A bayesian network analysis of reforestation decisions by rural mountain communities in Vietnam

Thi Mai Anh Tran, Dongwook W. Ko, Chan Ryul Park and Hai Dinh Le

College of Science and Technology, Kookmin University, Seoul, South Korea; Urban Forests Research Center, National Institute of Forest Science, Seoul, South Korea; Faculty of Economics and Business Management, Vietnam National University of Forestry, Hanoi, Vietnam

ABSTRACT
Reforestation is a primary factor in protecting upland forests providing economic sustenance for livelihood and keeping watersheds intact. In this study, we evaluated the importance of several direct and indirect drivers that can influence people’s decision for reforestation. Acquiring data from Cao Phong district of Vietnam, we utilized Bayesian Network (BN) to analyze how household characteristics, socio-economic status, biophysical environment, institutional support, and farm characteristics influenced reforestation decisions of local people. BN allowed us to identify 1) the main drivers that affect landholders’ planted forest area, 2) how the key drivers affect among themselves, and 3) what causes constraints in tree planting. We surveyed 100 households for potential drivers, identified significant drivers by using bivariate analysis and stepwise linear regression, and created a BN to predict scenarios with different household’s perception regarding the planted forest area. The results revealed five direct drivers (attitude of household to tree planting, sources of investment capital for planting practice, land area, distance from household to market, experience of participating in forestry program) and seven indirect drivers (information about forestry program, incentives supported for tree planters, land tenure, accessibility to plantation forest, rotation length of planting trees, forest area, household income) that significantly influenced farmers’ reforestation decisions. Constraints in planting trees were due to the difficulties in protecting property from mortality and unreliable profit. Our results can assist design efficient forestry programs in Vietnam and in other comparable areas.

Introduction
Forests play an important role in enhancing human well-being and providing ecosystem services (Millennium Ecosystem Assessment 2005). They are direct sources for supplying food, fiber, and genetic resources, sustaining fresh water, regulating air quality and climate, purifying water and providing pollination. Benefits from non-material values such as spirituality and religion, education, recreation, and ecotourism are irreplaceable in human belief and culture.

Recognizing the importance of forests, Vietnam heavily invested in reforestation activities over the last few decades. From 2002 to 2016, natural and planted forest area in Vietnam increased by 377,122 ha and 2,215,972 ha, respectively, covering bare hills (MARD 2016), and creating income and resilience for local people (Reed et al. 2017).

In Vietnam, a revision of land law in 1999 enabled unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
household characteristics, socio-economic characteristics, institutional and policy characteristics, farm characteristics, and biophysical characteristics. Main household characteristics are the number of laborers in a family, age of household head, and education level (Mercer and Pattanayak 2003). Economic characteristics can influence land use decision of the household, based on potential net benefits and time frame of profitability (Jagger and Pender 2003). Recently, interests in climate change have motivated state-led efforts to facilitate planting activities, which can also provide supplemental income for local households (Kallio 2013). Institutional and policy characteristics such as tenure security, rural development, forestry policies, and information sources can influence land use decisions. For example, uncertain tenure or right of access can significantly hinder decision to plant trees (Otsuka et al. 1997; Sjaastad and Bromley 1997).

Farm characteristics such as farming intensity, size of landholding, household income, access to own forest resources, diversity of production system, and distance to market are important factors that influence landholders’ decision on their forest land (Glendinning et al. 2001; Ashraf et al. 2015). Biophysical characteristics are essential, as sites with poor soil fertility for food crop or erosion susceptibility are more likely to be planted with trees (Pattanayak et al. 2003). Having a profound insight into such characteristics can promote stakeholders to increase planted forest area.

Bayesian network (BN) is known as belief network, which is widely used in real-world data analysis and management questions. BN provides good prediction with high accuracy even with relatively small sample sizes while avoiding over-fitting (Uusitalo 2007). BN can incorporate qualitative variables with quantitative and spatially-explicit data, and explore scenario-based questions. Overall, BN is useful to identify the significant factors for qualitative reasoning, and to decide how to improve or discourage certain decisions among a complex set of interacting factors (Frayer et al. 2014). Furthermore, decision making is a complex process which is influenced by a number of inter-related variables. As Bayesian network is known to better capture such interdependencies without penalizing significant variables that do not have the strongest effect, it is a proper tool to address our research questions.

In our study, we aim to analyze and identify key drivers for households’ decision on reforestation, as represented by planted forest area, and how much effort they are willing to spend. Our study was conducted in a mountainous rural area in Vietnam using household survey and BN analysis. Specifically, we attempt to answer the following questions:

1. What are the key drivers affecting landholders’ reforestation decision?
2. How do the drivers influence the area to be planted?
3. What are the main reasons that discourage tree planting?

Materials and methods

Study area

Our study areas were Bac Phong and Xuan Phong communes, located in mountainous terrain within the Cao Phong district of Hoa Binh province in Vietnam. The areas were selected for their central location, importance in headwater protection, and forestry playing important part in their livelihood. Deforestation and land use change were the critical challenges for protecting the forest in the area (Lan et al. 2016). Cao Phong has complex topography, with elevation ranging from 200 m to 800 m, and belongs to a tropical monsoon climate. The annual temperature is between 22°C and 24°C with annual precipitation of 1,845 mm (1900–2010) (Bui et al. 2013). Illegal deforestation has been widespread, as approximately 70% of households have cut down their forests to plant fruit trees, causing stream discharge reduction, water pollution, and soil degradation (Bac Phong 2015).

Populations of Bac Phong and Xuan Phong communes were 4,167 and 3,485, respectively, and the estimated average GDP in Cao Phong district was around 8.5 million VND/person/year (Hoa Binh Statistics Office 2015). Most inhabitants in Cao Phong work in agroforestry, depending most of their local livelihood and income on tree planting activities.

Data collection

A total of 100 households, 50 in each commune, were interviewed on tree planting decisions in 2015. Based on their estimated wealth, households were ranked and grouped into rich (income >10 million VND, land area >2 ha), moderate (income 6.30–10 million VND, land area 0.5–2 ha), and poor households (Hoa Binh Statistics Office 2015).

Variable description

A list of variables was acquired representing the households’ willingness to expand their forest area and influencing such decision (Table 1). The variables were classified into five groups: household characteristics including ethnicity, education, age, silviculture knowledge, laborer number, experience, attitude; socio-economic characteristics including expense, market knowledge, income sources, investment capital; institutional and policy characteristics including information, participation, incentives, harvest rights, land tenure, plantation management; farm characteristics including wealth ranking, land area, forest area, income, market distance, and accessibility; and biophysical characteristics including rotation length (choice of plantation species depends on environmental conditions and productivity), forest distance (terrain-dependent), and climate.

Experience and Participation were ‘yes’ if the households had planted or participated in any forest programs in the past, and ‘no’ otherwise. Income sources
Table 1. States and discretization methods for variables.

| Variable (node)                      | States (range)                      |
|--------------------------------------|-------------------------------------|
| Ethnicity                            | Muong; Kinh; Others                  |
| Education                            | Illiterate; primary school; secondary school; high school or above, of household head |
| Wealth ranking                       | Poor; moderate; rich                 |
| Income sources                       | Agriculture crops; animal husbandry; forest & NTFP; off-farm |
| Investment capital                   | Forestry program; bank; self-investment |
| Rotation length                      | Long time; short time                |
| Attitude                             | Very favorable to very unfavorable   |
| Experience                           | Yes/no                              |
| Land tenure                          | Yes/no                              |
| Age                                  | 20–35; 35–50; >50                    |
| Laborer number                       | 1–2; 3–4; >5; age 15–60              |
| Land area                            | 0–0.5 ha; 0.5–2 ha; >2 ha            |
| Forest area                          | 0–0.5 ha; 0.5–2 ha; >2 ha            |
| Income                               | 0–50; 50–100; >100                   |
| Market distance                       | 0–6; 6–12; >12                       |
| Forest distance                       | 0–3; >3                             |
| Planted forest area                  | 0–0.5 ha; 0.5–2 ha; >2 ha            |

Note: Age, Land area, Forest area, Income, Planted forest area were discretized by expert knowledge, equal width method; Laborer number, forest distance were discretized by equal frequency; Market distance was discretized by equal width, equal frequency. Muong is classed as Muong and Kinh are the dominant ethnic group in the interviewed group. Ethnicity is classed as based on interviewing local people in study area. NTFP, non-timber forest products.

(major source of cash income), Investment capital (sources of investment for tree planting), and Incentives (incentives from forestry program) were recorded. Harvest rights and Land tenure was based on defined harvest and log transport rights and land tenure of surveyed households. Plantation management described difficulty levels in protecting plantation area. Accessibility measured as ‘difficult’ if plantation was accessible on foot only, ‘medium’ on motorbike or bicycle, and ‘easy’ on car. Rotation length of tree species was labeled as ‘short’ (<10 years) for Eucalyptus camaldulensis Dehn, Acacia mangium Willd, and Dendrocalamus membranceus Munro; or ‘long’ (>10 years) for Chukrasia tabularis A.Juss, Cinnamomum cassia Nees ex Blume, Melia azedarach Linn, Aquilaria crassna Pierre, Dalbergia tonkinensis Prain, and Dracontomelon dao (Blanco) Merr. & Rolfe. Silviculture knowledge assessed how well the household was aware of financial or training programs. ‘Planted forest area’ represented tree planting area expected in the future. Details on other variables are provided in Table 1.

Since all random variables in Bayesian network are assumed as discrete (Chen et al. 2017), we converted the continuous variables into discrete variables by heuristic methods (e.g., equal interval/width, equal frequency, and entropy minimization).

Data analysis

We used linear regression analysis to explore associations between ‘planted forest area’ and continuous variables, and Student’s t-test to explore associations between ‘planted forest area’ and categorical variables (Table 1). Planted forest area was used to represent the decision to plant trees. Statistically significant variables (p-value ≤ .05) were considered for further analysis with stepwise linear regression, with planted forest area as dependent variable, so that the most significant variables could be identified and used for the final BN model. In stepwise regression analysis, variables were entered and removed as default criteria (i.e., p-value in Student’s t-test used $P_{\text{entry}} = 0.05$ and $P_{\text{removal}} = 0.1$) (Mundry and Nunn 2009).

Bayesian network (BN)

We created the BN to explore the main drivers affecting planted forest area using Netica (Norsys Software Corp. 1990–2013). First, we created a BN structure with the significant variables. Second, we generated links among variables using stepwise linear regression and Student’s t-test. The resulting model was used for scenario analysis.

Scenario analysis

We projected scenarios to evaluate how household economic status influenced planted forest area. We individually adjusted specific probability distributions of notable socio-economic factors (land area, income, and forest area) and other selected significant variables, while keeping other variables constant, and analyzed how the indicator planted forest area changed.
Table 2. Model summary for key drivers affecting planted forest area of surveyed households.

| Independent variables          | Unstandardized Coefficients (B) | Standardised Coefficients (Beta) | t-value | Significant (p-value) | VIF |
|-------------------------------|---------------------------------|----------------------------------|---------|-----------------------|-----|
| (Constant)                    | 0.28                            |                                  |         |                       |     |
| Attitude                      | –0.35                           | –0.26                            | –2.760  | 0.007                 | 1.310 |
| Investment capital            | 0.31                            | 0.23                             | 2.497   | 0.014                 | 1.108 |
| Land area                     | 0.03                            | 0.216                            | 2.524   | 0.013                 | 1.016 |
| Market distance               | 0.08                            | 0.207                            | 2.308   | 0.023                 | 1.112 |
| Participation                 | 0.62                            | 0.200                            | 2.063   | 0.042                 | 1.306 |

Dependent variable: planted forest area
Number of Observations 100
F 9.292***
R-squared 0.336
Adj R-squared 0.299

Note: ***p < .001, **p < .01, *p < .10 (two-sided).

Table 3. Bivariate correlation between variables in reforestation decision model (n = 100).

| V1: Planted forest area | V2 | V3 | V4 | V5 | V6 | V7 | V8 | V9 | V10 | V11 | V12 | V13 |
|-------------------------|----|----|----|----|----|----|----|----|-----|-----|-----|-----|
| V1: Planted forest area | 1  |    |    |    |    |    |    |    |     |     |     |     |
| V2: Attitude            | –0.388** | 1   |    |    |    |    |    |    |     |     |     |     |
| V3: Participation       | 0.384** | –0.437** | 1   |    |    |    |    |    |     |     |     |     |
| V4: Land area           | 0.214*  | 0.076 | 0.007 | 1   |    |    |    |    |     |     |     |     |
| V5: Investment capital  | 0.242*  | –0.039 | 0.207 | 0.097 | 1  |    |    |    |     |     |     |     |
| V6: Market distance     | 0.240*  | –0.227* | 0.114 | 0.033 | 0.007 | 0.288  | 1   |    |     |     |     |     |
| V7: Incentives          | 0.226*  | –0.330* | 0.289* | 0.017 | 0.036 | 0.225* | 1   |    |     |     |     |     |
| V8: Land tenure         | 0.112  | 0.004 | 0.089 | 0.088 | 0.269** | –0.365** | 0.114 | 1   |     |     |     |     |
| V9: Accessibility       | 0.083  | –0.165 | 0.277** | 0.068 | 0.316** | 0.130 | 0.203* | 0.018 | 1   |     |     |     |
| V10: Rotation length    | –0.246* | 0.106 | –0.349** | –0.167 | –0.447** | –0.112 | –0.455** | –0.339** | –0.288** | 1   |     |     |
| V11: Forest area        | 0.195  | 0.075 | –0.010 | 0.996** | 0.089 | –0.021 | –0.011 | 0.066 | –0.075 | –0.153 | 1 |     |
| V12: Income             | 0.192  | 0.120 | –0.072 | 0.215* | 0.010 | –0.216* | 0.055 | 0.128 | –0.086 | –0.042 | 0.182 | 1   |
| V13: Information        | 0.297** | –0.276** | 0.440** | 0.193 | –0.003 | 0.158 | 0.552** | 0.152 | 0.174 | –0.435** | 0.189 | 0.075 | 1  |

*p < .05, **p < .01, ***p < .001.
Note: Participation, Incentives, Information (1 = yes; 0 = no); Attitude (1 = very favorable; 5 = very unfavorable).

Results and discussion

Overall, the percentage of tree planters was 45%. The average of total land area per household was approximately 4 ha: 13% of the households had less than 1 ha, and 25% had more than 3 ha. Plantation forest, protection forest, and community forest accounted for 85% of the total land area. The rest were agriculture land, residential area, and rented land. Education levels of households were: high school and above (43%), secondary school (35%), primary school (20%), and illiterate (2%). Thirty-three percent of households had difficulties accessing market due to long distance (>6 km). The main sources of income were agricultural crops (74%) and off-farm (19%).

What are the key drivers affecting landholders’ reforestation decision?

Stepwise regression showed that attitude, investment capital, land area, market distance, and participation were significant variables directly influencing planted forest area. The standardized coefficient revealed that the attitude of households on tree planting was the most important factor (B = –0.268), followed by investment capital (B = 0.223), land area (B = 0.216), market distance (B = 0.207), and participation (B = 0.200) (Table 2). The negative influence of attitude is surprising: it was caused by the largest and smallest landowners’ intermediate attitude tied with strong willingness to plant more, in contrast to the intermediate landowners’ positive attitude but reluctance to plant. Its complex nature is implicated in its negative correlation with other variables (Table 3), which is further discussed in the following section.

How do the drivers influence the planted forest area?

The scenario analysis was based on a BN model of directed acyclic graph of significant variables constructed (Figure 1). We selected three variables among the direct variables identified (attitude, investment capital, land area), and two additional socio-economic factors (income and forest area), and changed each value and evaluated how planted forest area was influenced.

Changing the optimistic proportion of the attitude (inclined to planting activities) to 100% increased the mean planted forest area 0.23–0.65 ha. However, if
100% of landholders were indifferent, unfavorable or very unfavorable to plant trees, mean planted forest area decreased to 0.14–0.62 ha. While this result seems to contradict the negative effect of attitude as shown in the stepwise regression, it also captures the complexity of attitude functioning as both direct and indirect variable (Figure 1). Those with positive attitude did not always have positive experience with planting (participation, incentives), neither planned to plant more in the future, and attitude was not always significantly correlated with landowners’ economic condition (e.g., land area, income) (Table 3).

The investment capital for tree planting also made notable changes in planted forest area upon each sources of investment. When the percentage of households who self-invested or borrowed a loan from banks increased to 100%, mean planted forest area increased to 0.20–0.46 ha. In contrast, if 100% of households received investment from forestry program (such as seedling and fertilizer), mean planted forest area decreased to 0.04–0.22 ha. Approximately 48% household admitted that they were likely to plant less than 0.5 ha if received government investment because the supported seedlings were long harvesting rotation species which were not preferred.

The household characteristics of their owned land area showed an interesting effect. While land area was not correlated with most other variables except for forest area (Table 3), when the proportion of households with the smallest (0–0.5 ha) and largest (greater than 2 ha) land area was increased to 100%, mean planted forest area increased by 0.27 ha and 0.39 ha, respectively. However, when intermediate households’ (0.5 to 2 ha) land area was increased to 100%, mean planted forest area decreased to 0.46 ha. The results suggested that the household groups with the smallest and largest land area were more inclined to tree planting. The smallest owners wanted to plant since any planting brings extra income, while cost can be subsidized by government incentives. Largest owners were more likely to plant as they already had the resources to do so, which also enabled them for greater profits over long term. However, households with intermediate land area were reluctant since the cost and risk of expanding the plantation became higher, especially with increasing maintenance cost and natural disturbances. In such case, government incentives and the forest protection cost were often insufficient to encourage more tree planting.

The household income had a mixed influence on planted forest area. When the percentage of the lowest group of income (0 to 50 million VND/year) increased to 100%, mean planted forest area decreased to 2.02–2.01 ha. This reduction was due to 45% of the group only owning 0.5–2 ha of land area and were unlikely to plant trees. In contrast, when the percentage of the intermediate group of income (50 to 100 million VND/year) increased to 100%, mean planted forest area increased by 0.04 ha because 47% of the group owned greater than 2 ha and tended to expand their plantation. When the highest income group (> 100 million VND/year) percentage was increased to 100%, mean planted forest area decreased by 0.01 ha, even though the mean planted forest area was still high (2.01 ha). The results showed the willingness and capacity of the intermediate income group, and that improvements are needed to facilitate tree planting by the lowest and highest income group.

The forest area is a direct driver to land area and an indirect driver to planted forest area. When each of the three forest area groups (0 to 0.5 ha, 0.5 to 2 ha, and > 2 ha) increased to 100%, mean planted forest area changed from 2.0 ha to 1.8 ha, 1.8 ha, and 2.4 ha, respectively. These scenario outcomes suggest that households with larger forest area are more likely to plant trees considering land security and potential

Figure 1. The final Bayesian network of planted forest area. Note: The values 44.2; 30.2; 25.5 in planted forest area is percentage (%); 2.02 ± 2.7 in planted forest area is (mean ± standard deviation).
economic gain. As most households with small land area relies on diversity of crops that provide regular income and subsistence throughout the year, they prefer short term over long term species. In contrast, households with large forest area were more concerned about maintaining forest land tenure, preventing soil erosion, and reliable long term investment.

**What are the main reasons that discourage tree planting?**

The frequently admitted disadvantages of tree planting were high tree mortality (60%), low price (47%), and longtime investment (37%). Main causes that were quoted to trigger tree mortality were inclement climate, pest, and livestock grazing. Due to low price of forest products, landholders hesitated to invest in planting trees. Five percent of households used timber for fuelwood rather sell in the market. Besides, wood production and market unpredictability over long time were also reasons that deterred reforestation. The long investment period (seven to ten years) for *Acacia mangium* Willd and *Melia azedarach* Linn was a common reason to convert forests to fruit farms.

Approximately 59% of surveyed households involved in the Afforestation and Reforestation Clean Development Mechanism (AR-CDM) program stated that the lack of official acceptance of the project prevented them from participating in forestry program again. Participants were confounded when no official agency could provide an accurate estimate of carbon sequestered to their forests, and failed to explain how they could receive the benefits from the program. The other mentioned reasons were lack of fertilizer, poor soil, and water shortages.

**Conclusion**

The study found a total of twelve significant drivers that influenced *planted forest area*: five direct drivers were *attitude*, *investment capital*, *land area*, *market distance*, and *participation*; seven indirect drivers were *information*, *incentives*, *land tenure*, *accessibility*, *rotation length*, *forest area*, and *income*.

BN successfully identified important variables influencing tree planting decision, and proved to be useful in showing the complexity of how decisions are made. Based on the BN, our study found out that government policy contributes greatly to tree planting decision of local people (38% increase of planted forest area). In particular, the highest income group contributed greatest to tree plantation compared to lower income groups. Raising positive attitude from local households on planting tree can allow a 30% increase in forest area. Households tend to plant larger forest area when they invested by themselves or borrow a loan from a bank, compared to receiving seedling and fertilizers from forest program (33%). The results also demonstrated the usefulness of BN for understanding socioeconomic variables. In our study, *land area* and *attitude* were complex variables influenced by and influencing many other variables, and their influences in tree planting did not manifest in a linear manner.

The foreground of livelihood in Cao Phong district is to maintain regular income source. Thus, to encourage local people engage in reforestation projects, it is critical to combine benefits from forestry projects and the basic needs of community, and provide knowledge to increase the amount and reliability of their income, such as information about price changes, accessibility to markets, and tree planting practices, which can promote farmers to plant more tree in the future.

Greatest obstacles to reforestation came from the risks due to long harvesting rotation, such as tree mortality, and low and unpredictable market price. Lack of continuing public professional support for program participation was also an important factor for hindering reforestation.

For future studies, we suggest elaborating on the relationships between specific group characteristics and factors of both encouraging and discouraging factors for reforestation. In addition, factors such as gender dimensions and social norm through communication in the community would help us further understand the rich and dynamic nature of decision making for reforestation in Vietnam. Our results are based on two mountainous communes with a relatively small sample size, therefore a more extensive survey is required to represent a greater diversity of communities.

**Acknowledgments**

We would like to thank the staffs of Communal People Committee of Cao Phong district, and local people in Cao Phong district for their help during the survey. We also thank the financial support provided by Korea Forest Service from ’Development and Application of a Forest Healing Information System Utilizing Forest and Meteorological Information’ project (2016S1100037) and the Asian Forest Cooperation Organization (AfOCo) of Korea. This manuscript is improved upon the presentation made at the 10th International Conference on Traditional Forest Knowledge and Culture in Asia, South Korea, 2017.

**Disclosure statement**

No potential conflict of interest was reported by the author(s).

**References**

Ashraf J, Pandey R, de Jong W, Nagar B. 2015. Factors influencing farmers’ decisions to plant trees on their farms in Uttar Pradesh, India. Small-Scale Forestry. 14(3):301–313.

Bui DT, Pradhan B, Lofman O, Revhaug I, Dick ØB. 2013. Regional prediction of landslide hazard using probability analysis of intense rainfall in the Hoa Binh province, Vietnam. Nat Hazards. 66(2):707–730.

Chen Y-C, Wheeler TA, Kochenderfer MJ. 2017. Learning discrete bayesian networks from continuous data. JAIR. 59: 103–132.

Clement F, Amezaga JM, Orange D, Duc Toan T, Large ARG, Calder IR. 2007. The impact of government policies on land use in Northern Vietnam: an Institutional approach for understanding farmer decisions. Colombo, Sri Lanka: International Water Management Institute.
Cochard R, Waever P, Ngo DT, Kull C. 2016. Extent and causes of forest cover changes in Vietnam’s provinces 1993-2013: a review and analysis of official data. Environ Rev. 25(2): 199–217.

Dinh HH, Nguyen TT, Hoang V-N, Wilson C. 2017. Economic incentive and factors affecting tree planting of rural households: evidence from the Central Highlands of Vietnam. J Forest Econ. 29:14–24.

Frayer J, Sun Z, Munder D, Munroe DK, Xu J. 2014. Analyzing the drivers of tree planting in Yunnan, China with Bayesian networks. Land Use Policy. 36:248–258.

FSIV 2009. Vietnam Forestry Outlook Study. Bangkok, Thailand: Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific.

Glendinning A, Mahapatra A, Mitchell C. 2001. Modes of communication and effectiveness of agroforestry extension in Eastern India. Human Ecology. 29(3):283–305.

Government of Vietnam 1992. Decision 327-CT dated 15.09.1992 the Greening the Barren Hills Program. Hanoi, Vietnam: President of the Council of Ministers.

Government of Vietnam 1994. Decision number 747/QD-TTg dated on 7.09.1994, the project on population stabilization and socioeconomic development of population in Da River 1995-2001. Hanoi, Vietnam: The Prime Minister of Government.

Government of Vietnam 1998. Decision number 661/QD-TTg dated 29.07.1998 by Prime Minister on the objectives, tasks, policies, and organizations for the establishment of five million hectare of new forest. Hanoi, Vietnam: The Prime Minister of Government.

Government of Vietnam 2001. Law on Land amended by Resolution 51-2001-QH10 dated 25.12.2001. Hanoi, Vietnam: The National Assembly.

Hoa Binh Statistics Office 2015. Hoa Binh Statistical Yearbook. Hanoi, Vietnam: General Statistics Office.

Jagger P, Pender J. 2003. The role of trees for sustainable management of less-favored lands: the case of eucalyptus in Ethiopia. Forest Policy Econ. 5(1):83–95.

Kallio MH. 2013. Factors influencing farmers’ tree planting and management activity in four case studies in Indonesia. University Of Helsinki, Viikki Tropical Resources Institute: Faculty of Agriculture and Forestry, University of Helsinki.

Lan LN, Wichelns D, Milan F, Hoanh CT, Phuong ND. 2016. Household opportunity costs of protecting and developing forest lands in Son La and Hoa Binh Provinces. Int J Commons. 10(2):902–928.

Mahapatra AK, Mitchell CP. 2001. Classifying tree planters and non-planters in a subsistence farming system using a discriminant analytical approach. Agroforestry Systems. 52(1):41–52.

MARD 2016. Decision No 3158/Q-D-BNN-TCLN. Announcement on Forest Status in 2015. Hanoi, Vietnam: Ministry of Agriculture and Rural Development.

Mercer DE, Pattanayak SK. 2003. Agroforestry adoption by smallholders. Forests in a market economy. Dordrecht, Netherlands: Kluwer Academic Publishers. p. 283–299.

Millennium Ecosystem Assessment 2005. Ecosystems and human well-being: synthesis. Washington, DC: Island Press.

Mundry R. 2009. Stepwise model fitting and statistical inference: turning noise into signal pollution. Am Nat. 173(1):119–123.

Norsys Software Corp 1990–2013. Norsys Software Corp Netica Version 5.12 (1990–2013) http://www.norsys.com/

Otsuka K, Suyanto S, Tomich T. 1997. Does land tenure insecurity discourage tree planting? Evolution of customary land tenure and agroforestry management in Sumatra. EPTD Discussion paper No.31. IFPRI, U.S.A.

Pattanayak S, Evan Mercer D, Sills E, Yang J-C. 2003. Taking stock of agroforestry adoption studies. Agroforest System. 57(3):173–186.

Phong B. 2015. Report of land use investigation in Bac Phong commune. Communal of People committee in Bac Phong.

Rambo AT, Reed RR, Cuc LT, DiGregorio MR. 1995. The Challenges of Highland Development in Vietnam. Hawaii: East-West Centre: America.

Reed J, van Vianen J, Foli S, Clendenning J, Yang K, MacDonald M, Petrokofsky G, Padoch C, Sunderland T, et.al. 2017. Trees for life: The ecosystem service contribution of trees to food production and livelihoods in the tropics. Forest Policy and Econ. 84:62–71.

Saastad E, Bromley DW. 1997. Indigenous land rights in sub-Saharan Africa: appropriation, security and investment demand. World Dev. 25(4):549–562.

Solomon T, Demel T. 2017. Perceptions and attitudes of local people towards participatory forest management in Tarmaber District of North Shewa Administrative Zone, Ethiopia: the case of Wof-Washa Forests. Ecological Processes. 6:17.

Uusitalo L. 2007. Advantages and challenges of Bayesian networks in environmental modelling. Ecological Modelling. 203(3–4):312–318.