forests. For the third objective, the use of remote sensing time series data for detecting spatial and temporal changes in forest cover in tropical environments was tested. The disturbance index (DI) model was applied to detect spatial changes in different forest cover types, whilst the Breaks For Additive Season and Trend (BFAST) approach was used to examine temporal changes in these land covers. Results showed that the DI was capable of detecting vegetation changes during a seven-year period with high overall accuracy (82%); however, it showed low accuracy in detecting forest clearance (42%). The BFAST analysis detected abrupt temporal changes in vegetation in the tropical forests, especially in large conversions of mixed wooded/cleared area into plantation (from 2004 to 2007). From these two approaches, it was found that MODIS time series data may be suitable for continental and national monitoring of land cover, although it may not provide the level of geographic detail and accuracy required for local assessments.

As a result of these findings, further analysis of forest cover changes at a finer resolution was required to improve monitoring approaches. Therefore, the fourth aim was to detect and map vegetation cover changes at a higher spatial resolution over a period of ten years between 2003 and 2012. Landsat ETM+ imagery from 2003 and 2012 was used in principal component analysis (PCA). This technique detected areas of vegetation cover change (both vegetation increase and loss) with high overall accuracy (87%). The results of these four studies provided new information on where and when recent forest cover changes have occurred in southern Lao PDR. The final step was to analyse the reasons underlying these changes. Thus, the final research task was to investigate potential factors associated with forest cover change in the study area, by using logistic regression analysis. The results of the analysis suggested that particular socio-economic and physical factors have a significant association with forest cover change. Forest clearance was associated strongly with elevation, distance to main roads and shifting cultivation practices. Meanwhile, vegetation increase was more likely to correlate with rubber plantations. Native forest and shifting cultivation lands were vulnerable to being converted into rubber plantations. This final research component contributes to a better understanding of ongoing land cover change processes to inform land use management. This is key information for policy and decision makers, and may be

used to minimize deforestation and deal with potential risks associated with land cover changes.

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By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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