# Vietnam's forest cover changes 2005-2016: veering from transition to (yet more) transaction?

*Roland Cochard[1,*], Van Hai Thi Nguyen[1], Dung Tri Ngo[2] & Christian A. Kull[1]*

[1]Institute of Geography and Sustainability, Faculty of Geosciences and Environment, University of Lausanne, CH-1015 Lausanne, Switzerland

[2]Consultative and Research Centre on Natural Resource Management (CORENARM), 29/9 Le Quy Don street, Hue City, Vietnam

*corresponding author

Author contacts:
*Roland Cochard* (Roland.Cochard@unil.ch; phone ++41 79 88 573 44; office ++41 21 692 36 09)
*Van Hai Thi Nguyen* (ThiHaiVan.Nguyen@unil.ch)
*Dung Tri Ngo* (dzungtringo@gmail.com)
*Christian A. Kull* (Christian.Kull@unil.ch)

**Highlights:**

- Notions of 'forest transition in Vietnam' imply a long-term trend towards a stable forest cover
- New forest policies in Vietnam largely concentrate on fostering economic productivity
- Renewed deforestation has been linked to policy-driven decreases in 'protection forestlands'
- Until now, 'payment for forest ecosystem service' policies had no visible effect to counter forest loss
- Aspects of 'good governance' are important for a 'sustainable transition' in forestry

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**Abstract:**

In Vietnam, rapid deforestation until the 1980s was followed by a period of widespread reforestation. Acclaimed as the first 'forest transition' in Southeast Asia, this turn-around resulted from major environmental/socio-economic policy changes (notably land titling), successes in agriculture and plantation forestry, and state-led efforts in upland forest protection/restoration. We investigated forest trends after new shifts in forest governance towards more commodity/production orientation, underlining that recent advances are not irreversible. Using official provincial data and applying multivariate statistics, we elicited major factors influencing cover changes of two types of 'physical forests' ('natural forests' and exotic-species 'planted forests'), in relation with changes in 'political forestlands' of contrasting types (lands designated either for forest 'protection' or for wood 'production'), comparing periods before (2005-2010) and after (2011-2016) the introduction of Payments for Forest Ecosystem Services (PFES) policies. We find that a 'forest transition' only continues if the tree plantation boom (now reaching remote/marginal/poor upland provinces) is factored into 'forest change'. Country-wide natural forest cover decreased slightly since 2006, with however regionally differentiated trends (northern increases *versus* southern losses, renewed deforestation near population centres). Widespread re-allocation of protection forestlands to production allowed expansion of plantations. Natural forests decreased in provinces where protection forestlands were reduced, and/or where – during 2011-2016 – plantation forests and crop fields expanded. PFES policies exerted minor influences (none to negative) on natural forest cover. PFES funding concentrated on provinces where protection forestlands contracted, and where forestland allocation to households was comparatively undeveloped. Conversely, 'good governance' indicators were positively correlated with sustained protection of natural forestlands. We conclude that governance emphasis on forest protection/restoration during the 1990s-2000s ['transition'] has reverted towards a primacy of forests as spaces of economic production ['transaction']. Policy schemes aimed at forest protection and poverty reduction need to incorporate efficient and transparent mechanisms of participation, monitoring, and adaptive management.

**Keywords:**

forest governance, political forestlands, acacia plantations, deforestation and reforestation, payments for forest ecosystem services (PFES), state forest companies

## Introduction

Southeast Asia – an extraordinarily biodiverse region – is still the scene of some of the world's fastest rates of deforestation (Stibig *et al.* 2014). In the past, Vietnam was no exception. The country's forest cover shrunk from perhaps ~43% in 1943 to 16-27% in 1993 (estimates vary, de Koninck 1999), due to actions of warfare (before 1975), timber exploitation by state forest enterprises, and forest clearing for agriculture (McElwee 2016, Biggs 2018). However, following fundamental policy changes and structural reforms after Đổi Mới ("Renovation"; nation-wide economic reforms in 1986), Vietnam recorded a turnaround and increase in net forest cover, attaining 31.4% in 'natural forest' and 10.6% in 'planted forest' cover in 2013 (MARD 2015). This turnaround was hailed as the first 'forest transition' (FT) in a Southeast Asian country (Mather 2007, Meyfroidt & Lambin 2008a, b, Li *et al.* 2017, Truong *et al.* 2017; cf. McElwee 2016, Lestrelin *et al.* 2013).

An FT represents a country's historic turnaround from net deforestation to reforestation. The idea was initially centred on late 19th century country case studies in temperate regions (Mather 1992), and is widely understood as an advent of sustainable forest management and development (cf. Mather & Fairbairn 2000). What FTs imply in terms of sustainability goals remains, however, largely unexplored, especially for recently 'transitioning' countries in tropical bioregions, such as Vietnam. Unlike temperate forests, highly disturbed biodiverse tropical rainforests rarely regenerate in fast and easily predictable ways; forest cover increases are therefore no evidence of a return towards pre-impact quasi-'pristine' conditions (Chazdon 2014; McElwee 2016, Nicolic *et al.* 2008, Le *et al.* 2012). Within economically useful timespans, re-growing forests can barely reconstitute the timber and other resources/services that were once exploited. As a result, wood products are increasingly farmed in single-species tree plantations (in Vietnam nowadays mostly stocked with alien acacia species). Such plantations have frequently been factored as 'forest regrowth' in FT theorizing (Mather 2007, Li *et al.* 2017, Truong *et al.* 2017; cf. McElwee 2016), but such FTs evidently conceal important subsidiary transitions from biodiverse native-species forests to alien tree monocultures. Associated landscape transformations entail dramatic changes in environmental and social qualities, and alter many parameters of socio-ecological opportunities/risks (Perz 2007, Putz & Redford 2010, de Jong 2010, van Holt *et al.* 2016).

In a previous study (Cochard *et al.* 2017) we used official provincial data, backed-up by an exhaustive review of scientific case studies, to document and analyse forest cover changes during Vietnam's 1993-2013 period of 'FT'. We showed that spontaneous and sometimes human-aided regrowth of 'natural forest' was recorded during the 1990s-2000s on abandoned lands, especially in the northern mountainous provinces (Cochard *et al.* 2017, Meyfroidt & Lambin 2008a, b). In parallel, plantation forests rapidly expanded, especially in less-remote hilly provinces. Significant increases of both forest types since 1993 were largely an outcome of 1.) forestland allocation (FLA) to households and communities, 2.) abandonment of upland swidden fields (resulting from stringent 'forest protection' policies and/or – more indirectly – economic growth and agricultural intensification), 3.) nationwide reforestation programs, and 4.) various pro-plantation development efforts (e.g. setting-up of tree nurseries and pulp-and-paper factories, improved transport networks).

These developments went along with a re-structuring and re-orientation of the entire state forestry governance system (McElwee 2016). Until the 1980s forests mainly served as a reservoir for timber to be exploited and managed by state forest enterprises (SFEs). Under Đổi Mới and subsequent legal reforms (Decree 1171-QD of 1986, Forest Protection and Development Law 1991; Nguyen *et al.* 2013) three distinct forestland management zones were created, namely 1.) special-use forests (designated to set aside valuable natural forests for conservation); 2.) protection forests (to achieve forest protection and/or restoration in key watersheds and sensitive mountainous areas); and 3.) production forests (for exploitation of wood for timber and pulp production). In accordance with the management objectives of these zones, SFEs were eventually dissolved and – in most cases – transformed into forest protection management boards (FPMBs; state organs responsible for the management of special-use and protection forests) and state forest companies (SFCs; economically-oriented state-owned companies tasked with operations in production forests, but also contracted for forest restoration/protection activities) (Dang *et al.* 2012a, To *et al.* 2015).

After 2003, forest increases appeared to meet some limits, with – in many provinces – increasing spatial competition between expanding forests and fixed crop fields, and shifts towards more plantation-based state forestry (Cochard *et al.* 2017). Besides conceptual issues of forest definition noted above, various uncertainties remain regarding claims that an 'FT' had occurred. Net forest cover gains are relatively recent, and often marginal. There are no definite assurances against reversing trends, especially considering that 1.) past reforestation programs came at significant, perhaps unsustainable costs (more than US$ 2 billion were invested, sourced from the state budget, aid loans, donor support, and private sector; McElwee 2009); 2.) some programs (especially prohibition of swiddening; Castella *et al.* 2006, Chi *et al.* 2013) incited land use conflicts with poor/marginalized communities, with unresolved tensions; and 3.) externalization of deforestation to neighboring countries (Laos, Cambodia; Meyfroidt & Lambin 2009, Lestrelin *et al.* 2013, Pfaff & Walker 2010) will likely decline, leading to renewed pressures on domestic rainforests.

Despite such challenges, the Vietnam Forestry Development Strategy 2006-2020 (VFDS 2007; signed by the Prime Minister in 2007) set a further target to increase the total forest cover (including plantations) to 47% of national land area in 2020 (with 49% [16.24 million ha] as 'land planned for forestry'). To reach such targets, the VFDS (2007) took the perspective that forestry development should be based on strengthened 'socialization', and it called for new sources of investment and financial instruments. 'Payments for forest ecosystem services' (PFES) were announced as an innovative mechanism to secure funding, with revenues predicted to bring in around US$ 900 million from 'forest ecosystem services' (FES) commodification by 2015, rising to US$ 2 billion by 2020. PFES schemes were piloted in Sơn La and Lâm Đồng provinces during 2008-2010, whereby water flow regulation, soil erosion reduction and scenic landscape amenities were identified as FES whose values could be determined and harnessed economically. Accordingly, the buyers of FES were mostly state-owned hydropower operators, water suppliers and tourism companies (Kolinjivadi & Sunderland 2012). The sellers could be state forest owners (SFCs, FPMBs), or private owners and managers, including households and communities which managed forestlands under legal provisions of FLA, or contractual agreements with SFCs/FPMBs. PFES was enshrined in national legislation in 2010 (Decree 99/ND-CP/2010; McElwee 2012), and programs started in January 2011 in 29 provinces (MARD 2014).

PFES (which is often seen as a neo-liberal, green policy instrument) was inspired from compensation schemes developed in market-economies. In the Socialist Republic of Vietnam PFES programs are essentially determined and directed as governmental subsidy schemes (McElwee 2012, McElwee *et al.* 2014); this has incited doubts about whether PFES would actually contribute to improve overall forest conditions (based on efficiency and conditionality), safeguard the targeted FES, and alleviate poverty (Pham *et al.* 2008, To *et al.* 2012, Suhardiman *et al.* 2013). Catacutan *et al.* (2012) identified challenges in regards to participation of local forest users, lack of indicators on FES performance, high PFES transaction costs, poor engagement of FES buyers, and issues of equity and effectiveness related to bio-physical and social differences/particularities among regions.

PFES has attracted much interest from researchers and international donors. It almost seems that debates surrounding PFES (cf. also Discussion) have distracted attention from overriding state-led governance which unfolds through the three-tiered management system of special-use, protection and production forests (McElwee 2016), and it is noteworthy that much emphasis of the VFDS (2007) was actually on boosting plantation development. The VFDS (2007; p. 13) stated that there were "needs for production forest development in order to meet socio-economic objectives", and the revenues derived from 'forest products' (mainly timber/wood) were projected to increase from US$ 1.7 billion in 2005 to US$ 7.8 billion by 2020 – i.e. four times the revenue estimated for FES commodification[1]. Correspondingly, production forestland areas were scheduled to increase from 7.1 million hectares (4.48 mil. ha of 'forestland' plus 2.62 mil. ha 'unused land') in 2005 to 8.4 million hectares in 2020, largely at the expense of protection forestlands (9.47 mil. ha in 2005, to be reduced to 5.68 mil. ha in 2020). While not all protection forestlands were actually covered by 'natural forests', the planned move to the 'production' forestland category was likely to also affect natural forests either directly or indirectly. Indeed, 43% (3.63 mil. ha) of production forests in 2020 were projected to be natural forests – despite an official 'logging ban' for natural forests since 1993 (To & Sikor 2006, McElwee 2004)[2].

Our previous study (Cochard *et al.* 2017) reported on longer-term changes and developments of forests in Vietnam's 63 provinces during the 'FT' period of 1993-2013, as influenced by broader political/economic changes after Đổi Mới. In the present study we focussed on trends since the VFDS (2007), using newly available official data. We investigated changes in reported 'natural' and 'planted' forest cover (physically materialised cover), in inter-relation with changes of politically designated forestland extent (specifically 'protection' and 'production' forestlands; i.e. politically 'intended' forest cover which currently may or may not be stocked with trees). We used a multi-variate analytical approach, examining the effects of many factors (geographical, demographic, socio-economic, agricultural, political) which could be relevant to explain the changes of forest spatial variables. This included an assessment of newly available data on PFES funding; we examined in which ways PFES may or may not have influenced recent forest/forestland developments. *First*, we posited that – contingent on influences by other factors – changes in 'physical' forest cover were not independent of changes in the 'political' forestland cover. *Second*, we posited that the dynamics of forestland changes during the period before the introduction of PFES (2005-2010; referred to as 'pre-PFES period') differed from the dynamics after the introduction of PFES (2011-2016; referred to as 'with-PFES period'), and that the PFES schemes directly or indirectly influenced the outcomes.

[1] Timber exports for 2019 in fact amounted to US$ 11.5 billion (MARD 2019).

[2] A 'ban of logging in natural forest' was implied or explicit in 1.) Directive 462-TTg, 1993, "on tightening wood transportation and export"; 2.) Directive No.12/2003/CT-Tg, 2003, "on enhancing urgent measures to protect and develop forests"; 3.) Decision 2242/QD-TTg by the Prime Minister, 2014, "stop exploiting timber in natural forests nationwide"; 4.) Notification 191/TB-VPCP by the Prime Minister, 2016, "stop exploiting timber in natural forests nationwide" (including previous two exceptions of Dak To SFC [Kon Tum] and Long Dai SFC [Quang Binh]). 5.) The term "logging ban" was officially enacted in the Forestry Law 2017.

## Methods and Materials

*Vietnam's geography and forest cover*

Vietnam's 63 provinces within eight geographic regions differ markedly in latitude, terrain, and associated climate and land uses (Fig. 1 a, b, c). Environmental differences are also reflected in the distribution of the population and levels of poverty (Fig. 1c), as well as various other demographic, economic and developmental parameters, which in turn can influence forest cover extent and dynamics. Furthermore, differences are reflected in the provinces' ethnic composition. Apart from the majority Kinh people (accounting for 85.7% of the total population), there are 53 ethnic minority groups in Vietnam, many of which constitute the majority population in remote mountain areas (Fig. 1d). Most of the ethnic minority people have traditionally practiced shifting cultivation in forest areas (Do 1994, Castella *et al.* 2005). By far the largest part of Vietnam's forest cover (and hence also the largest changes in absolute terms, Fig. 2) is found in the more mountainous and remote provinces, i.e. provinces which at the same time tend to be sparsely populated, poorer, rural, and more dominated by ethnic minority people (Epprecht & Heinimann 2004, Epprecht *et al.* 2011).

*The database*

For this study we used various province-level data variables provided by government agencies, mostly accessible directly from government sources, or indirectly from NGOs or via international publications (cf. Table 1). In total we assessed 201 variables - 54 from a previous study (Cochard *et al.* 2017) and 147 additional/new. The entire database included potentially relevant indicators of the provinces' terrain and geography (G variables), forestland and tree plantation cover/changes (F), population density/changes and ethnic composition (P), labor and poverty (L), development of infrastructure (S) and hydro-electric capacities (H), agricultural cultivations/changes and productivity (A), industrial wood processing capacities (W), illicit logging (C), forestland tenure/contracts (T), PFES funding/coverage (E), as well as various indices of governance, institutional and public administration, and socio-economic performance (I). For a listing of variables which were significant in regression models see Table 1; for a description of all variables see Appendix A (Supplementary Materials). All the data can be retrieved from https://zenodo.org/record/3903596.

*Description of the forest variables*

Official statistics distinguish type of tree cover (natural *versus* planted forests) and political forestland categories. The category of 'natural forests' represents forests composed of native tree species. Only very few old-growth forests remain. Most natural forests are secondary forests of differing composition and quality. Forests (or forest-like vegetation resembling thickets) may have regrown spontaneously on abandoned agricultural fields. Species composition and structure of newly growing forests is typically impoverished in comparison with forests which were not completely cleared (Nicolic *et al.* 2008, Cochard *et al.* 2018, Chazdon 2014).

'Planted forests' are largely synonymous with single-species 'tree plantations'. Planted forests were initially based on native species, especially pines (*Pinus merkussi*, *P. massoniana*) and some other species. In the 1990s the dominance in tree planting shifted to mono-cultures of alien acacia species (*Acacia mangium*, *A. auriculiformis*, and their hybrids) and – to far lesser degrees – eucalypts, melaleuca, teak or other species (Nguyen 2007).

Throughout the paper we refer to 'political forestlands' instead of 'political forests' (cf. Peluso & Vandergeest 2001) because 'cover' may include 'bare lands' which were previously deforested but are (or were) slated to be 'reforested'. There are three categories of political forestland. The first is 'special use forestland', with the goal of conservation. We can assume that 'special-use forestlands' are mostly fully stocked with natural forests – i.e. relatively undisturbed timberlands of high biodiversity. Special-use forestlands are relatively well protected, but illegal deforestation has occasionally occurred in remote regions (Nguyen *et al.* 2013).

Second, 'protection forestlands' serve to protect watersheds, degraded lands, and steep slopes. These are mainly covered by natural forests but may also include areas of planted forests (often 'forests' of exotic acacias) as well as bare lands targeted for forest restoration. Certain forest uses may be allowed on protection forestlands, but many planted forests under 'protection' are being progressively colonized by native tree species, thus eventually blurring the natural-planted forest categorical divide.

Third, 'production forestlands' (designated for timber, wood and pulp production) are increasingly stocked with industrially managed tree mono-cultures (nowadays mainly acacias) of differing growth stages. For a few months after tree harvesting the forestlands may be without woody cover, exposing the soils. Hence under conventional management, production forestlands are of lesser utility for land and watershed protection (cf. Sidle *et al.* 2006, Cochard 2013). Some production forestlands are still natural forests which may or may not be managed using forestry techniques and nursing of desired species. Despite a logging ban[1] many of these forests have been replaced by tree mono-cultures.

*Statistical analyses*

Using the database, we examined correlative patterns via multivariate regression analyses. We specifically focused on how during the period 2005-2016 variables representing agricultural, forestry, and land policy changes, and predisposing environmental factors, influenced the extents and cover changes of protection and production forestlands on the one hand, and natural and planted forests on the other hand. For each of these forestland and forest types we conducted one analysis focusing on the pre-PFES period (2005-2010), and another one focusing on the with-PFES period (2011-2016). We did not specifically investigate special-use forestlands because their extent is relatively minor.

MS Excel and Minitab 17 software (Minitab Inc., State College, PA) were used for calculations and statistical analyses. Data variables were checked for normality; if necessary data were transformed (Box-Cox or Johnson transformation; in a few cases normal score function). Multivariate linear regression (MLR) was used to assess variable interrelationships. To work out optimal MLR predictor subsets we used best subsets regression (BSR). Outlier/leverage points were identified using residual, Cox's distance and DFIT plots; if necessary observations were deleted to improve MLR models. Non-significant predictors ($p$-value > 0.05) were dropped from models in a step-wise mode (if not previously excluded by BSR selection). Principal components analysis was another aid used to better interpret data correlations and to separate relevant from irrelevant factors. While variables followed spatial patterns according to Vietnam's geography (Fig. 1), the residuals data of final regression models did not show statistically significant spatial autocorrelation (determined via testing the correlation of residuals with between-province spatial distance data). MLR model equations and relevant statistics are provided in Table 2.

## Results and Discussion

*An ongoing 'forest transition'? Changes in the extent of physical forests and political forestlands, 2005-2016*

According to official data at the national scale, the net cover of natural forest grew from the early 1990s (from around 86'309 km$^2$ in 1993; Cochard *et al.* 2017) to a maximum in the year 2006 (104'101 km$^2$), thereafter remaining more or less constant (slight decrease to 102'421 km$^2$ in 2016; Fig. 2). Hence, considering natural forests only, and at national scale, a purported 'forest transition' (FT) would have been 'completed' by around 2006. The maps in Figs. 3 and 4, however, show that natural forest cover was still changing in regionally divergent ways. As was also the case during the 1990's (Cochard *et al.* 2017), forest cover was generally increasing in the North-Central Coast Region and parts of the Northern Mountain and South-Central Coast Regions, whereas it continued to decrease in the Central Highlands and some Southeast Region provinces. Several provinces near Hanoi which had previously gained forest cover (Cochard *et al.* 2017) started to lose cover again after 2005 (Fig. 4). Such shifts in forest cover imply an ongoing net degradation of vegetation. This is because regrowing forests cannot be expected (within foreseeable timespans) to attain similar biomass and biodiversity as compared to 'high-value' forests which are still being lost in other regions. In this regard it should also be noted, that data of 'net forest cover change' at provincial level may hide significant intra-provincial forest cover shifts (deforestation in one region or commune *versus* reforestation in another; cf. Castella *et al.* 2006, Jadin *et al.* 2013, Hoang *et al*. 2014, Clement & Amezaga 2009; other references cited in Cochard *et al.* 2017).

Planted forests (mostly exotic plantations) continued to increase at fairly constant rates at the national level (almost doubling from 23'335 km$^2$ in 2005 to 41'355 km$^2$ in 2016; Fig. 2). If overall forest cover includes planted forests, one can possibly argue for an ongoing FT with an increase from 126'167 km$^2$ in 2005 (38% national land cover) to 143'777 km$^2$ in 2016 (43.4% cover). As with natural forest cover there are, however, regional divergences. Most of the expansion occurred in the Central Coast and Northern Mountain Regions. In contrast, some provinces in the Southeast Region and the Red River and Mekong Deltas lost plantation cover during 2005-2016 (Figs. 3 and 4).

Physical forest cover changes can be compared to changes in politically-defined forestland extent. There was a marked reduction of total protection forestland area from 71'737 km$^2$ in 2005 to 58'273 km$^2$ in 2011, paralleled by an even steeper increase of production forestlands from 54'348 km$^2$ to 74'065 km$^2$. In contrast, the area of special-use forestland (20'688 km$^2$ in 2005) remained approximately constant (Fig. 2). The cumulative area of all political forestlands has – at national level – been in excess of the physical forest cover. Between 2005-2013 this excess (i.e. non-forested 'forestlands') has stayed at around 12-14% of physical forest cover whereby political forestland extent increased in accord with physical cover, mainly resulting from an increase in production forestlands (Fig. 2). The total political forestland area reached a maximum in 2013 at 158'453 km$^2$. This represents 47.8% of Vietnam's land area – close to the 49% cover target set by VFDS (2007) for 2020. However, after 2013 the total designated forestland area was gradually reduced to 45.0% (149'084 km$^2$), and the gap between political forestland and physical forest area narrowed to 3.6% in 2016. This gap-closure resulted from growing plantations in combination with reductions in protection forestlands 2013-2014 (Fig. 2).

As with physical forests, the overall trends of political forestlands mask major regional and provincial variations (Figs. 2, 3 and 5). Special-use forestlands were enlarged (especially during 2005-2011) in some provinces (mostly Central Coast Region) but were reduced in other provinces (north and south). With a few exceptions, protection forestlands decreased in most provinces during 2005-2011. During 2011-2016 reductions (or re-allocation to other management types) occurred mostly in the Northwest Mountain provinces (Fig. 5). Reductions of protection forestlands appeared to be partly mirrored by increases of production forestlands – except in the Central Highlands and southern provinces (where production forests were mostly reduced along with protection forests), and in the Northeast Mountain Region (where production forests were increased along with little changes in protection forests) (Fig. 5). Detailed results from multivariate analyses, discussed in the following sections, provide more indications about relevant trends and processes, including links between changes of political forestlands and physical forests.

*Transitions of 'forest protection' governance: Factors relevant to explain changes of protection forestland area, 2005-2016*

During the 1990s to early 2000s forest-dominated upland landscapes considered important for watershed protection, or deemed sensitive or unsustainably used (often with signs of soil erosion, and/or located on steep and unstable lands) were set aside by the state as protection forestlands. In conjunction, various policies and internationally sponsored programs aimed at better protection of remaining forests and restoring deforested areas (Cochard *et al.* 2017, Dang *et al.* 2012a). In 2005 as well as 2016 the extent of protection forestlands in the Vietnamese provinces (described by variables *protfland05* and *protfland16*) was therefore largely explained not only by the cover of natural forests (+*natforest05****, +*natforest16****) but also by the cover of newly planted forests (+*plantforest05****, +*plantforest16****; model equations M1 and M2; all variable descriptions and statistical models see Tables 1 and 2). Furthermore, there was an apparent spatially determined contingency and land tradeoff between the alternate 'protection' and 'production' forestland management zonation categories (–*prodfland05****, –*prodfland16****; M1, M2; conversely: –*protfland05***, –*protfland16****; M5, M6).

Several social, economic and political factors were, however, also relevant as predictors of protection forestland designation among different provinces. Protection forestlands were generally more extensive in the remoter, poorer provinces (+*bpoverty09***(*); M1, M2), and especially where the (official) agricultural labor sector tended to be somewhat smaller (–*workagri09**, M1)[3]. Protection forestlands were also predominant in provinces where relatively large forestland areas were allocated to households and communities (by 'Red Book' tenure; mostly in the Northern Mountains Region, cf. Cochard *et al.* 2017) and/or where large swathes of forestland were contracted by 'management boards for protection forest' (MB-PFs) in 2004 (+*hhften04****, +*hhcften04****, +*mbpfcon04***(*); M1, M2)[4]. Overall, the patterns of protection forestland extent during both years (2005, 2016) still reflected the outcomes of the 1990s state-dominated policy drive for watershed protection (especially in the 'hinterland' of Hanoi, in conjunction with FLA) and for re-greening of so-called 'barren hills' – despite a strong trend (2005-2016) to re-assign more forestlands to 'production' purposes (Figs 2, 3 and 5).

[3] The variable *workagri09* denotes the 'share (%) of employment in agriculture' by official records as differentiated from the 'share in self-employment' and/or 'share in wage labor'. Agricultural activities (e.g. swidden farming) which were not officially recorded may fall under 'self-employment' rather than 'employment in agriculture'.

[4] In 2015 around 38% of protection forestlands were under tenure by MB-PFs whereas only 12% were under tenure of households (MONRE 2016). The positive correlation between variables *protfland05/protfland16* and *hhften04*/*hhcften04* (M1, M2) may be partly explained by a direct link, but partly it seems to be explained by spatial and historical factors (cf. Cochard *et al.* 2017).

An analysis of change patterns allows further insights into the characteristics and contributing factors of this general trend. During the pre-PFES study period 2005-2011 decreases of protection forestland extent (*protfrch05-11*) were particularly high in the Central Highlands and Nghe An Province (Fig. 5), and in provinces with highly developed wood-based industries (*–pulpcap04***; M3). In contrast, the cutbacks were relatively lesser in the more northern, larger and – in terms of household water supply infrastructure – better developed provinces (*+latitude****, *+provarea**, *+water09****; M3), with regional gradients suggesting lesser reductions in provinces adjacent to the Red River Delta lowlands and Hanoi as compared to more remote mountain provinces (gradients as characterized by the variables *–Thai****, *+Muong**; cf. Fig. 1). This indicates that – until 2011 – protection forestlands remained largely in place in extensive upland watersheds considered of importance to provide services for water regulation, hydro-electricity and flood mitigation, especially in the hinterland of Hanoi and near other industrialized and municipal centers. Reductions of protection forestlands were also lower in provinces where large tracts of forestland were under the tenure of 'other' landowners (*+otherften04****; M3), a category that includes the army. During 2005-2011 changes in protection forestland extent were apparently independent (no significant statistical effects) of changes in production forestlands or physical forest cover (cf. also M7, M9), but this pattern evidently differed in the with-PFES period.

During 2011-2016 changes in the extent of protection forestland (*protfrch11-16*) were strongly negatively associated with areal changes in production forestland (*–prodfrch11-16****), but positively associated with changes in natural and planted forest cover (*+natfrch11-16****, *+plantfrch11-16****, M4). Hence, after 2011 protection forestlands have been reduced mostly in provinces which were characterized by a decreasing or stagnant forest cover, and reductions often occurred at the cost of enlarging production forestlands. Changes in protection forestlands, however, also varied according to regional patterns. On the one hand, reductions were relatively higher in the intensively cultivated and increasingly urbanizing Red River and Mekong Deltas (*+nodelta****), indicating pressures on remaining forest resources through increasing land rents. On the other hand, reductions also tended to be higher in more remote, sparsely populated, and lesser agriculturally developed[2] provinces (*+workagri09**, *+popdens13****, *–distcoast****; M4), and – accordingly – in provinces where large forestland areas had been controlled by forest protection management boards (FPMBs) and/or communal people's committees (CPCs) in 2004 (*–fpmbfcon04****, *–cpcften04****). This trend centered in the remoter regions may indicate a gradual policy shift towards an opening-up for more economic enterprise, and an associated partial retreat of state organizations in control of forest management. Concomitant relaxation of administrative regulations and control is partly suggested by the fact that – during 2011-2016 – protection forestland reductions were higher in provinces where in 2009 citizens' options of political participation were rated as relatively high, and where corruption in public service delivery apparently represented no major obstacle (*–Icivicknow****, *–Iservdelcorr***; M4). Notably, controlling for these factors, the reductions nonetheless tended to be somewhat lesser in provinces dominated by upland ethnic-minority groups (*+mtethnic***; M4). This probably implies persistent state control on forests and fewer political/commercial opportunities for the generally more marginalized ethnic-minority communities (cf. To 2009, McElwee 2016, To *et al.* 2015, Pham *et al.* 2018).

Overall, the patterns suggest that economic tradeoffs and pressures have become increasingly important. Protection forestlands were gradually re-assigned into direct or future wood production or other land uses in the intensively cultivated lowlands, and in remote upland provinces. This re-assignment was largely guided by state actors, whereby protection forestlands were mainly maintained in the hinterland of urban centers and in ethnic minority areas. Notably, PFES schemes did not appear to influence the changes in protection forestlands (nor production forestlands, see next section: no significant effect of PFES variables).

*Transitions to industrial forestry: Factors relevant to explain changes of production forestland extent, 2005-2016*

Production forestlands were designated for sawlog and wood production for the construction, furniture and pulp/paper industries. Wood products constitute Vietnam's sixth most important export commodity which has consistently grown over the last decades (annual growth rate of 13% during 2010-2017). With around 4500 registered businesses, and providing significant incomes for millions of farming households, the forest processing and export industry has become a principal sector of the national economy. In 2017, the export value reached over US$ 8 billion, exceeding the VFDS (2007) target set for 2020 (Notification No.325/TB-VPCP, 2018).

Wood production is now mostly based on fast-growing acacia-based tree plantations which can be harvested in a short rotation. Since 'planted forests' mostly represent such 'industrial' plantations it comes as no surprise that in 2005 as well as in 2016 the extent of production forestlands (*prodfland05* and *prodfland16*) was highly correlated with the cover of planted forests (+*plantforest05****, +*plantforest16****; M5, M6). Natural forest cover, in contrast, appears as a significant predictor only for 2016 (+*natforest16****; M6), but not 2005. It indicates that natural forests were still mostly under 'protection' (including special-use forestlands) in 2005, but were partly re-assigned until 2016 to eventually serve again production objectives (despite a logging ban[1] which currently still is in place). Notably, forestlands which were under contracts for 'forest regeneration' purposes in 1999 and/or were managed by FPMBs in 2004 were negatively associated with production forestlands in 2005 (–*regenfcon99****, –*fpmbfcon04****; M5), indicating a trade-off in land area between these alternate forestland usages. In contrast, by 2016 many of the 'regenerated' and FPMB-managed areas were apparently returned into the production category (positive association: +*regenfcon99****; *fpmbfcon04* insignificant; M6).

As may be expected, state forest companies (SFCs) were important managers of production forestlands in 2005 as well as in 2016 (+*sfcfcon04****; M5, M6). The data analyses, however, signal a noticeable shift away from other types of state actors (forest tenure by 'economic organizations' and 'other owners'; +*ecorgften04*** in 2005, +*ecorgften04** in 2016; +*otherften04*** in 2005, insignificant in 2016) to increased involvement in wood-based 'production' by individual households (Red book tenure and contracts; +*hhften04** in 2005 to +*hhften04**** and +*hhfcon04** in 2016). In 2005 production forestlands were more predominant in large midland and upland provinces (+*elevation***, +*provarea****; M5), whereas this spatial effect became insignificant in 2016. Controlling for the other factors, production forestlands were, furthermore, more extensive in provinces which were characterized by lesser developed water supply infrastructure; this pattern was more distinctly pronounced in 2016 (–*water09****; M6) as compared to 2005 (–*water09**; M5). These changes in patterns suggest a policy-driven expansion of plantation-based forestry on diverse terrain – but to a relatively lesser extent in provinces with water-dependent municipal centers and industries.

An analysis of the relative areal changes of production forestlands (*prodfrch05-11*, *prodfrch11-16*; M7, M8) provides additional insights. During the pre-PFES period production forestland area increased in most provinces, particularly in northern and mountainous regions (+*latitude****, +*elevation****; M7; Fig. 5). Enlargement of production forestland areas was particularly high in provinces which in 2005 had comparatively fewer production forestlands (–*prodfland05****). The increases were also significantly related to increases (or stability) in natural and (to a lesser degree) planted forest cover (+*natfrch05-10****, +*plantfrch05-10**; M7; forest cover increases were also highest in the northern provinces, cf. following sections). The increases were particularly high in provinces where many forestlands were contracted to FPMBs and households in 2004 (+*fpmbfcon04****, +*hhfcon04****; M7). Provinces with high increases of production forestlands were, furthermore, characterized by comparatively high employment levels and good ratings of 'public-sector employment equity' (+*labor09****, +*Iequitempl**), but – controlling for these factors – also somewhat higher levels of poverty, lower development of the agricultural sector, and corruption of provincial officials (+*bpoverty**, –*workagri09**, –*Iinfcharge**; M7). Overall, it appears that expansion of production forestlands was primarily spurred by economic pressures. It was facilitated by land available for forest growth, interests by relevant state agencies and private landholders, and strong wood-based industries and commerce.

During the with-PFES period, production forestland extent increased in some provinces in the north, but actually also decreased in many provinces in the south (+*latitude**; M8; Fig. 5). Production forestlands were enlarged in provinces which in 2011 still had somewhat fewer production forestlands, yet comparatively larger areas of natural forest (–*prodfland11**, +*natforest11**), and where natural forest cover had also grown (or remained stable) during the preceding years (+*natfrch05-10**; M8). Notably, changes in production forestland were not statistically explained by concurrent changes in planted or natural forest area; rather, the changes were highly positively associated with forest tenure by households/communities and (more marginally) economic organizations/joint ventures, and management by SFCs (as by 2004 data; +*hhcften04****, +*ecofjvften04**, +*sfcfcon04****; M8). This suggests that further expansion of production forestlands was more an outcome of deliberately administered utilitarian (re)allocation of forestlands to private landowners and the economically-oriented SFCs, rather than an outcome of *post-facto* adjustments after unregulated physical tree cover changes (cf. Sikor & Baggio 2014). Provinces with increases of production forestlands, furthermore, tended to be characterized by lower rural population densities, higher employment levels, and – in contrast to the pre-PFES period – lower poverty (–*rurpopd10**, +*labor09**, –*bpoverty**; M8).

The overall patterns indicate a shift away from a focus on forest protection and restoration (largely financed through large reforestation programs such as the 'five million hectare program' or the 'greening barren hills program') towards a higher emphasis on economic activity in the forestry sector. The shift mainly benefited state-owned forestry organizations seeking to become economically self-sufficient (as stipulated in Decree 141/2016/ND-CP). In some regions (especially in the Northern Mountains) some strong local communities may, however, equally have benefited from the gradual opening-up of forestlands and/or the conversion of degraded lands to plantations.

*Transitions to 'novel forests': Factors relevant to explain cover changes of planted forests between 2005-2016*

Economically and politically driven changes in forestlands evidently influenced the development of tree cover. During the pre-PFES period increases of planted forest cover were particularly high in provinces where the extent of production forestlands was still relatively minor at the outset in 2005 but grew substantially until 2011 (–*prodfland05**, +*prodfrch05-11****; M9). In addition to this, 'forests' were still planted in provinces where extensive forestlands were under protection contracts in 1999 (+*protfcon99**), under tenure by economic organizations/joint ventures in 2004 (+*ecofjvften04**), and/or in provinces with significant hydro-energy production (+*hydroMW**; M9) – thus provinces which presumably invested in forest restoration/afforestation within key watersheds. It is notable that during both study periods growth in planted forest cover was particularly high in provinces where wood processing capacities were comparatively low (*–pulpcap04***; M9, M10a). This suggests that plantation growth potentials closer to wood-processing centers were largely realized before 2005 (Cochard *et al.* 2017, Sandewall *et al.* 2010), whereas after 2005 plantation growth was nurtured in the remoter provinces, possibly partly through improving road access (Thulstrup 2015, Thulstrup *et al.* 2013, Pietrzak 2010). During 2005-2010 land areas for plantations were in apparent competition with expanding staple-crop cultivations. Tree plantation increases were significantly higher in provinces where rice cultivation areas were already extensive in 2005 (*+riland05**), where rice cultivations increased only marginally (or not) until 2010 (*–rilch05-10****), and where the 2005-2010 per-hectare increase of maize yield was high (presumably sparing land area through per-field productivity intensification; *+mapch05-10***; M9; cf. Keil *et al.* 2008).

Factors relevant to explain changes of planted forest cover were markedly different during the with-PFES period. Agricultural land use changes were no longer important to explain changes in planted forest cover. Further expansion of plantation cover was, however, mainly recorded in the more mountainous provinces dominated by ethnic minority groups (*+elevation****, *–Kinh****), yet provinces which – controlling for these factors – apparently tended to be characterized by somewhat richer (*–hpoverty*$^{**(*)}$) and economically better connected resident populations (i.e. comparatively high labor employment levels, *+labor09****; M10a, b). Whereas in the 1990s to early 2000s many tree plantations were established on privately owned lands (after FLA), especially near wood processing industries (Cochard *et al.* 2017), such lands apparently no longer provided much space for plantation expansions during 2011-2016 (*–hhften04*$^{**(*)}$; *–pulpcap04***; M10a, b). In contrast, the results suggest that forestlands under management control (contracts) by SFCs were increasingly subjected to plantation forestry (*+sfcfcon04****), likely implying further industrial/profit-making transformations and intensifications of forestland uses by state-owned forest managers.

During 2011-2016 increasing intrusion of exotic plantations into natural forest areas is also signaled by contrasting inter-relations of the political and physical forest data variables. As in the pre-PFES study period, changes in planted forest cover were strongly positively associated with changes in production forestland area (*+prodfrch11-16****), but the changes were also positively associated with areal changes of protected and special-use forestlands (*+protfrch11-16****, *+spusefrch11-16*$^{*(*)}$; M10a, b), and notably – in the case of special-use forestlands – also with changes during the antecedent pre-PFES period (*+spusefrch05-11*$^{*(**)}$; M10a, b). This may partly reflect that non-forested forestlands under protection were still being planted with trees until 2016, and/or that some forest conversion (replacement of natural forest with planted forest) actually occurred. However, the observed patterns probably also ensued from certain contravening socio-political undercurrents. The patterns indicate that forestland protection efforts via increasing/maintaining forestland protection areas (in particular special-use forestlands) by provincial decision makers also led to increased tree planting by potentially affected housholds who aimed to assert claims on forest management and/or land ownership (cf. Sikor & Baggio 2014, To 2009, To *et al.* 2015, Thulstrup *et al.* 2013, Marschke *et al.* 2012). As discussed in the next section, during 2011-2016 many new plantations were apparently set up at the expense of (perhaps already degraded) natural forests (Vogelmann *et al.* 2017, Van & Cochard 2017, Grogan *et al.* 2015).

One might argue that many policy measures directed at more sustainable forest uses did not (yet) lead to hoped-for outcomes. Besides the above-discussed consequential shifts of political forestlands, this is indicated by inter-relations of forest changes with PFES variables, and with index variables describing aspects of governance. PFES schemes – meant to incentivize protection/regeneration of natural forests – were mostly insignificant as predictors of natural forest cover changes (cf. next section). Regarding planted forest cover, the data indicate that PFES payments had a slowing-down-effect on the plantation 'boom' during an initial PFES phase 2011-2013 (–*PFESpay11-13***). This possibly initially reduced infringement rates on natural forests (cf. next section). As it seems, however, this effect was reversed after 2014. Planted forest cover changes were positively associated with PFES payments during the phase 2014-2016 (+*PFESpay14-16***) as well as – marginally – with total forestland areas under PFES schemes in 2016 (+*PFESarea16**; M10b). By 2014 it had presumably become clear to many stakeholders targeted by PFES programs that the payments and associated forest protection regulations were administered in fairly intangible and/or malleable ways. PFES payments thinly spread over large areas of natural forestland in 2016 were perhaps (during the study period) more a manifestation of policy pronouncement and/or 'wishful thinking' rather than a feat with demonstrable effects in terms of forest preservation (cf. McElwee *et al.* 2019, Le *et al.* 2016). In general agreement with such observations, results also suggest that the plantation boom tended to be buoyed in provinces which had been rated more positively in terms of allowing and fostering private enterprise (+*Ienterprise***; M10a, b) as well as citizens' political participation (+*Icivicknow****; M10b), however less positively in terms of governmental achievements to combat corruption (*–Ifightcorr****; M10b).

The results present a picture of a continuing tree plantation boom spreading into more remote and peripheral areas (abetted by newly-built roads and various economic/policy incentives). In many regions, plantations have met spatial limits with respect to croplands and have thus increasingly infringed on naturally forested areas. The boom concurred with an increase in production forestland area, but in recent times it likely included both legal and illegal plantations on protection forestlands. The boom was fostered by local households and communities affiliated with plantation extension networks and the acacia wood products value chain. The boom was however also dynamized by increasingly industrialized plantation forestry practiced by SFCs and FPMBs. Tree plantations have become an important revenue source of many SFCs and some FPMBs, largely superseding or complementing subsidies received from governmental funding schemes such as PFES.

*Transitions to 'natural recovery'? Factors relevant to explain cover changes of natural forests, 2005-2016*

Changes of natural forest cover were influenced by changes in political forestlands, both directly as well as indirectly via changes in the dynamics of planted forest cover. During 2005-2010 natural forests tended to grow or remain stable in provinces where production forestlands were already relatively extensive at the outset in 2005, and where – conversely – protection forestland areas were not very large in 2005 and were not much reduced until 2010 (+*prodfland05***, *–protfland05**, +*protfrch05-11**; M11). Notably, during the pre-PFES period natural forest cover changes were positively associated with changes in planted forest (+*plantfrch05-10****; M11), indicating that plantations were still growing mostly without affecting natural forests. The strong positive association suggests that newly established plantations absorbed some of the pressures on natural forests and perhaps allowed for surplus forest regeneration (cf. Pirard *et al.* 2016, Rahman *et al.* 2017). The analyses furthermore show that natural forests tended to grow or remain stable in provinces where extensive forestlands had been contracted for forest regeneration purposes in 1999 (+*regenfcon99****) but where fewer lands were under management by SFCs in 2004 (*–sfcfcon04***); where smaller volumes of illegal timber were confiscated during 2007-2010 (*–conftimb07-10**); and where land use planning and pricing policies were rated relatively positively (+*Ilanduseplan**; M11). It suggests that management for forest regeneration in combination with regulated land use planning tended to foster natural forest protection and growth, whereas pressures for economic exploitation, especially under unlawful conditions, were rather detrimental to the forests. In addition, geographical gradients and factors were important.

Natural forest regeneration largely occurred in the more northern and more mountainous provinces (+*latitude***, +*elevation****; as was already the case during the 1990s; Cochard *et al.* 2017), especially in provinces where – controlling for the other factors – the agricultural labor sector tended to be smaller (–*workagri09***)$^2$, but development levels were higher in terms of household water supply infrastructure (+*water09**; M11; cf. above discussion). Forest increases were, however, reduced in the northeastern mountainous border provinces largely dominated by the Tay ethnic minority (–*Tay****; M11). This possibly resulted from certain re-emerging socio-political factors which – during this period – lead to increasing agricultural land uses (including plantation forestry) in those provinces (cf. Castella *et al.* 2006, Sandewall *et al.* 2010, Turner & Pham 2015, Cochard *et al.* 2017).

Several forest-influencing factors relating to geography and regional development remained significant in the with-PFES period, yet with somewhat shifting importance. Natural forest increases were still higher in the more mountainous, poorer and more rural provinces (+*elevation**, +*hpoverty09****, +*rurpopd10**; i.e. predominantly provinces inhabited by ethnic minority groups; Fig. 1), and in provinces where the (official) agricultural labor sector tended to be comparatively small (–*workagri09****; M12)$^2$. Comparatively small shifts in forest cover (with some marginal increases) were recorded within the already largely deforested provinces of the Red River and Mekong deltas (–*nodelta****; M12).

Direct and indirect effects of policy-driven shifts in forestland management, and pressures from overall land use changes, became more manifest during 2011-2016. Natural forests remained largely stable or continued to increase in provinces where protection forestlands remained mostly unchanged (did not decrease much, or increased) during 2011-2016 (+*protfrch11-16****), where the change 2011-2016 in the production/protection forestland ratio was small or negative (–*prod/ptsp:ch11-16**), and where special-use forestland areas had been increased during the preceding period (+*spusefrch05-11**; M12). Most notably, however, the positive association of natural with planted forest cover changes during 2005-2010 turned into a strong negative association during 2011-2016 (–*plantfrch11-16****; M12). We may thus infer that the continuing plantation boom had ceased to absorb pressure on natural forests; instead it had itself started to exert direct negative impacts on naturally forested lands. In addition, natural forests also came under increasing pressure from cropland agriculture. Forest cover tended to decrease in provinces where in 2011 land values were high in terms of per-acre rice productivity (–*cerprod11****), and where maize fields expanded a lot, especially in provinces with little improvements in per-acre maize productivity (–*mailch11-16****, +*mapch11-16***; M12; cf. Keil *et al.* 2008).

In the face of mounting pressures from intensive agricultural and plantation-forestry-based industries, newly introduced PFES policies exerted as yet insubstantial outcomes on natural forest conservation and regeneration – at least if one considers the data on forest cover. In fact, the weak negative association of provincial natural forest cover change with the percentage area of forestland under PFES schemes in 2016 (–*pfes:area%16**; M12) may hint at hidden perverse incentives which – during the with-PFES study period – bolstered tree farming rather than favored natural forest protection (cf. To & Dressler 2019, McElwee *et al.* 2019, Le *et al.* 2016). Conversely however, this association may also reflect *post facto* policy responses to already ongoing deforestation problems, with perhaps better outcomes for the natural forest cover in the future. In any case, it seems that factors of 'good governance' play a role in effective forest protection efforts; this is indicated by the observation that natural forest losses were significantly lessened (resp. forest increases fostered) in provinces where public sector corruption was rated as relatively low (+*Ipublicorr****; M12).

The overall patterns show that in many provinces natural forests are still under significant pressure from deforestation and conversion to plantations or other land uses, especially in the southern parts of Vietnam. Some forest regeneration still occurs in northern provinces, but the overall trend is heralding a definite end of the so-called 'forest transition' – certainly in terms of a 'natural FT'. New challenges are arising for natural forest protection and management, particularly from the pressures of the plantation boom, which are obviously linked to issues of land ownership and associated development programs and land use policies. Whether or not PFES schemes can assist to maintain and establish sustainable management regimes of naturally forested areas will probably mainly depend on whether or not such schemes can contribute to produce real tangible benefits for the livelihoods of local communities, including the poor and marginalized parts of society (cf. McElwee *et al.* 2019, To & Dressler 2019, Trædal *et al.* 2016, Trædal & Vedeld 2018).

*Transitions to novel 'pro-forest transaction' schemes? Regional variations of PFES schemes*

Between 2011 and 2016 PFES schemes were set up in provinces where large forest areas provided major services in terms of watershed protection for hydro-electricity and drinking water production. After PFES schemes were piloted in Sơn La and Lâm Đồng provinces, 29 upland provinces in the Central Highlands and Northern Mountain Region were fast to set up similar schemes in 2011-2013 (covering in total around 40.5% of Vietnam's natural forest areas in 2013), whereas seven provinces in more coastal regions followed suit after 2013 (reaching in total 57.4% of natural forest areas in 2016; Fig. 6a). Results from statistical analyses reflect that PFES schemes were established (*pfes·yes/no*) in mountainous provinces (+*elevation****) with strong hydro-electric production capacities (+*hydro·kwh/y**; Fig. 6a, c) and rich natural forest areas which were however under pressure from illegal logging (+*conftimb07-10****). The PFES-provinces were, furthermore, characterised by (controlling for the other factors) comparatively smaller areas of production forestlands in 2011 (*–prodfland11****; M13)[5]. Analyses focusing solely on PFES-provinces provided similar results. In 2016 large forestland areas were covered by PFES schemes (*pfes·area16*) in PFES-provinces with extensive natural forest cover (in 2011, +*natforest11****; especially forests under special-use protection, +*spusefrch05-11**) and strong hydro-electric production capacities (+*hydro·kwh/y****), particularly so in the more northern and lesser remote (near coastal) regions (+*latitude**, –*distcoast**; M14).

Several results give the impression that PFES funds may benefit the livelihoods of poor rural people. Extensive forestland areas covered by PFES schemes (*pfes·area16*) were located in provinces with particularly high levels of poverty (+*bpoverty09****), rural population increases (+*rurpch03-10****), and/or major population shares of the H'Mong ethnic minority (a major group traditionally practicing shifting agriculture; +*H'Mong****), but relatively smaller labor shares in the (official) agricultural sector (*–workagri09**; M14)[2]. However, PFES forestlands overlap either with protection and/or special-use forestlands, and/or natural production forests (currently under logging ban policies), and in most provinces these forestlands are almost exclusively owned and managed by state forest organisations such as FPMBs, SFCs, EOs (economic organisations), and LAs (local authorities) (Fig. 6b). Some forest areas were contracted for management to individual households (+*hhfcon04***), in addition to contracts to MB-PFs and SFCs (+*mbpfcon04**, +*sfcfcon04**; M13, M14). Nonetheless, in most cases forestlands covered by PFES schemes are probably a rather inadequate indicator for remunerations for ecosystem services that effectively increase the incomes and livelihood options of people living in forested upland catchments. The negative association of PFES forestland area with several indices of 'good governance' (including

[5] Valuable legal timber is produced in plantation forestlands which are however not eligible for PFES funding, hence there is a spatial trade-off. It also partly explains the significance of the variable *conftimb07-10* which is largely correlated with natural forest cover.

‘transparency in commune budgets’, *–Icombudget****; ‘transparency in land use planning and pricing policies’, *–Ilanduseplan**; and ‘administrative performance in addressing applications for personal documents’, *–Ipersproc**; M14) may partly back up this assumption.

In 2016 only 17.4% of the total PFES forestland area in Vietnam was managed by individual households and village communities (Fig. 6b). While PFES funds were presumably important to sustain the operation and activities of state forest organisations, benefits of PFES schemes to local people's livelihoods in most provinces probably remained limited (cf. To & Dressler 2019, McElwee *et al.* 2019). Substantial household livelihood incomes are typically derived from forestlands under household tenure (Thulstrup *et al.* 2013, Trædal & Vedeld 2016, Villamor *et al.* 2017). Even if many forestlands are now plantations excluded from PFES schemes, the results suggest that involvement of local communities in PFES schemes was higher in provinces where household tenure of forestlands and associated rights tended to be strong. Tenure of forestlands by households and communities was generally higher in PFES-provinces as compared to non-PFES-provinces (*+hhcften04****; M13). Furthermore, the share of PFES-forestland area managed by households (as compared to the share of state organisations engaged in forestry; *pfes·hh/state16*) was manifestly higher in provinces with relatively well-developed land tenure by households (*+hhcften04****) and higher provisional tenure by commune people's committees in 2004 (CPCs; *+cpcften04***; M15)[6]. In contrast, the share was lower in provinces where households managed extensive forestlands under contracts issued by SFCs (*–hhfcon04***; M15). Controlling for other geographical factors (latitude, *–latitude****; provincial area, *–provarea**; rural population density, *–rurpopd10****), the household-PFES-share (by area) was also higher in provinces dominated by the Thai ethnic minority group – a group which traditionally depended on forestlands for upland farming (*+Thai****; M15; cf. Figs 1d and 6b; cf. Dung *et al.* 2016). Notably, the household-PFES-share was higher in provinces characterized by ‘good governance’ in terms of ‘transparency in commune budgets’ (*+Icombudget****; M15).

Notwithstanding regional variations in the allocation of PFES-subsidised lands, and associated engagement of local communities, statistical assessment of aggregate investments of PFES funds in Vietnam's provinces from 2011-2016 (*pfes·pay11-16*) reveals an image yet more flavoured by political pursuits towards an economically profitable national forestry sector (cf. Fig. 6c, d). Absolute PFES funds were highest in mountainous provinces (*+elevation****; particularly provinces dominated by the Thai, *+Thai****; and/or in more southern parts of Vietnam, *–latitude***) with strong hydro-electric production capacities (*+hydro·kwh/y****), and – as may be expected – in provinces with relatively large areas of protection forestlands and fewer areas of production forestlands (*+protfland16****, *–prodfland16**; M16). Controlling for these factors, the payments were, however, also highest in provinces where the area of protection and special-use forestlands were significantly reduced during the same period 2011-2016 (*–protfrch11-16****, *–spusefrch11-16****), and in provinces where forestland tenure by local communities was still weakly developed (as by 2004 data; *–hhften04****; M16). Hence, overall PFES investments were neither in apparent agreement with forestland protection governance nor with FLA policies (rather in contrary). In addition to these findings, statistical results indicate that provinces characterised by high economic competitiveness in terms of relative ‘ease to open a new business (obtain land title and legal documentation)’ received comparatively more PFES funds (*+Imarketentry****; M16).

*Conclusion – forest landscapes swaying from ‘protection’ to ‘production’, and back?*

[6] CPC tenure was mostly transitional, i.e. tenure to be scheduled for transferal to households or communities.

Forests have always been important for Vietnam's socio-economic and political development (McElwee 2016). Domestic-sourced natural timber was once a major (albeit unsustainably managed) tradeable commodity. The 'success' of the 'forest transition' (FT) allowed for renewed 'savings' of natural forest capital. Yet, progressively, more and more transactions of forest capital (productive forestland, industrially produced timber stock, NTFPs, bushmeat, etc.) are once again taking place. Can such potentially 'erosive' transactions be countered by transactions of financial capital, aimed at regulating and maintaining some of the vitally important 'savings'?

The outcomes of FTs are neither deterministic nor irreversible (cf. Lambin & Meyfroidt 2010, Singh *et al.* 2015). Vietnam has been described as the first country in Southeast Asia to experience an FT, but it is notable that 1.) at national level, natural forest cover has not increased since 2006, and 2.) a natural FT (*sensu* Mather 1992) occurred only regionally within the country. In some southern provinces (especially in the Central Highlands) deforestation rates have exceeded forest regeneration throughout the 1990s to 2010s (Cochard *et al.* 2017, Meyfroidt *et al.* 2013). Between 2005-2016 the net natural forest cover continued to grow in many coastal and northern provinces, but backsliding to deforestation also occurred, especially in some mountain provinces surrounding the densely populated Red River delta (Fig. 4).

This study indicates that the changes in the 'political' forestland zoning significantly influenced the changes in 'physical' forest cover – confirming the first posit of our study (cf. Introduction). Changes in political forestland cover were likely driven by both top-down and bottom-up pressures to return valuable forestland areas (probably mostly degraded natural forests slated for conversion to plantations, and/or already existing afforestations of alien species) into economic production. Aside from strong market demands for wood products, this trend is fuelled by the phenomenal success of acacia-based plantation forestry since the 1990s.

The 'tree plantation boom' was initially linked to large, partly internationally funded reforestation programs. Initially, 'reforestation' through tree plantations was centered on areas which had previously been deforested (McElwee 2009, McElwee 2016). In conjunction with an array of new policies, such as FLA, reforestation efforts probably alleviated land use pressures on more marginal areas, thus also allowing for some natural forest regrowth (Cochard *et al.* 2017). The acacia-based reforestation model for so-called 'bare hills' has however since spread to more remote, mountainous parts of the country. Small-scale short-rotation acacia plantation forestry is being increasingly embraced by upland minority communities as a lucrative new livelihood base (Sandewall *et al.* 2010, Thulstrup *et al.* 2013, Sikor 2012). Similarly, acacia plantations are now managed as a source of wood-based revenue by many economically-oriented SFCs (Smith *et al.* 2017, To *et al.* 2015).

With growing demand for timber for the construction and furniture industry, there are now increasing efforts by policy makers (partly in conjunction with new certification schemes such as the Forest Stewardship Council – FSC, or the Program for the Endorsement of Forest Certification – PEFC) to encourage growers to extend the rotation cycle of plantations and produce higher quality timber (Maraseni *et al.* 2017a, 2017b, Frey *et al.* 2018, Iwanaga *et al.* 2019). As Vietnam's economy grows (alongside growing economies of powerful neighbouring countries, most notably China) and trade is increasingly facilitated through extensive economic networks and free trade agreements (cf. ARIC 2019), the growth in demand for wood products is open-ended[7]. This, in turn, will put

[7] The Forestry Law 2017 emphasises that the forestry sector shall be restructured as an effective 'economic sector' by promoting and strengthening the entire forest products industry, including strengthening the various segments in the wood/furniture production value chain.

increasing pressure on policy makers to establish effective mechanisms to safeguard and restore natural forestlands[8].

PFES may be one such mechanism that could potentially contribute to more effective forest protection. During recent years much academic theorizing, debate and research has converged on questions about how this policy should be implemented and to what degree it can improve the safeguarding and/or restoration of natural forest ecosystems (thereby ensuring sustainable delivery of specific services, such as water for hydro-power) and poverty reduction in rural communities (cf. McElwee *et al.* 2019, 2014, 2012, To & Dressler 2019, To *et al.* 2012, Suhardiman *et al.* 2013, Trædal *et al.* 2016). In Vietnam PFES is now firmly entrenched as a policy, and schemes have now been implemented in 44 provinces, with variable outcomes. Our study shows, however, that the advent of PFES was relatively unimportant to explain forest cover changes in the provinces from 2011 to 2016. Hence, we cannot unreservedly confirm our study's second posit. Even if the set of factors explaining forest cover changes shifted in significant ways from the pre-PFES to the with-PFES study period, those shifts mostly related to wider agricultural-economic developments (and associated policies), conventional forestland governance (mainly through the system of state forestry organizations), and associated land cover changes. However, despite hitherto little influence on forest cover changes, PFES may still have been important to foster qualitative aspects, i.e. the regeneration of degraded forest in conjunction with improvements of people's livelihoods. Yet, here too, the available evidence appears equivocal.

There are no finite proofs of causalities inferred from regression analyses. Nonetheless, several findings of our study echo critical voices (e.g. McElwee *et al.* 2019, To & Dressler 2019, Duong & de Groot 2018, Tran *et al.* 2016, To *et al.* 2012) who noted that PFES funds were often controlled or seized by powerful stakeholders, were sometimes misappropriated, and were rarely used efficiently to achieve stated policy goals. Clearly, PFES policies are in tune with a territorial organization of 'forestlands' that primarily follows rationales of national economic development, and where other concerns are subordinate (cf. Zingerli 2005). In principle, PFES schemes are directed at better protection and restoration of forests in upland watersheds (mainly those sourcing hydro-electric dams) through a state-directed compensation mechanism. In their current form the schemes are, however, implemented in ways which are probably neither effective, efficient, and equitable. The schemes are not particularly appreciative of socio-historical livelihood patterns and associated needs, nor do the schemes incorporate monitoring and evaluation systems which are based on an adequate attention and research-based understanding of FES (cf. Thu *et al.* 2015, Tran *et al.* 2016). This includes the fact that evaluation of FES is biased towards certain types of FES (e.g. water regulation services for hydro-electricity), whereas other FES (e.g. biodiversity conservation, cultural ecosystem services) are still poorly reflected within the design and implementation of the schemes (cf. Nguyen *et al.* 2018). Internationally funded schemes under the United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD) that are currently in planning may largely follow on the model of the national PFES schemes, with similar hitches and challenges (To *et al.* 2017, Trædal *et al.* 2016, Sikor & Hoang 2016).

The acacia-based plantation boom has contributed to Vietnam's economic growth and associated reduction of rural poverty since the 1990s (Economist 2016, Sikor 2012, Nambiar *et al.* 2015). In many regions, acacia plantations have helped to re-green 'barren hills', thereby reportedly stabilizing and improving soil conditions, contributing to hydrological regulation, and occasionally even facilitating the regeneration of native-species forests

[8] Notably, important free trade agreements explicitly stipulate the adoption of specific sustainability standards in forestry production (cf. Tröster *et al.* 2019).

(Amat *et al.* 2010, McNamara *et al.* 2006, de Jong *et al.* 2006, Tran 2014). Despite of this, intensive plantation forestry has also raised new specters of risks, e.g. emerging impacts of plant pests and diseases or insidious changes in soil chemistry (cf. Lee 2004, Nambiar *et al* 2018, Dong *et al.* 2014). Furthermore, the outlook for biodiverse natural forests is still rather unedifying. Fewer than 0.8% of Vietnam's natural forest cover nowadays remains as 'primary forest' (FAO 2016), and in many regions timber and wildlife poaching remains a serious problem (Ngoc 2017, Sikor & To 2011, Gray *et al.* 2018, Corlett 2019). Secondary natural forests may still harbor considerable biodiversity (Chazdon 2014, Van & Cochard 2017), but information about the actual state and ecology of Vietnam's natural forests is very incomplete. This, in turn, constitutes a barrier to adequate assessments of trajectories of species succession, and regeneration rates within 'degraded' natural forests (within a context of persistent disturbances), and actual changes in forest ecosystem qualities and services (cf. Cochard 2016). Under increasing pressure from plantation forestry, natural forest landscapes are at risk of becoming ever more fragmented, impoverished in species composition and ecosystem functions, and vulnerable to transformations driven by new plant pests/diseases, invasive species, and climate change (Martin 2015, Cochard 2011, 2013, Cochard *et al.* 2018, Richardson *et al.* 2015, Rijal & Cochard 2016, Colwell *et al.* 2008, Dang *et al.* 2012b). Policy schemes which are aimed at improving forest protection in conjunction with poverty reduction need to incorporate efficient mechanisms which ensure transparency and accountability (cf. Thu *et al.* 2015). This should optimally include systems of monitoring and adaptive management which are informed by reliable ecological and participatory research.

**CRediT authorship contribution statement:**

**Roland Cochard**: Conceptualisation, Methodology, Visualisation, Writing - original draft, Data curation, Resources, Writing - review & editing, Funding acquisition, Project administration. **Van Hai Thi Nguyen**: Data curation, Resources, Writing – review & editing. **Dung Tri Ngo**: Data curation, Resources, Writing - review & editing, Funding acquisition, Project administration. **Christian Kull**: Writing - review & editing, Funding acquisition, Project administration.

**Declaration of Competing Interest:**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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**Table 1**: Summary of the dependent (*F* and *E*) data variables and significant predictor variables (*G*/*F*/*P*/*L*/*S*/*H*/*A*/*W*/*C*/*T*/*E*/*I*) in multivariate models (Table 2). References for data sources and footnotes are listed at the bottom of the table.

| Variable name | Variable description | Source |
|---|---|---|
| ***Geographical and terrain (G) variables*** | | |
| *nodelta* | Whether [0] or not [1] the province lies in the Red River or Mekong Delta | GEA |
| *latitude* | Latitude: north UTM coordinates (m) at approximate center of the province | GEA |
| *elevation* | An index of the estimated mean elevation (meters a.s.l.) of the province | GEA |
| *distcoast* | The nearest distance from the province border to the coast (km) | GEA |
| *provarea* | The provincial area cover ($km^2$) | WB |
| ***Physical forest/plantation cover/change and political forestland extent/change (F) variables*** | | |
| *natforest05 / 11 / 16* | Natural forest cover (ha) in 2005; respectively 2011; respectively 2016 | MA8 |
| *natfrch05-10 / 11-16* | Relative (ratio) natural forest cover change, 2005-2010; respectively 2011-2016 | MA8 |
| *plantforest05 / 11 / 16* | Planted forest cover (ha) in 2005; respectively 2011; respectively 2016 | MA8 |
| *plantfrch05-10 / 11-16* | Relative (ratio) planted forest cover change, 2005-2010; respectively 2011-2016 | MA8 |
| *protfland05 / 11 / 16* | Extent of protection forestlands (ha) in 2005; respectively 2011; resp. 2016 | MA8 |
| *protfrch05-11 / 11-16* | Relative (ratio) protection forestland area change, 2005-2011; resp. 2011-2016 | MA8 |
| *spusefland05 / 11 / 16* | Extent of protection forestlands (ha) in 2005; respectively 2011; resp. 2016 | MA8 |
| *spusefrch05-11 / 11-16* | Relative (ratio) special-use forestland area change, 2005-2011; resp. 2011-2016 | MA8 |
| *prodfland05 / 11 / 16* | Extent of production forestlands (ha) in 2005; respectively 2011; resp. 2016 | MA8 |
| *prodfrch05-11 / 11-16* | Relative (ratio) production forestland area change, 2005-2011; resp. 2011-2016 | MA8 |
| *prod/ptsp:ch11-16* | Relative (ratio) change in production/protection forestland area ratio, 2011-2016 ⌈[1] | MA8 |
| ***Population indicator (P) variables*** | | |
| *popdens13* | Population density (people $km^{-2}$) in 2013 | GSO |
| *rurpopd10* | Rural population density (people $km^{-2}$) in 2010 | GSO |
| *rurpch03-10* | Relative change (ratio) in rural population density from 2003-2010 | GSO |
| *Tay*, *Thai*, *Muong*, *H'Mong*, *mtethnic* | Tày, Thái, Mường, H'Mong, respectively all 'ethnic mountain minority' populations in provinces (% of total population) in 2009 | UNP |
| *Kinh* | Kinh majority population (% of total population) in 2009 | UNP |
| ***Labor and poverty indicator (L) variables*** | | |
| *labor09* | Labor force (% of working, economically active population) in 2009 | WB |
| *workagri09* | Labor force working in agriculture (% of all labor forces) in 2009 | WB |
| *hpoverty09* | Households (% of all households in province) below poverty line in 2009 | WB |
| *bpoverty09* | Population (%) in the 'national-level 40% income bottom' in the province in 2009 | WB |
| ***Infrastructural (S) and hydro-electric capacity (H) development indicator variables*** | | |
| *water09* | Water infrastructure (% of households with water [tap, well] in or near house), 2009 | WB |
| *hydroMW16* | Potential hydro-electric production (mega-watt per hour) in the province, 2016 | PAN |
| *hydro·kwh/y16* | Effective hydro-electric production (kilo-watt per hour per year), 2016 | PAN |
| ***Agricultural productivity (A), wood processing (W), and illicit logging (C) indicator variables*** | | |
| *cerprod11* | Average productivity (tons $ha^{-1}$) of cereal crop cultivations in the province in 2011 | GSO |
| *riland05* | Land area (1000 hectares) planted with rice in 2005; respectively 2013 | GSO |
| *rilch05-10* | Rice crops land area change: 2010 cover minus 2005 cover | GSO |
| *malch11-16* | Maize crops land area change: 2016 cover (in 1000 hectares) minus 2011 cover | GSO |
| *mapch05-10 / 11-16* | Maize field productivity change: 2010 output (tons $ha^{-1}$) minus 2005 output | GSO |
| *pulpcap04* | Index for provincial pulp-and-paper wood processing capacities in 2004 ⌈[2] | NSY/GEA |
| *conftimb07-10* | Reported total 'confiscated illegally-cut timber (in $m^3$)', 2007-2010 | FPD |

Footnotes: ⌈[1] Protection forestlands in this case include protection as well as special-use forestlands. ⌈[2] Index calculated using original NSY data and UTM coordinates (cf. Cochard *et al.* 2017)

List of data sources: GEA - compiled manually from Google Earth™; GSO - GSO (2018); FPD - FPD (2015); MA8 - MARD (2018); PAN - PanNature (2018); UNP - UNFPA (2011); WB - World Bank (2015); in analyses we also included data from ICEM (2003; variables not significant)

**Table 1:** continued.

| Variable name | Variable description | Source |
|---|---|---|
| ***Forest land tenure and land contractual indicator (T) variables*** | | |
| *hhften04* | Forestland tenure (ha) by 'households and individuals' in 2004 | NSY |
| *hhcften04* | Forestland tenure (ha) by 'households, individuals or communities' in 2004 | NSY |
| *cpcften04* | Forestland tenure (ha) by 'communal people's committees' in 2004 | NSY |
| *ecorgften04* | Forestland tenure (ha) by 'economic organizations' (EOs) in 2004 | NSY |
| *ecofjvften04* | Forestland tenure (ha) by 'economic or foreign organizations, or joint ventures' in 2004 | NSY |
| *otherften04* | Forestland tenure (ha) by 'other' non-specified owners in 2004 | NSY |
| *regenfcon99* | Forestland area (ha) contracted for 'zoning for regeneration' in 1999 | NSY |
| *protfcon99* | Forestland area (ha) contracted for 'protection and management' in 1999 | NSY |
| *sfcfcon04* | Forestland area (ha) contracted by state forest companies (SFCs or SFEs) in 2004 | NSY |
| *hhfcon04* | Forestland area (ha) contracted to households by SFEs/SFCs in 2004 | NSY |
| *mbpfcon04* | Forestlands (ha) contracted by protection forest management boards (MB-PFs) in 2004 | NSY |
| *fpmbfcon04* | Forestlands (ha) contracted by forest protection management boards (FPMBs)[3] in 2004 | NSY |
| ***Payments for forest ecosystem services (PFES) schemes indicator (E) variables*** | | |
| *pfes·yes/no* | Whether [0] or not [1] a PFES scheme was launched in the province, 2011-2016 | MA7 |
| *pfes·area16* | Total forestland area (ha) covered by PFES schemes in PFES-provinces in 2016 | MA7 |
| *pfes:area%16* | Total forestland area (as % of natural forest cover) covered by PFES schemes in 2016 | MA7 |
| *pfes·hh/state16* | Ratio of household-managed over state-managed PFES-forestlands (by area) in 2016 | MA7 |
| *pfes·pay11-13 / 14-16 / 11-16* | Total payments (in VN Đồng) under PFES schemes in PFES-provinces, 2011-2013; respectively 2014-2016; respectively 2011-2016 | MA7 |
| ***Indices (I) of governance, institutional and public administration, and socio-economic performance*** | | |
| *Icivicknow* | Index of 'citizens' knowledge of their electoral rights and awareness of institutions that safeguard political participation at grassroots level' in 2014 | PAP |
| *Icombudget* | Index of 'citizens' assessments of the level of transparency in commune budgets' (relevant for keeping misuse of communal funds in check) in 2014 | PAP |
| *Ilanduseplan* | Index of 'citizens' assessment of the level of transparency in land use planning and pricing policies' (~lawfulness and performance during land policy changes), 2014 | PAP |
| *Ipublicorr* | Index of 'limits on public sector corruption' (~citizen's views/experiences regarding 'corrupt practices', e.g. diversion of public funds, bribes taken, etc.) in 2014 | PAP |
| *Iservdelcorr* | Index of 'limits on corruption in public service delivery' (~citizen's perceptions/experiences regarding corruption levels [bribing, favoritism] when using public health care and primary schools) in 2014 | PAP |
| *Iequitempl* | Index of citizens' views of 'equity in public sector employment' (indices on 'no bribes for state employment' and 'public sector jobs not requiring connections') in 2014 | PAP |
| *Ifightcorr* | Index (knowledge/experience-based) of 'perceived government efforts to combat corruption and engage citizens to fight corruption in their jurisdictions' in 2014 | PAP |
| *Ipersproc* | Index of 'performance of commune People's Committees addressing applications for personal documents (e.g. birth/marriage certificates, residency registrations, housing/employment subsidies, ethnicity-related procedures) in 2014 | PAP |
| *Imarketentry* | Index of the ability and ease of new firms/businesses to enter the market (time register a business, and obtain land titles and legal documentations) in 2011 | GCI |
| *Iinfcharge* | Index of corruption as assessed by businesses (need to pay informal charges [bribes] to provincial officials during business operations) in 2011 | GCI |
| *Ienterprise* | Index of 'proactivity' by provincial officials to facilitate private enterprise and business operations (working within the law to solve problems of private enterprises) in 2011 | GCI |

*Footnotes:* ⌈[3] FPMBs include MB-PFs (MBs of protection forest) and MB-SUFs (MBs of special-use forest)
*List of data sources:* GCI - Malesky (2011); MA7 - MARD (2017); NSY - Nguyen et al. (2009); PAP - CECODES, VFF-CRT & UNDP (2015).

**Table 2**: Listing of multivariate regression model equations (M1-16) for political forestland extent or change variables, physical forest cover or change variables, and variables describing 'payments for forest ecosystem services' schemes (with 63 provinces, i.e. 'observations') during the study focus period 2005-2016 (description of variables see Table 1). Statistical significance of the predictors is indicated by underlining as $\underline{\underline{\text{strong}}}$ ($p < 0.0005$), $\underline{\text{medium}}$ ($0.0005 < p < 0.005$), and rather marginally significant ($0.005 < p < 0.05$; no underlining). The adjusted $R^2$ statistic and the number of observations used for models are indicated in brackets after the equation. The function nscor indicates a normal score transformation, JT a Johnson transformation.

| | |
|---|---|
| **Protection forest cover and cover changes 2005-2016** | |
| M1 | $[\mathit{protfland05}]^{0.2} = 3.64 + 0.035 \times [\underline{\mathit{bpoverty09}}] - 0.0026 \times [\mathit{workagri09}]^{1.41} + 0.258 \times [\underline{\underline{\mathit{natforest05}}}]^{0.27} + 0.75 \times \text{JT}[\underline{\underline{\mathit{plantforest05}}}] - 0.26 \times [\underline{\underline{\mathit{prodfland05}}}]^{0.21} + 0.254 \times [\underline{\underline{\mathit{hhften04}}}]^{0.17} + 0.495 \times \text{nscor}[\underline{\underline{\mathit{mbpfcon04}}}]$ (adjusted $R^2$: 97.0%; 57 observations) |
| M2 | $[\mathit{protfland16}]^{0.2} = 4.05 + 0.026 \times [\underline{\mathit{bpoverty09}}] + 0.245 \times [\underline{\underline{\mathit{natforest16}}}]^{0.27} + 1.14 \times \text{JT}[\underline{\underline{\mathit{plantforest16}}}] - 0.33 \times [\underline{\underline{\mathit{prodfland16}}}]^{0.22} + 0.258 \times [\underline{\underline{\mathit{hhcften04}}}]^{0.17} + 0.46 \times \text{nscor}[\underline{\underline{\mathit{mbpfcon04}}}]$ (adjusted $R^2$: 94.6%; 59 observations) |
| M3 | $\text{JT}[\mathit{protfrch05\text{-}11}] = -4.89 + 0.000001 \times [\underline{\underline{\mathit{latitude}}}] + 0.954 \times [\mathit{provarea}]^{0.16} + 0.021 \times [\underline{\underline{\mathit{water09}}}] - 0.723 \times [\underline{\mathit{pulpcap04}}] - 0.379 \times (-[\underline{\underline{\mathit{Thai}}}]^{(-0.4)}) + 0.377 \times (-[\mathit{Muong}]^{(-0.33)}) + 0.137 \times [\underline{\underline{\mathit{otherften04}}}]^{0.19}$ (adjusted $R^2$: 52.6%; 57 observations) |
| M4 | $\text{JT}[\mathit{protfrch11\text{-}16}] = -0.34 + 1.18 \times [\underline{\underline{\mathit{nodelta}}}] - 0.634 \times \text{nscor}[\underline{\underline{\mathit{distcoast}}}] + 0.992 \times \ln[\underline{\underline{\mathit{popdens13}}}] + 0.0018 \times [\mathit{workagri09}]^{1.41} + 0.43 \times [\underline{\underline{\mathit{mtethnic}}}] + 1.26 \times (-[\underline{\underline{\mathit{natfrch11\text{-}16}}}]^{(-1.7)}) + 0.81 \times \text{JT}[\underline{\underline{\mathit{plantfrch11\text{-}16}}}] - 0.349 \times \text{JT}[\underline{\underline{\mathit{prodfrch11\text{-}16}}}] - 0.063 \times [\underline{\underline{\mathit{cpcften04}}}]^{0.17} - 0.381 \times \text{JT}[\underline{\underline{\mathit{fpmbfcon04}}}] - 1.02 \times [\underline{\underline{\mathit{Icivicknow}}}] - 1.68 \times [\underline{\underline{\mathit{Iservdelcorr}}}]$ (adjusted $R^2$: 81.8%; 54 observations) |
| **Production forest cover and cover changes 2005-2016** | |
| M5 | $[\mathit{prodfland05}]^{0.21} = -7.84 + 1.83 \times [\underline{\mathit{elevation}}]^{0.13} + 3.48 \times [\underline{\underline{\mathit{provarea}}}]^{0.16} - 0.0145 \times [\mathit{water09}] + 0.765 \times \text{JT}[\underline{\underline{\mathit{plantforest05}}}] - 0.258 \times [\underline{\mathit{protfland05}}]^{0.2} - 1.75 \times ([\underline{\underline{\mathit{regenfcon99}}}]+20)^{0.08} + 0.186 \times [\mathit{hhften04}]^{0.17} + 0.42 \times [\underline{\mathit{ecorgften04}}]^{0.15} + 0.195 \times [\underline{\mathit{otherften04}}]^{0.19} + 0.56 \times [\underline{\underline{\mathit{sfcfcon04}}}]^{0.16} - 0.755 \times \text{JT}[\underline{\mathit{fpmbfcon04}}]$ (adjusted $R^2$: 96.5%; 55 observations) |
| M6 | $[\mathit{prodfland16}]^{0.22} = 2.82 - 0.0294 \times [\underline{\underline{\mathit{water09}}}] + 0.24 \times [\underline{\underline{\mathit{natforest16}}}]^{0.27} + 0.95 \times \text{JT}[\underline{\underline{\mathit{plantforest16}}}] - 0.446 \times [\underline{\underline{\mathit{protfland16}}}]^{0.2} + 0.362 \times [\underline{\underline{\mathit{hhften04}}}]^{0.17} + 0.306 \times [\mathit{ecorgften04}]^{0.15} + 1.397 \times ([\underline{\underline{\mathit{regenfcon99}}}]+20)^{0.08} + 0.462 \times [\underline{\underline{\mathit{sfcfcon04}}}]^{0.16} + 0.407 \times \text{nscor}[\mathit{hhfcon04}]$ (adjusted $R^2$: 98.4%; 56 observations) |
| M7 | $\text{JT}[\mathit{prodfrch05\text{-}11}] = -5.1 + 0.000001 \times [\underline{\underline{\mathit{latitude}}}] + 0.9 \times [\underline{\underline{\mathit{elevation}}}]^{0.13} + 0.076 \times [\underline{\underline{\mathit{labor09}}}] + 0.016 \times [\mathit{bpoverty09}] - 0.0025 \times [\mathit{workagri09}]^{1.41} + 0.216 \times \text{JT}[\underline{\mathit{natfrch05\text{-}10}}] + 0.131 \times \text{JT}[\mathit{plantfrch05\text{-}10}] - 0.16 \times [\underline{\underline{\mathit{prodfland05}}}]^{0.21} + 0.394 \times \text{nscor}[\underline{\underline{\mathit{hhfcon04}}}] + 0.356 \times \text{JT}[\underline{\mathit{fpmbfcon04}}] + 0.71 \times [\mathit{Iequitempl}] - 0.142 \times [\mathit{Iinfcharge}]$ (adjusted $R^2$: 86.9%; 56 observations) |
| M8 | $\text{JT}[\mathit{prodfrch11\text{-}16}] = -8.11 + 0.0000001 \times [\mathit{latitude}] - 0.57 \times [\mathit{rurpopd10}] + 0.143 \times [\mathit{labor09}] - 0.0243 \times [\mathit{bpoverty09}] + 0.09 \times [\mathit{natforest11}]^{0.26} + 0.22 \times \text{JT}[\mathit{natfrch05\text{-}10}] - 0.41 \times [\mathit{prodfland11}]^{0.22} + 0.179 \times [\underline{\mathit{hhcften04}}]^{0.17} + 0.218 \times [\mathit{ecofjvften04}]^{0.16} + 0.305 \times [\underline{\mathit{sfcfcon04}}]^{0.16}$ (adjusted $R^2$: 83.7%; 56 observations) |

**Table 2:** continued.

**Changes in planted forest cover 2005-2016**

M9 JT[*plantfrch05-10*] = -0.44 + 0.199 × JT[*riland05*] – 0.31 × JT[*rilch05-10*] + 0.29 × JT[*mapch05-10*] – 0.43 × [*pulpcap04*] + 0.087 × [*hydroMW*]$^{0.23}$ + 0.11 × [*protfcon99*] – 0.073 × [*prodfland05*]$^{0.21}$ + 0.404 × nscor[*prodfch05-11*] + 0.224 × [*ecofjvften04*] (adjusted $R^2$: 74.4%; 57 observations)

M10a JT[*plantfrch11-16*] = -7.97 + 1.65 × [*elevation*] – 0.02 × [*hpoverty09*] + 0.1 × [*labor09*] – 0.38 × [*pulcap04*] – 0.103 × [*hhften04*] + 0.164 × [*sfcfcon04*] + 0.292 × JT[*prodfrch11-16*] + 0.31 × JT[*protfrch11-16*] + 0.224 × nscor[*spusefch05-11*] – 0.19 × nscor[*spusefch11-16*] + 0.091 × [*Ienterprise*] (adjusted $R^2$: 82.1%; 58 observations)

M10b JT[*plantfrch11-16*] = -5.13 + 0.9 × [*elevation*] – 0.27 × [*Kinh*] – 0.03 × [*hpoverty09*] + 0.124 × [*labor09*] – 0.174 × [*hhften04*] + 0.144 × [*sfcfcon04*] + 0.278 × JT[*prodfrch11-16*] + 0.258 × JT[*protfrch11-16*] + 0.124 × nscor[*spusefch05-11*] – 0.123 × nscor[*spusefch11-16*] + 0.3 × nscor[*pfes·area16*] – 0.56 × nscor[*pfes·pay11-13*] + 0.624 × nscor[*pfes·pay14-16*] + 1.675 × [*Icivicknow*] – 2.1 × [*Ifightcorr*] + 0.092 × [*Ienterprise*] (adjusted $R^2$: 87.4%; 61 observations)

**Changes in natural forest cover 2005-2016**

M11 JT[*natfrch05-10*] = -7.86 + 0.000001 × [*latitude*] + 2.82 × [*elevation*] – 0.61 × [*Tay*] – 0.0031 × [*workagri09*] + 0.013 × [*water09*] + 0.384 × JT[*plantfrch05-10*] + 0.18 × [*prodfland05*]$^{0.21}$ – 0.124 × [*protfland05*]$^{0.2}$ + 0.224 × JT[*protfrch05-11*] + 1.36 × [*regenfcon99*] – 0.353 × [*sfcfcon04*] – 1.28 × [*conftimb07-10*] + 1.59 × [*Ilanduseplan*] (adjusted $R^2$: 66.3%; 59 observations)

M12 -[*natfrch11-16*]$^{(-1.7)}$ = -1.987 – 0.25 × [*nodelta*] + 0.203 × [*elevation*] – 0.0026 × [*workagri09*] + 0.087 × [*rurpopd10*] + 0.023 × [*bpoverty09*] – 0.092 × JT[*plantfrch11-16*] – 0.086 × JT[*cerprod11*] – 0.293× JT[*mailch11-16*] + 0.266 × JT[*mapch11-16*] + 0.121 × JT[*protfrch11-16*] + 0.031 × JT[*spusefrch05-11*] – 0.036 × JT[*prod/ptsp:ch11-16*] – 0.0013 × [*pfes:area%16*] + 0.403 × [*Ipublicorr*] (adjusted $R^2$: 81.9%; 57 observations)

**Predictors of 'payments for forest ecosystem services' variables**

M13 [*pfes·yes/no*] = -1.308 + 0.472 × [*elevation*] + 0.025 × [*hydro·kwh/y*]$^{0.24}$ – 0.058 × [*prodfland11*]$^{\wedge 0.22}$ + 0.086 × [*hhcften04*] + 0.136 × [*hhfcon04*] + 0.058 × [*mbpfcon04*] + 0.789 × [*conftimb07-10*] (adjusted $R^2$: 85.4%; 60 observations)

M14 JT[*pfes·area16*] = 1.9 + 0.0000001 × [*latitude*] – 0.35 × nscor[*distcoast*] + 0.105 × [*hydro·kwh/y*]$^{0.24}$ + 0.12 × [*natforest11*]$^{0.26}$ + 0.068 × JT[*spusefrch05-11*] + 0.21 × JT[*rurpch03-10*] – 0.0054 × [*workagri09*]$^{1.41}$ + 0.032 × [*bpoverty09*] + 0.5 × JT[*H'Mong*] + 0.087 × [*sfcfcon04*]$^{0.16}$ + 0.183 × nscor[*hhfcon04*] – 0.92 × [*Icombudget*] – 0.91 × [*Ilanduseplan*] – 1.84 × [*Ipersproc*] (adjusted $R^2$: 97.7%; 31 observations)

M15 nscor[*pfes·hh/state16*] = -1.83 – 0.000002 × [*latitude*] – 0.926 × [*provarea*]$^{0.16}$ – 0.68 × JT[*rurpopd10*] + 0.239 × (-[*Thai*]$^{(-0.4)}$) + 0.53 × [*hhcften04*]$^{0.17}$ + 0.053 × [*cpcften04*]$^{0.17}$ – 0.44 × nscor[*hhfcon04*] + 2.97 × [*Icombudget*] (adjusted $R^2$: 84.7%; 30 observations)

M16 JT[*pfes·pay11-16*]= -5.71 – 0.0000001 × [*latitude*] + 1.01 × [*elevation*] + 0.145 × (-[*Thai*]$^{(-0.4)}$) + 0.17 × [*hydro·kwh/y*]$^{0.24}$ – 0.048 × [*prodfland16*]$^{0.22}$ + 0.25 × [*protfland16*]$^{0.2}$ – 0.447 × JT[*protfrch11-16*] – 0.27 × nscor[*spusefrch11-16*] – 0.165 × [*hhften04*]$^{0.17}$ + 0.345 × [*Imarketentry*] (adjusted $R^2$: 98.2%; 28 observations)

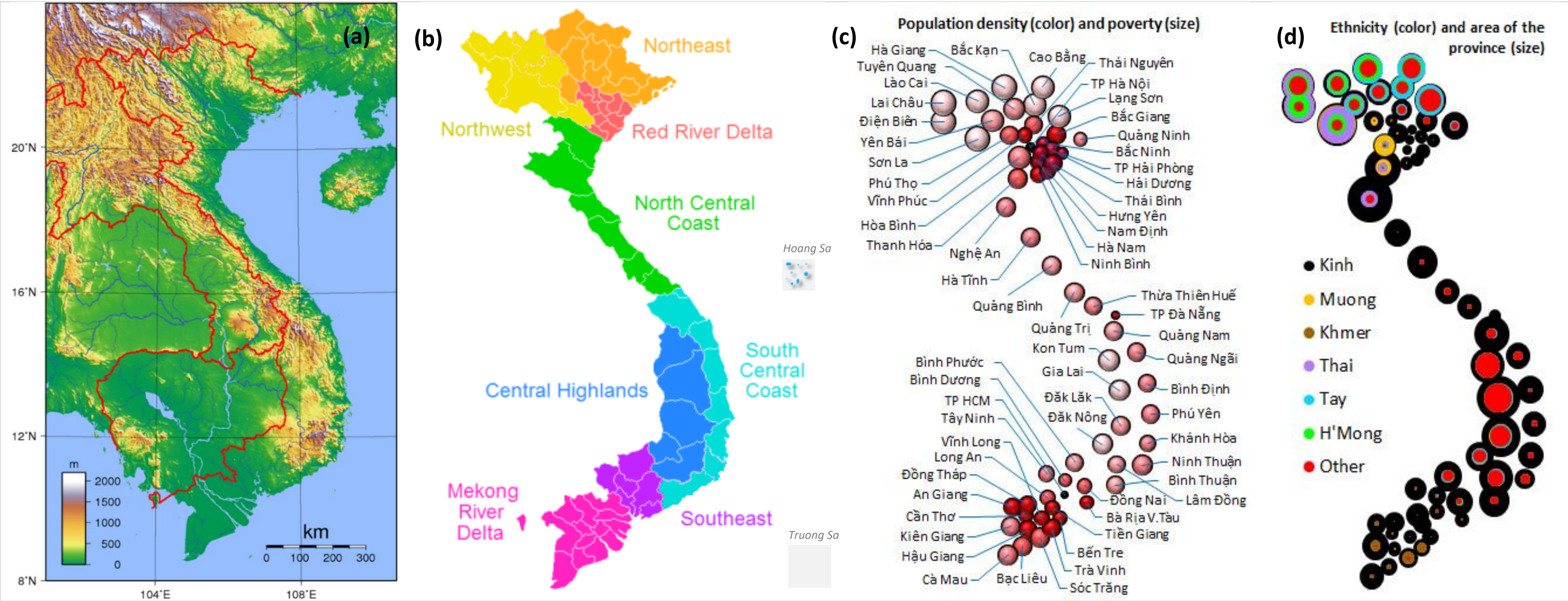


**Fig. 1:** Maps of Vietnam. (a) The overall terrain. (b) The main eight regions. (c) The provinces' population density (indicated by red colours) and poverty share (bubble size; i.e., percentage in the national 40% income bottom, ranging from 9% in TP HCM to 87% in Lai Châu Province). (d) The relative ethnic composition of the provinces (indicating the majority Kinh and the five most populous minority groups). The bubble size represents the land area ($km^2$) of each province. Source of maps a and b: https://en.wikipedia.org/wiki/Geography_of_Vietnam (https://creativecommons.org/licenses/by-sa/3.0/). Data sources for maps c and e: World Bank (2015) and UNFPA (2011).

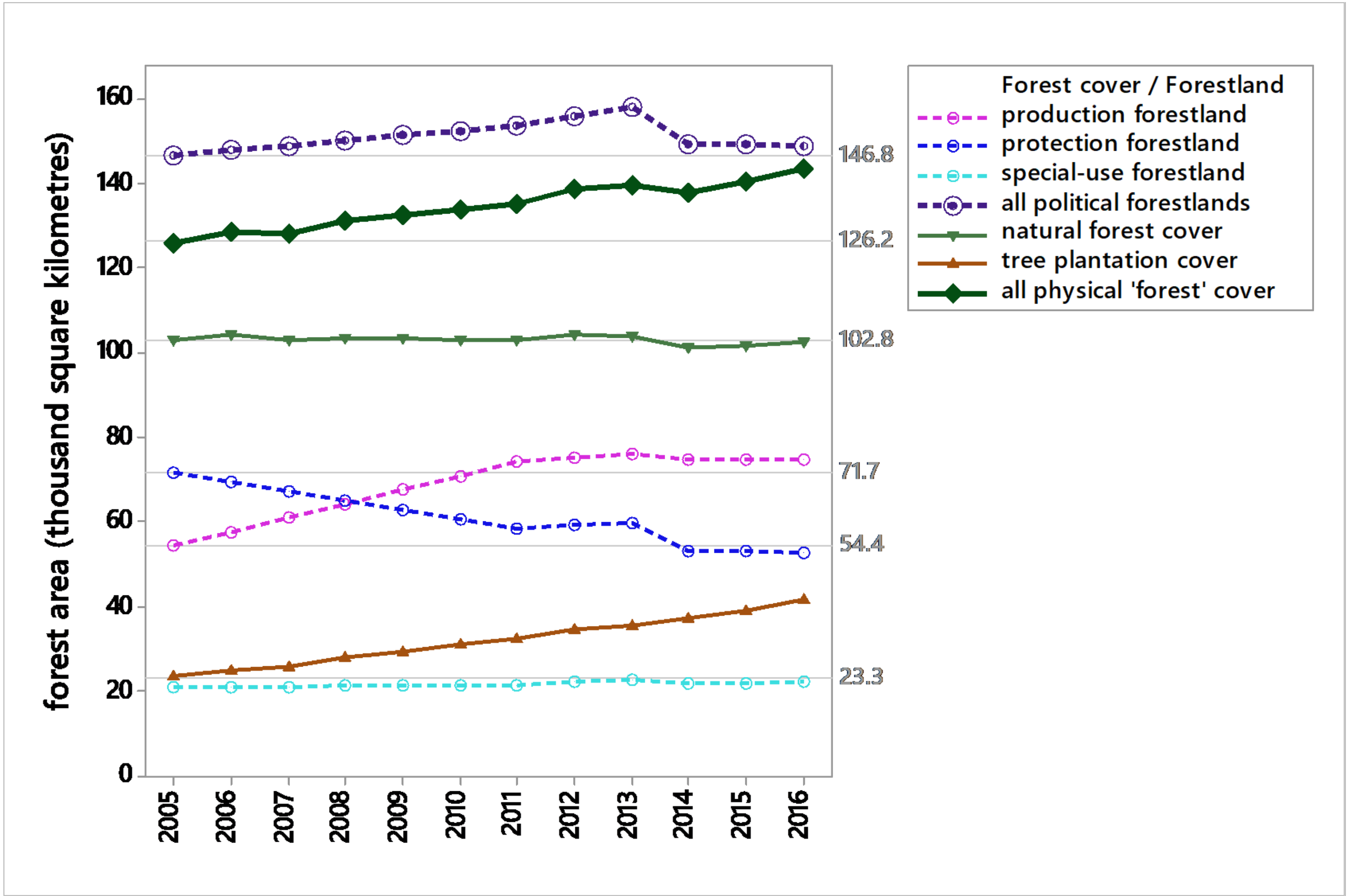


**Fig. 2:** Changes (years 2005-2016) in total national forest cover and forestland area (in thousand square kilometres; as by official data) in Vietnam, in terms of politically defined forestlands (i.e., production, protection and special use forestland) and actual physical forest and plantation cover (i.e., natural and planted forest). Note that data of political forestland extent was unavailable for the years 2006-2010 and 2012. Data: MARD (2018).

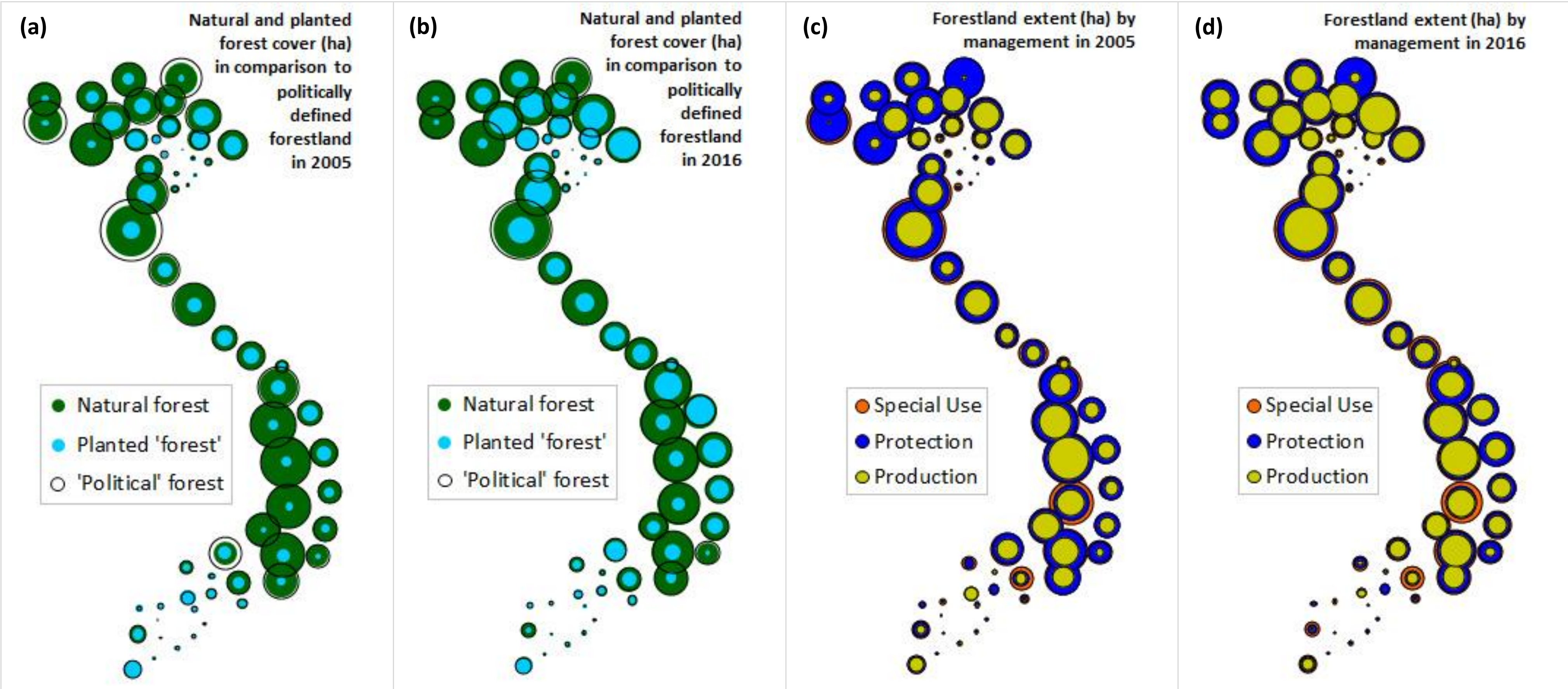


**Fig. 3:** The physical forest cover (official data) and politically defined (management types) forestland extent in Vietnamese provinces in 2005 and 2016. 1.) Physical forest cover of natural forest and tree plantations (planted 'forest') as compared to politically defined forestlands in 2005 (a) and 2016 (b). 2.) The cover of the three politically defined forestland management types, i.e. special-use, protection, and production forestland, in 2005 (c) and 2016 (d). Data: MARD (2018).

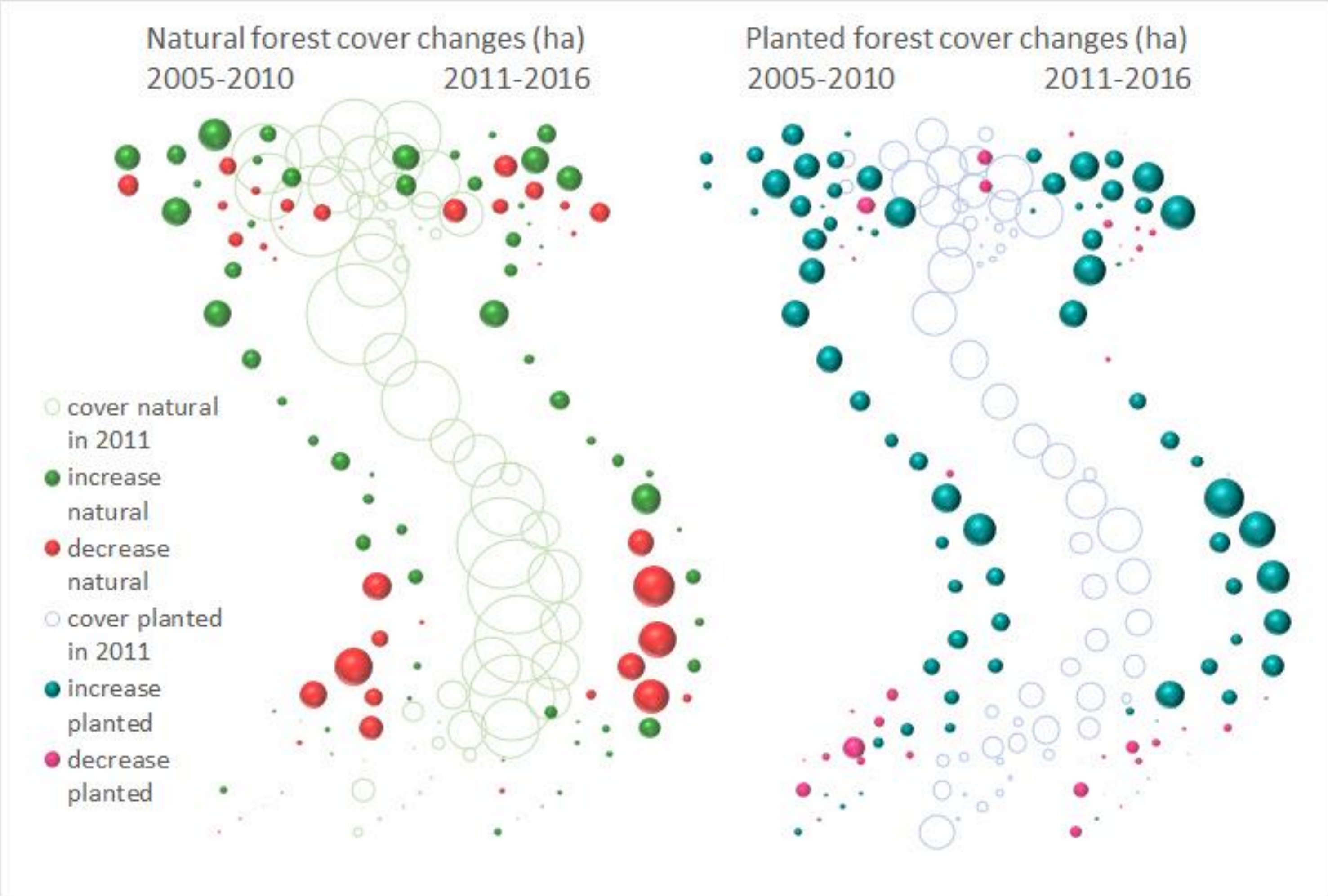


**Fig. 4:** The physical forest cover changes in Vietnamese provinces during the periods 2005-2010 and 2011-2016 (as compared to total forest cover in 2011) for 1.) natural forests, and 2.) planted ‘forests’ (i.e. mostly tree plantation mono-cultures). Data: MARD (2018).

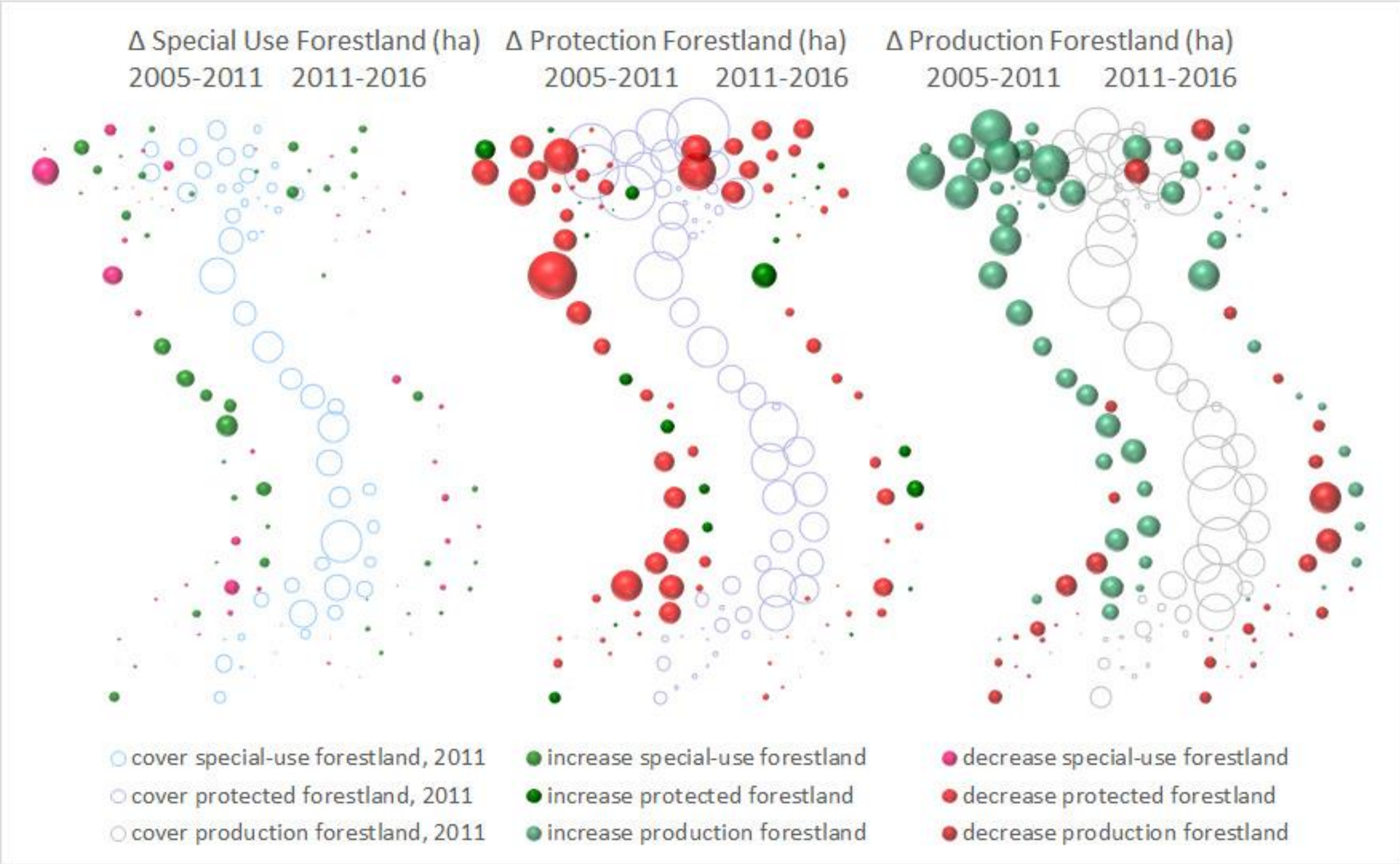


**Fig. 5:** The cover changes of politically defined forestlands in Vietnamese provinces during the periods 2005-2011 and 2011-2016 (as compared to total cover in 2011) for 1.) special use forestland, 2.) protection forestland, and 3) production forestland. Data sources: MARD (2018).

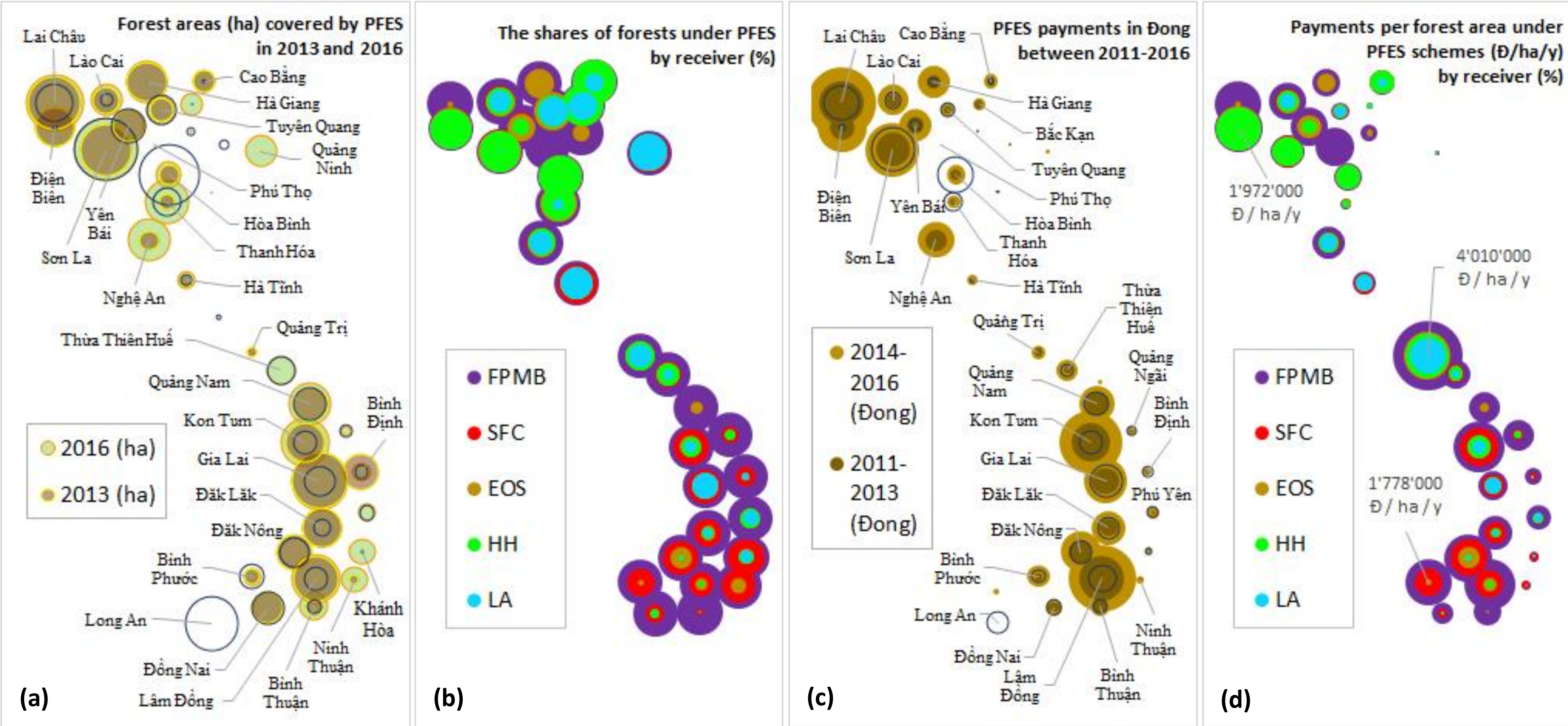


**Fig. 6:** Provincial payments for forest environmental services (PFES) schemes illustrated in terms of (a) forest areas covered by PFES schemes in 2013 and 2016 (orange circle showing total cover in 2016; in proportional comparison to volumes of hydro-electric dams in cubic metres – blue circles); (b) the relative percentage area of PFES-forestland by owners/managers (i.e., forest protection management boards FPMBs, state forest companies SFCs, economic organisations EOs, individual households or communities of households HHs, and commune people committees and other local authorities LAs); (c) total amounts of payments per province 2011-2013 and 2014-2016 (in proportional comparison to energy production from hydro-electric dams in kw/h – blue circles); and (d) annual PFES-payments per hectare PFES-forestland by forestland owner/manager. Data: MARD (2017).